SPECIAL REPORT

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Blazing a Trail to DOCSIS 3.1

By Carl Weinschenk

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SPECIAL REPORT

Blazing a Trail to DOCSIS 3.1

It isn't here yet, but it is coming. And when it does arrive, it will be a big darn deal, to stop short of precisely quoting Joe Biden. DOCSIS 3.1 offers higher speeds and greater throughputs in both the upstream and downstream. It is a vital element of the industry's ability to fight, toe to toe, with its competitor's fiber deployments.

DOCSIS 3.1 is a big change. It is important for operators to understand the parameters of the new specification and to prepare. They also must be ready to test and measure it once it is deployed. Broadband Technology Report has asked several of the leading organizations in the cable industry to describe why DOCSIS 3.1 is important, what changes it entails and how best to prepare.

BTR would like to thank our sponsors, Trilithic, ComSonics and VeEX, for their support in the creation of this report.

The Vital Issue of DOCSIS 3.1 Testing

DOCSIS 3.1 presents a number of concerns and challenges. Experts say testing is critical for successful deployment. The DOCSIS 3.0 rollouts show that the process is an evolution. Each step must be evaluated and modified as necessary. A major lesson is that implementation does not always work out as planned. Services are modified and mature with time. For example, a 4x4 cable modem was first specified. Carriers started with a subset of 4.4 (2x1) then went to 8 channel modems. Sixteen, 24 and 32 channel modems now are available.

"It must be verified that the cable plant can support DOCSIS 3.1 signals. One key is increasing the sweep on the forward path of the spectrum that has not been used before."

Cyrille Morelle, CEO, VeEX

It must be verified that the cable plant can support DOCSIS 3.1 signals. One key is increasing the sweep on the forward path of the spectrum that has not been used before. This is especially true from 1 GHz to 1.2 GHz. The previous spectrum increase — from 870 MHz to 1 GHz — showed that this can be problematic. In that case the network was saturated and did not support sweep. The same holds true as speeds and spectrum increase. Verifying only the physical layer is not sufficient. The potential delivery of 10 Gbps services to a subscriber makes service level agreements (SLAs) mandatory. Thus, test tools that provide 10 Gbps

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throughput verification will become a necessary part of the MSO toolset.

When planning for test equipment, qualifying the physical layer from 1.2 GHz to 1.5 GHz and 1.7 GHz (future) are necessary steps. This includes mapping the differences from DOCSIS 3.0 to 3.1 and from 8x4 to 16x8 or 24x8 cable modems. This gap must be addressed. The next step is increasing the capacity of the equipment. This is tricky since the cost of the upgrade must be reasonable.

Customers need to make sure their architecture can grow with the technology. A solution is adding functionality to the test set without changing the whole device. The idea is to simply replace and add features without changing the entire unit. This also holds true for referencing test gear. As shown with current and previous successful DOCSIS rollouts, test gear must be readily available for installers. DOCSIS 3.1 will require 10 GigE tools for installation. This will put a strain on test vendors and MSOs with limited capital budgets.

Answers to Key DOCSIS 3.1 Migration Questions

Service providers face the imperative of optimizing their networks in response to growing demand for TV Everywhere, OTT, IP video, and tomorrow's bandwidth-hungry services. DOCSIS 3.1 is one way in which this network evolution is taking place. Most MSOs are taking full advantage of DOCSIS 3.0 today, but the impending migration to DOCSIS 3.1 has sparked many new questions. This article will address the ones heard most frequently.

What exactly will DOCSIS 3.1 do for MSOs? DOCSIS 3.1 technology effectively increases the bandwidth of existing HFC networks by using the spectrum more efficiently in both the upstream and downstream. Under appropriate conditions, DOCSIS 3.1 enables MSOs to achieve a 20% to 90% increase compared to DOCSIS 3.0 in data throughput (in the same amount of spectrum) and enables speeds of up to 10 Gbps downstream and 1-plus Gbps upstream.

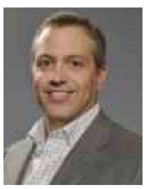
How does this data throughput increase happen? DOCSIS 3.1 uses new techniques to increase the number of bits per hertz, or the "density" of data. One of the techniques is Orthogonal Frequency Division Multiplexing (OFDM), which uses multiple sub-carriers in channels up to 192 MHz in width. A second is Low Density Parity Check (LDPC) forward error correction (FEC), which is more efficient than the Reed-Solomon FEC used in prior DOCSIS versions. The OFDM/LDPC combination enables providers to use higher modulation orders—1024, 2048 and 4096 QAM—and achieve maximum throughput across various HFC plant conditions.

How quickly should I be ready to migrate to DOCSIS 3.1? DOCSIS 3.1 specifications were released in October 2013, and many vendors are currently developing compatible products. The expectation is that DOCSIS 3.1 testing will begin early next year, and early deployments will likely begin in late 2015 and early 2016.

We're currently making CCAP/DOCSIS 3.0 investments. How can I protect this investment in a DOCSIS 3.1 migration path? Deploying CCAP today is critical to cost-effectively meeting consumers' downstream bandwidth needs. It involves bonding more than eight D3.0

channels. This investment can be protected if currently deployed CCAP technologies offer software upgrades to key aspects of DOCSIS 3.1. This will enable a CCAP to offer enhanced downstream speeds beyond what is possible with the bonding of multiple D3.0 channels, assuming the CCAP has sufficient forwarding capacity.

> "Thankfully, the migration to DOCSIS 3.1 can be a multi-phased approach, making it easier to adapt to the change."



Todd Kessler, Vice President for CMTS/CER Product Management, Arris

What's the right migration path? Should I focus first on downstream channels? Thankfully, the migration to DOCSIS 3.1 can be a multi-phased approach, making it easier to adapt to the change. It can be done separately on the downstream and upstream channels. This enables quicker expansion on the congested downstream channels. Upstream support can be implemented later.

The downstream channels will see the most congestion as video usage increases. MSOs can start using DOCSIS 3.1 on their existing spectrum in 96MHz or 192MHz blocks and subsequently adapt their plant and expand to use the higher downstream frequencies — up to 1.2GHz or 1.7GHz — that are defined in the standards. This approach can make use of "holes" in existing spectrum today and support the gradual insertion of the DOCSIS 3.1 modems into their systems.

It's not a question of "if" but "when" operators must address the DOCSIS 3.1 migration path. But with proper knowledge and preparation, they can implement this technology in ways that can be tailored for both their network and for future entertainment services.

Challenges in DOCSIS 3.1 Field Testing

Orthogonal Frequency Division Multiplexing (OFDM) lies at the heart of the new DOCIS 3.1 specification. Although it is new to some HFC test equipment vendors, this type of modulation has been used for years by ADSL, VDSL, MoCA, WLAN, Digital Radio/TV and 4G cellular networks.

The next generation of field testing devices designed for DOCSIS 3.1 must provide quick and accurate measurements for channels as wide as 192 MHz with thousands of narrowband (25 kHz or 50 kHz) subcarriers. If that's not complex enough, each of these subcarriers is capable of independent configuration with unique modulation and FEC rates.

Watch Trilithic's video addressing challenges in the field testing of DOCSIS 3.1

A great new feature of DOCSIS 3.1-compliant CMTS and CPE equipment is Proactive Network Maintenance (PNM). PNM automatically resolves most transmission issues. However, PNM isn't designed to correct physical impairments. A new set of tools will be needed to guide technicians through the troubleshooting process when there is a severe transmission issue or physical impairment.

In the past, troubleshooting impairments consisted of testing single carrier QAM (SC-QAM) channels individually using measurements such as MER, BER and QAM constellation. But with each DOCSIS 3.1 channel potentially including thousands of subcarriers of varying modulations and error correction factors, the individual channel field testing methodology will be far too time consuming.

In the past it was very easy to calculate and display the MER & BER of a SC-QAM channel with a single modulation type and FEC rate. However, the subcarriers within an OFDM channel produce many combinations of modulation and FEC rates. These factors, combined with the sheer number of subcarriers available within a single channel, will make it very difficult to find MER and BER issues in individual subcarriers as we have in the past.

See a DOCSIS 3.1 update from VeEX

The QAM constellation of each subcarrier will also become more difficult to interpret with up to 1000 times the number of carriers (as compared to DOCSIS 3.0) and higher order modulations requiring high resolution LCDs.

"The simplest testing approach is to calculate the minimum, maximum and average values for MER and BER across an entire channel."

Gary Sinde, Vice President of Engineering, Trilithic

So, how do you quickly determine the health of an OFDM channel without overloading a technician with so much data that they can't efficiently troubleshoot system impairments? The simplest testing approach is to calculate the minimum, maximum and average values for MER and BER across an entire channel. However, these calculations have drawbacks that may hide impairments that are isolated to a few subcarriers or small frequency range within the channel. A more useful testing approach would be to calculate equalizer stress, in-channel response, group delay and other physical layer measurements in an easily understood graphical or numerical scale format.

The success of vendors designing new DOCSIS 3.1 test and measurement equipment depends on the ability to develop all new algorithms to test entire channels while automatically identifying subcarriers that have MER, BER or ingress issues. It is important to recognize that a few thoughtful modifications will enable

existing measurement techniques to be adapted to provide technicians with simple, intuitive and actionable test procedures that don't require a steep learning curve or additional training.

DOCSIS 3.1: The Latest Weapon in the Battle for Bandwidth

In the battle for bandwidth, the latest weapon for cable operators DOCSIS 3.1. It equips them to fight the competition by providing speeds beyond 1Gbps. DOCSIS 3.1 provides a toolbox of approaches that can be implemented in an a la-carte or a mix-and-match fashion so operators can economically add capacity to their networks. Wholesale swap out of the network is not required to take advantage of DOCSIS 3.1. For operators, the DOCSIS 3.1 toolbox includes upstream plant expansion, downstream plant expansion, 24/32 x 8 bonding of legacy DOCSIS carriers and OFDM Downstream carriers, and OFDM-A upstream carriers. Each of these approaches requires operators to choose how to plan, test, and deploy in an efficient and cost-effective manner.

One of the most direct and efficient tools available to get beyond 1Gbps on the downstream is to take advantage of the mandatory higher channel bonding count of 24 downstream legacy carriers or the optional 32 downstream legacy carriers that DOCSIS 3.1 supports. Operators can build the bridge to DOCSIS 3.1 now with existing DOCSIS 3.0 CPE equipment designed to support the 24/32 bonded downstream carriers. This high bonding count of legacy carriers is often referred to as Phase-1 of DOCSIS 3.1 by vendors. New DOCSIS 3.1 CPE equipment can be rolled out to support the higher bonding count and can take on additional downstream capacity later by merely adding OFDM carriers. The high bonding count of legacy DOCSIS QAM carriers also tracks well with CCAP CMTS deployments. Getting to the 1Gbps service using 24/32 bonded carriers puts new testing practices into play that may require both DOCSIS and Ethernet service-level testing.

To prepare for additional downstream carriers including 24/32 bonded DOCSIS QAM or new DOCSIS 3.1 OFDM carriers, operators are typically faced with expanding the capacity of the downstream. This is done by combinations of channel reclamation of analog carriers and frequency expansion. Plant expansions may entail simply expanding to 860MHz, 1GHz or adapting their plant and amplifiers for 1.2 GHz, the newly supported DOCSIS 3.1 specification.

> "Operators can build the bridge to DOCSIS 3.1 now with existing DOCSIS 3.0 CPE equipment designed to support the 24/32 bonded downstream carriers."

Robert Flask, senior product line manager, JDSU

Operators are faced with the construction, turn-up and service validation in the new spectrum.

In the upstream, most of North America is bandwidth constrained by the 42MHz return path. This leaves operators with options of expanding the upstream to 85MHz or even going to the new mid-split option of 204MHz. By going up to 85MHz operators can easily offer upstream speeds of more than 300 Mbps using as many as 8 bonded legacy DOCSIS carriers or a combination of legacy DOCSIS QAM carriers and DOCSIS 3.1 OFDM-A carriers. To reach 1 Gbps upstream, operators must look at expanding to a mid-split system of 204 MHz. Moving to the a mid-split at 204 MHz typically requires a much more intensive upgrade than expanding to 85MHz. Therefore, operators also may weigh different fiber-deep architectures such as Node+0 or Node+1.

Upstream changes task operators with RF, DOCSIS, Ethernet, and optical testing and monitoring challenges. With the wide variety of options available for the migration to DOCSIS 3.1, operators must carefully consider flexible and scalable test solutions to accommodate the different architectures and services.

DOCSIS 3.1 vs. G.fast and the Battle for Speed-Hungry Consumers

On July 9, 2014, Bell Labs, the research arm of Alcatel-Lucent, announced a broadband speed record of 10 gigabits-per-second (Gbps) using traditional copper telephone lines in a demonstration of how a symmetrical speed of 1 Gbps could be offered over existing copper networks. This announcement represented the latest shot fired in the battle for market share in a broadband market centered on bandwidth-hungry consumers.

The "XG-FAST" technology is an extension of G.fast, expected to be commercially available in 2015. The capabilities of the G.fast and its derivatives are limited to short distances. This is not as much of a drawback as you might think, since it's really the "last mile" where fiber ends and copper takes over. Telcos now offer VDSL2 with speeds up to 150Mbps, G.fast to around 1.25Gbps — and XG.fast from 2Gbps up to 10Gbps.

The main goal for the technology is to bridge the gap from the fiber-to-the-curb (FTTC) that are currently prevalent to the future deployments of fiber-to-the-home (FTTH). FTTH is certainly the easiest way to achieve these speeds, but the cost of full deployment is prohibitive. The G.fast technologies use existing copper infrastructure, while allowing competition with the faster speeds that cable operators have been able to offer thanks to CableLabs' DOCSIS standards.

"In many ways, the XG-FAST announcement is an answer to the DOCSIS 3.1 standard that was released in October of 2013."

Chris Boring, Vice-President, Sales & Marketing, Promptlink Communications

In many ways, the XG-FAST announcement is an answer to the DOCSIS 3.1 standard that was released in October of 2013. DOCSIS 3.1 offers speeds 50 percent higher than current DOCSIS 3.0 deployments by using 4096 QAM. This is achieved by replacing the current 6 and 8 MHz channel spacing with 20 KHz to 50 KHz channel spacing. These are bonded together to achieve up to a 200MHz wide bonded spectrum.

The DOCSIS 3.1 modems may only support 4-5 Gbps downstream and 1 Gbps upstream, mostly due to legacy DOCSIS 3.0 support that still is required. The DOCSIS standard has always

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been one without the distance limitations issue faced by DSL.

But with more Telcos investing the money in FTTH deployments, cable operators must continue pushing the bandwidth envelope. I expect the adoption of DOCSIS 3.1 to come together with other new technologies, such as CCAP equipment that merges video and data technologies in the headend. While we may not see deployments until 2016, DOCSIS 3.1 promises to keep cable operators in the battle for consumers' insatiable bandwidth appetites.

Working Through a Major Inflection Point

In considering, from a measurement perspective, the development and deployment of DOCSIS 3.1, I can't help but think how chaotic, risky and ripe with potential any technology inflection point can be (take your pick from the early days of the automotive, aviation and computer industries, to name a few). While the behavior of a multitude of 6 MHz-wide SC-QAM signals on an HFC cable plant is very well understood, the introduction of OFDM, with channel widths up to 192 MHz, is another matter completely.

OFDM seems to be the "modulation de jour" these days. From a test and measurement perspective OFDM is a very well understood topic. It has proven itself in successful deployments in a variety of harsh telecommunications environments, including terrestrial broadcast and LTE.

But there is much we don't know about the performance of OFDM when placed on an HFC cable system. How will OFDM channels behave in the presence of multiple SC-QAM channels? What impact will ingress have on the functionality of the OFDM channel? How will such large channel bandwidths effect laser clipping? All of which, in the context of test and measurement, tee up the question: What potential features should a developer or cable operator look for when selecting tools for DOCSIS 3.1 signal analysis?

High modulation error ratio (MER) measurement capability will be required to determine loss in margin as early as possible. The ability to recognize an ARB-based DOCSIS 3.1-compliant signal will be necessary, but more important will be the ability to do a single-ended

"The complexity and signal performance requirements of DOCSIS 3.1 will certainly drive investment in test equipment, as all new standards do."

Greg Kregoski, Audio/Visual Business Development, Rohde & Schwarz USA

measurement from an unknown source, such as a cable modem termination system (CMTS). Additionally, providing MER measurements for individual sub-carriers within a DOCSIS 3.1 channel will be critical in determining which frequencies are being impaired within a 192 MHz-wide channel. The ability to enable filtering per QAM order for proper MER interpretation will also be essential in order to properly measure the saturation effect. Finally, calculating bit error rate (BER) will help early detection of laser clipping.

The complexity and signal performance requirements of DOCSIS 3.1 will certainly drive investment in test equipment, as all new standards do. In addition to the measurement capabilities described above, developers and operators considering new tools should also evaluate the supplier. How much cable TV measurement expertise does the test equipment provider have? Vendor experience that spans the cable evolution from analog to J.83B to DOCSIS 3.0 goes a long way toward ensuring their tools contribute to success at this latest inflection point.

Finally, if it's too difficult to compare potential solutions feature by feature, ask for a side-by-side shootout. Ensuring you have the proper test equipment will help manage the inherent risk of new technology and enable more focus on maximizing its potential.

Proactive Network Maintenance – A Toolkit that Makes All the Difference

Proactive Network Maintenance or PNM, has a rich history. It will become even more noteworthy with the launch of DOCSIS 3.1. Developed by the CableLabs PNM Working Group led by Dr. Alberto Campos – the group is now called InGeNeOs and led by Tom Williams — PNM started out as a reference implementation commonly called DOCSIS pre-equalization.

Pre-equalization's goal is to compensate for poor upstream performance due to impairments that create linear distortion such as micro-reflections and the resulting RF impedance mismatches. This technology has been implemented by many operators and has allowed them to pro-actively identify and address these types of issues before a customer is impacted, thus significantly improving subscribers' Quality of Experience (QoE).

Pre-equalization was the first tool in the PNM toolkit. Other tools have been introduced. One is spectrum analysis used in the CMTS for upstream analysis and in the downstream in cable modems using full bandwidth capture. This tool, one of several discussed in SCTE's Proactive Network Maintenance course, allows spectrum analysis through software and reduces the need for costly test equipment. It provides greater insight into the performance of the HFC network.

"With so many technological changes, operators will have to work through the deployments to see how the new software-based PNM tools integrate into and work within existing operational systems and processes."

Marty Davidson, Vice President of Engineering & Network Operations, SCTE

DOCSIS 3.1 is on the way. PNM was in the plans from the very beginning of its development. DOCSIS 3.1 introduces a host of new and potentially game-changing PNM tools, including spectrum analyzer functions such as noise power ratio notching (to help identify the dynamic range in the return path laser) and vector analyzer functions such as constellation displays and receive MER vs. subcarriers (introduced with OFDM). There are new FEC and impulse noise statistics and histograms as well.

DOCSIS 3.1 also provides a new ability to identify laser clipping on a per-symbol basis. Brady Volpe of The Volpe Group, a speaker at the upcoming Wireless and DOCSIS 3.1 Symposium at SCTE Cable-Tec Expo, calls this "a dramatic change from today's methods of laser clipping detection where one must look at the RF spectrum above 42 MHz and try to identify non-linear RF energy."

This raises a good question: What kind of new test equipment will be needed for DOCSIS 3.1? Certainly some will be required, particularly for early adopters and those who have not implemented previous PNM technologies. With so many technological changes, operators will have to work through the deployments to see how the new software-based PNM tools integrate into and work within existing operational systems and processes.

The real key to getting the most out of PNM is to prepare HFC networks for DOCSIS 3.1 deployments through programs such as SCTE's HFC Readiness effort. These will maximize the benefits that DOCSIS 3.1 provides. A good understanding of what's in the PNM toolkit, how it reduces capital and operational expense and how it significantly improves customer QoE is important. That knowledge must be used to create a roadmap for implementation that will significantly improve the experience for subscribers.

LTE Impacts Cable TV in the Home

There is a lot of buzz in the cable industry centered around the impact digital cable leakage on LTE cellular service. The SCTE Network Operation Subcommittee, part of the standards program, has done several studies to help quantify the performance impact to LTE services caused by leaking digital QAMs in both the uplink and downlink directions.

But what about the reverse scenario? How does LTE signaling impact the cable TV network? The short answer is that strong levels of LTE can cause serious impairments, such as channel blocking or worse, to the QAM channels that overlap the LTE spectrum via ingress. Ingress into the cable system can seriously degrade the performance of DOCSIS 3.1, which is on the way. Any noise that makes its way into the cable network decreases the potential for running DOCSIS 3.1 at higher orders of modulation.

There are two environments in which strong levels of LTE signaling are most likely to impact cable TV: Close proximity to an LTE cellular tower and within the home environment.

Why is the home a prime location for LTE interference to affect the overlapping digital QAMs?

Answer: LTE cell phones. LTE cellular phones, particularly when they have a poor connection to the serving cellular tower, have a maximum transmit power of up to 23 dBm. This is equivalent to a field strength of about 634,000 uV/m (measured 10' from the leak at 782 MHz). That measurement is extremely high compared to a cable leak which rarely exceeds several thousand uV/m.

Thus any ingress point or cable infrastructure in the home that has a shielding integrity less than 110 dB will be susceptible to possible LTE interference. As the number of LTE cell phones continues to increase exponentially, the interference problem will also increase at the same rate.

What can be done to limit the impact of the LTE interference in the home? Don't use LTE phones and never live near an LTE tower…just kidding.

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There are two primary measures that can be done to minimize LTE ingress: First, make sure that all in-home cable-related infrastructure — including cables, connectors, modems, STBs, etc. — have adequate shielding effectiveness and subscribe to a proactive maintenance plan to find and fix the cable leaks which act as an in-home ingress points.

> "Ingress into the cable system can seriously degrade the performance of DOCSIS 3.1, which is on the way."

Ken Couch, Vice President of Marketing and Business Development, ComSonics

Well-known reputable manufacturers of cable related infrastructure are producing products with superior shielding effectiveness ratings, particularly at the LTE spectrum frequencies. The cable industry must use these new products.

Ingress points in the home — which manifest themselves as leaks – are best found by outfitting service technicians with a small devices that will continuously monitor for leakage in the LTE band.

Both practices — using cable infrastructure with adequate shielding effectiveness and a proactive find-and-fix leakage program in the home — will both protect the digital QAM channels that overlap the LTE spectrum and provide a better operating environment for DOCSIS 3.1.

Back to Basics: OFDM with LDPC

Here's an observation, from somebody who routinely marinates in the underpinnings of the DOCSIS 3.1 specification: OFDM tends to get all or most of the fanfare, when it comes to the 50% capacity gains, upstream and downstream, that DOCSIS 3.1 brings.

Actually, though, its companion component — LDPC — does more of the heavy lifting, from both mathematics and engineering perspectives.

Here are the basics: OFDM (for Orthogonal Frequency Division Multiplexing) is modulation technique, just like QAM (Quadrature Amplitude Modulation), and is used to imprint data onto a carrier, to get from one place to another.

LDPC, which stands for Low Density Parity Check, is a 50-year-old method of correcting bits trampled during transit. So is "Reed Solomon," the forward error correction (FEC) method used since the advent of digital video transmission in cable. Both Reed Solomon and LDPC are mathematical ways of detecting and correcting errors.

Reed Solomon uses a simple, reliable formula that employs parity bits to recreate missing bits. It's tried, it's true, it works. LDPC, though, takes error detection and correction to a whole other level. Instead of parity bits, it formulates multiple, parallel equations, and will iterate 15 times before it gives up.

Unquestionably, LDPC takes error correction vastly wider from a spectral sense and is deeper computationally.

Here's an analogy. One of the major transmission culprits in any communications network — forever flaring, trampling bits — is the noise floor. If the noise floor is fire, the closer you get to it, the more bits you lose. And if the noise floor is fire, Reed Solomon is the thin gloves; LDPC the thicker, more protective gloves.

> "Unquestionably, LDPC takes error correction vastly wider from a spectral sense and is deeper computationally."

John Chapman, CTO, Cable Access Business Unit, Cisco

By the numbers, Reed Solomon provides about an extra 3 dB of noise floor leeway. Moving to LDPC adds another 5 dB to that number. And in the language of dealing with network noise, that's a HUGE "wow factor."

When combined with other techniques that DOCSIS 3.1 uses, this extra margin allows the modulation to be one or two orders higher. So, wherever 256-QAM was deployed, 1024-QAM should work. Anywhere where 1024-QAM could or did work (but was not deployed) it may be possible to use 2048-QAM or even 4096-QAM. That results in 30% more bits in the same spectrum!

Until recently, though, nobody really used LDPC. Only in the last five years, really, did it become a deployable reality. Why? You guessed it. The chips. LDPC is vastly wider and deeper means that it requires dedicated hardware. This hardware must have lots of gates. The application-specific integrated circuits (ASICs) necessary must be both dense and cost-effective.

None of this is to say, of course, that OFDM is a lightweight. Here's how it compares to QAM, the current and traditional method of video modulation in cable: Because it doesn't require (or care about) the 6 MHz channel spacing that defined analog carriers (and vestigially defined digital video carriers), it can instead stuff orders of magnitude more carriers into the same space.

OFDM uses a unit of measure that is 192 MHz, instead of 6 MHz, so let's compare it that way. 192 MHz is the equivalent of about 32 6 MHz QAM carriers (or 24 8 MHz carriers, with a nod to Europe). That's the upper end of DOCSIS 3.0's reach.

In that same 192 MHz, OFDM packs 8,000 carriers. And when it comes to reacting quickly to ingress and other noise floor contributions, those 8,000 carriers can much more lithely follow a tilt, or the edge of an ingress signal. That's how it is that OFDM truly gives service providers better resolution in response to changes in the noise floor.

In practice, it's the two together — OFDM with LDPC — that enable the 50% throughput gains, upstream and downstream, that people talk about when discussing DOCSIS 3.1.

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