White Paper

DOCSIS 3.1: Cable Tackles the Gigabit Challenge

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Introduction: Dawn of the DOCSIS 3.1 Era

With the rollout of the new DOCSIS 3.1 spec, the cable industry stands poised to compete in the emerging Gigabit Era. This new, fourth-generation DOCSIS standard, crafted and completed by CableLabs in record time and now in the preliminary stages of deployment, promises to give cable operators the ability to deliver data download speeds as high as 10 Gbit/s and upload speeds as high as 2 Gbit/s over their existing hybrid fiber/coax (HFC) lines. That ability will enable them to compete head-on with the growing number of telcos and other ISPs leveraging fiber-to-the-premises (FTTP) networks, including AT&T, Google Fiber and CenturyLink.

Besides the faster download and upload speeds, DOCSIS 3.1 also offers cable providers such other tangible benefits as higher bandwidth capacity, greater operational efficiencies, better quality control, real-time performance analysis and lower costs, all without necessarily having to upgrade their HFC networks, expand their RF plant spectrum or add more fiber lines. Beyond all that, DOCSIS 3.1 is also backward-compatible with DOCSIS 3.0, cable's current flagship broadband spec, which allows cable providers to roll out the new spec seamlessly on an incremental basis.

Not surprisingly, then, many cable operators are now eagerly awaiting the chance to deploy DOCSIS 3.1. In a survey of cable providers across the globe last year, IHS Inc. found that, on average, providers expect to pass about a third of their residential broadband subscribers with DOCSIS 3.1-enabled headends by April 2017. In the U.S. alone, that would translate to more than 17 million cable broadband subscribers passed by DOCSIS 3.1 by that date. If such a brisk rollout pace can be achieved, DOCSIS 3.1 will be far more widely deployed in the early going than its predecessor, DOCSIS 3.0, as well as all earlier versions of the cable broadband spec.

Similarly, in a study released in late January 2016, ABI Research predicted that 9 million cable households – about 1 percent of all cable broadband subscribers worldwide – will actually be using DOCSIS 3.1 technology by 2017, thanks mainly to aggressive MSO deployments in North America and Western Europe. Finally, in a Light Reading community poll conducted last year, readers selected DOCSIS 3.1 as the cable industry's leading technology priority. In fact, more than a third (36.5%) of the 1,004 survey participants chose DOCSIS 3.1; the only other next-generation cable technology that even came close – Distributed Access Architecture – drew votes from 22% of readers.

At the same time, DOCSIS 3.1 presents several major fresh challenges for the cable industry, demanding major technological shifts, operational changes and potential spectrum shifts for its full implementation. Moreover, cable operators will need new equipment, procedures, and testing and monitoring tools to turn their Gigabit dreams into reality. They will also have to carry out extensive staff training and retraining, even as they seek to fend off the competitive challenges from rivals deploying FTTP architectures, their own next-generation versions of passive optical networking (PON) and such other telco-friendly technologies as the emerging G.fast standard.

This white paper explores how MSOs can upgrade their plants, networks, operations, equipment, testing tools and workforce for DOCSIS 3.1. It delves into the key aspects of DOCSIS 3.1, including its higher data speeds, greater spectral efficiencies, adoption of orthogonal frequency-division multiplexing (OFDM) subcarriers and embrace of higher orders of QAM modulation. It spells out the myriad benefits that MSOs can reap from the introduction of the new spec and examines the technical, operational and other hurdles that operators face in implementing it. Finally, the paper explains how MSOs can overcome these obstacles to compete successfully in the new Gigabit Age, recommending some best practices for operators to follow.

Cable's Buildup to DOCSIS 3.1

As stated in the introduction, cable's development of the DOCSIS 3.1 spec has proceeded at a breakneck pace, taking significantly less time than all of the previous versions of the DOCSIS broadband standard. CableLabs released its original version of the new spec in October 2013, just one year after announcing its intention to draft it at the fall 2012 SCTE Cable-Tec Expo show in Orlando. By way of comparison, the previous version of the spec, the current DOCSIS 3.0 standard, took about two and a half years for cable technologists to craft after revealing their intentions to do so.

In the two-plus years since that initial release in late 2013, the DOCSIS 3.1 spec has continued to hum along on a fast track. At CableLabs headquarters in Louisville, Colorado, the special DOCSIS 3.1 Working Group has focused on upgrading and refining the spec to make it more powerful and efficient, updating the spec's requirements several times. In industry labs throughout the world, silicon providers have designed and developed the chipsets to support DOCSIS 3.1 cable modems, gateways, cable modem termination systems (CMTSs) and Converged Cable Access Platform (CCAP) devices and other gear. In other industry labs, equipment suppliers have worked on designing and developing the actual home and headend devices to make the promised gigabit speeds a reality for cable broadband subscribers. And, in still other industry labs, testing specialists have been designing and developing the probes and other tools to monitor the performance of those devices and the networks they're using.

At the same time, several large cable operators have been busy preparing their plant for DOCSIS 3.1 field trials and commercial deployments by expanding their capacity, clearing their existing spectrum and carrying out other necessary changes. Led by such major MSOs around the world as Comcast, Liberty Global, Cox Communications, Rogers Communications, Videotron, Suddenlink Communications and Vodafone New Zealand, they have also been busy formulating their plans for delivering gigabit services over their HFC networks. So have some small and midsized MSOs, including Mediacom, CableOne, GCI, Atlantic Broadband, Wave Broadband, MidContinent and others, although some plan to rely on the older DOCSIS 3.0 spec, at least initially.

In the midst of this frenzied activity, CableLabs began staging equipment interoperability tests, or "plugfests," of various vendor gear in December 2014 to see how well they performed together. Since then, the cable industry's research and development organization has conducted these equipment interops at least once every two months, wrapping up its seventh session in the series in December 2015. So far, more than two dozen equipment and test manufacturers have participated in these plugfests. Several more interops are scheduled for 2016, with the first one already held in January 2016.

In June 2015, CableLabs followed up this move by launching equipment "dry run" tests. These more advanced lab tests are designed to ensure that products are ready for certification testing. So far, CableLabs, which has been holding these dry runs almost monthly, has completed five rounds of pre-certification testing, doing it with extensive participation once again from both equipment and test vendors.

In late September 2015, CableLabs held its inaugural DOCSIS 3.1 Demo Day at its Louisville headquarters. This unprecedented event, designed to demonstrate the capabilities of the new spec and the equipment being built for it, featured cable modems, CMTS and CCAP devices and test gear from nearly two dozen manufacturers. Among other things, the demonstrations sought to highlight the spec's multi-

gigabit capabilities, backward compatibility with previous versions of DOCSIS, spectral efficiency and future scalability.

Finally, in a notable switch from previous practice, CableLabs started offering more flexible, "rolling certification waves" to equipment makers in August 2015. Unlike the pre-set certification testing rounds that the cable R&D group relied on for all of its earlier DOCSIS specs, these rolling waves allow manufacturers to correct issues found during the certification testing and stay in the certification phase until they pass all the tests. Products qualify for entry into the certification program once they have graduated from the dry run process.

While no DOCSIS 3.1 products were certified by the end of 2015, the new year has already brought the first approved DOCSIS 3.1 devices. On January 13, CableLabs proudly announced that it had certified the first five DOCSIS 3.1 cable modems for MSO deployment, approving devices from Askey, Castlenet, Netgear, Technicolor and Ubee Interactive. CableLabs officials boasted that these five hybrid modems, which can support both DOCSIS 3.1 and DOCSIS 3.0 traffic, mark the largest number of products ever approved in the first certification wave of a new DOCSIS specification. They also said they expect to certify more DOCSIS 3.1 products in early 2016.

In an early holiday present to a small, select group of broadband subscribers, Comcast announced what's believed to be the world's first deployment of DOCSIS 3.1 cable modems "in a customer-facing network" late last year. Living up to the pledge that it made earlier in 2015, Comcast began deploying the modems in its Philadelphia hometown market in late November. It then rolled out the DOCSIS 3.1 modems to other parts of Pennsylvania, Atlanta and northern California over the first three weeks of December.

Following up on the modem deployment announcement, Comcast spelled out its first five markets for DOCSIS 3.1 service in early Feb. 2016. Plans call for introducing service first in Atlanta and Nashville in the early part of the year, followed by service launches in Chicago, Detroit and Miami during the second half of 2016.

Figure 1: The DOCSIS 3.1 Development Roadmap

Date	Activity
Oct. 2012	CableLabs announces DOCSIS 3.1 spec drafting effort.
Oct. 2013	CableLabs releases initial version of DOCSIS 3.1 spec.
Dec. 2014	CableLabs starts staging equipment interops. Eight "plugfests" have been held so far, with 27 vendors participating.
June 2015	CableLabs launches "dry run" tests of DOCSIS 3.1 devices to prepare them for certification. Five rounds have been held so far.
Aug. 2015	CableLabs starts offering "rolling certification waves" for equipment makers.
Sept. 2015	CableLabs holds "Demo Day" at headquarters, with 22 equipment makers participating.
Jan. 2016	CableLabs certifies the first five DOCSIS 3.1 modems from Askey, Castlenet, Netgear, Technicolor and Ubee Interactive.

Source: CableLabs

Figure 2: Early MSO Deployment Plans for DOCSIS 3.1

MSO	Deployment Plans
Comcast	Started deploying DOCSIS 3.1 commercially in late 2015, after much testing; named first five markets – Atlanta, Chicago, Detroit, Miami and Nashville – in February 2016.
Liberty Global	Now testing DOCSIS 3.1; plans to start deploying DOCSIS 3.1 commercially in field in early 2016.
Cox Communications	Now testing DOCSIS 3.1; plans to start deploying DOCSIS 3.1 commercially in field in 2016.
Rogers Communications	Plans to start deploying DOCSIS 3.1 commercially in 2016.
NBN	Plans to start deploying DOCSIS 3.1 commercially in 2016.
Vodafone New Zealand	Started deploying DOCSIS 3.1 commercially in phases in November; plans to complete deployment in February 2016.

Source: Company reports

DOCSIS 3.1's Main Benefits

There are numerous reasons why cable technologists have brought DOCSIS 3.1 to market in such record time. The new broadband spec promises several major benefits for cable operators, including gigabit download and upload speeds, higher bandwidth capacity, greater operational efficiencies, improved quality control and lower costs. Perhaps just as critically, the new DOCSIS spec offers backward compatibility with DOCSIS 3.0, a factor that will likely play a crucial part in the industry's rollout plans. Further, DOCSIS 3.1 extends the life of the cable industry's entrenched HFC network even further, once again forestalling the need for what many experts still see as the industry's ultimate upgrade to fiber-to-the-premises (FTTP) networks.

As most industry observers undoubtedly know by now, the most obvious benefit of DOCSIS 3.1 is the higher broadband speeds that it can deliver over cable's existing HFC networks. Under the latest version of the spec crafted by CableLabs, cable providers will be able to offer download speeds as high as 10 Gbit/s and upload speeds as high as 2 Gbit/s to their broadband customers. These maximum speeds compare quite favorably with the approximate top download and upload speeds of 1.2 Gbit/s and 100 Mbit/s in a 5-42MHz upstream plant that the current DOCSIS 3.0 flagship standard can deliver in North American cable systems.

DOCSIS 3.1 can achieve these much faster speeds by making use of orthogonal frequency-division multiplexing (OFDM) and expanding both the upstream and downstream radio frequency (RF) spectrum. OFDM is a technology that has been leveraged by other communications providers (including those in the mobile phone, WiFi and HomePlug sectors), but, while used in proprietary systems, has never been a standard in cable until now. Doing away with the traditional 6 MHz (North America and Asia) and 8 MHz (Europe) wide channel spacing that the cable industry has employed for decades, OFDM splits the spectrum into much smaller, more flexible 20 kHz to 50 kHz-wide subcarriers.

Thousands of these subcarriers can be bonded inside much larger spectrum blocks that could end up being as wide as 192 MHz in size, enabling cable operators to offer much higher speeds than they can offer now even over multiple bonded 6 MHz and 8 MHz channels. In turn, these 192 MHz blocks can then be combined into even larger spectrum blocks to achieve speeds approaching 10 Gbit/s, and possibly higher if cable operators utilize the RF spectrum above 1 GHz and up to 9 Gbit/s for the more common cable plants with 860 MHz RF spectrum. The much higher speeds result from a combination of higher order modulation made possible by the more robust OFDM technology, improved efficiency from the use of Low Density Parity Check (LDPC) error correction codes, and the elimination of the guard bands between the 6 or 8 MHz channels that were previously required.

Further, cable operators will be able to use the new spectrum blocks more flexibly than their current bonded channels. Speaking at a BTR breakfast panel during the SCTE Cable-Tec Expo conference in New Orleans in October 2015, Jorge Salinger, vice president of access architecture for Comcast, explained that DOCSIS 3.1 will permit cable providers to configure various parts of their spectrum in different ways. Instead of configuring their entire spectrum one way, as they do now with single-carrier quadrature amplitude modulation channels, he said, operators could configure different segments separately, thereby making more efficient use of that spectrum. The DOCSIS 3.1 spec enables this by empowering operators to establish different modulation profiles in their downstream and upstream spectrum and even change those profiles as needed.

Besides enabling cable operators to make use of much larger, more flexible spectrum blocks for broadband service, DOCSIS 3.1 also allows them to upgrade to higher orders of quadrature amplitude modulation (QAM). By employing such higher, more efficient modulation orders as 1024 QAM or even 4096 QAM instead of the 256 QAM standard today, cable providers can pack in more bits per hertz. The estimates range as much as 50 percent higher, which includes the aforementioned improvements from greater coding efficiency and the elimination of the channel guard bands. In turn, this greater transmission efficiency allows operators to boost their broadband speeds even higher.

In addition to letting cable operators make more efficient use of their current spectrum below 1 GHz, DOCSIS 3.1 offers options for tapping into more RF spectrum than ever before. Under the new spec, operators can leverage as much as 1.2 GHz spectrum for downstream use now and up to 1.7 GHz in the future. They can also leverage more spectrum for upstream use by employing such techniques as "mid-splits" or "high-splits." Due to the current North American upstream split of 5-42 MHz and EuroDOCSIS standard of 5-85 MHz, operators now have limited upstream spectrum available. DOCSIS 3.1 allows operators to reallocate their lower downstream frequencies for upstream use by changing the upstream split to 5-85 MHz or even 5-204 MHz, thereby enabling upstream speeds of up to 2 Gbit/s, depending upon plant conditions.

Moreover, DOCSIS 3.1 introduces another new technology, Forward Error Correction (FEC) based on the LDPC codes mentioned earlier, to the cable universe. An LDPC code is a linear error correcting code, or a method of transmitting a message over a noisy channel. As such, it should allow cable operators to send data messages more crisply and efficiently than before. Indeed, with LDPC replacing today's Reed-Solomon FEC approach, not only will the upstream transmission be more capable of overcoming more noise, it should also be more efficient in allowing less overhead to be used for error correction and more for data transmission.

The improved efficiency comes from the fact that LDPC uses much more intensive computational algorithms to reduce the impact of noise in the link, thereby reducing the coding overhead required for error-free transmission. Although LDPC codes have been around for decades, only in recent years has the computational processing power of modem chips been sufficient to implement these more complex algorithms. LDPC coding can also be found now in other OFDM applications, such as mobile phones, WiFi, HomePlug and DVB-C2.

The new DOCSIS spec also brings a greater set of Proactive Network Maintenance (PNM) capabilities to cable networks. Once fully implemented, these capabilities will let cable operators report and tackle a variety of network transmission problems automatically, rather than manually. As a result, operators will be able to identify and correct transmission problems before subscribers notice them and complain, producing significant cost savings through fewer customer service calls and repair truck rolls. The reduction in Trouble Call Truck Rates (TCTR) will contribute to better overall performance and reliability for customers.

In particular, DOCSIS 3.1 PNM permits much greater accuracy in locating impairments on the cable network, from several feet to a few inches. It also standardizes the ability of cable modems to capture both upstream and downstream spectrum on the cable network. Experts liken it to having time-domain reflectometers and spectrum analyzers in every subscriber's home for automatically monitoring the network without requiring truck rolls or temporary outages to insert test equipment into the path.

Active Queue Management (AQM) represents one more new DOCSIS 3.1 feature. Designed to improve the broadband subscriber's quality of experience (QoE), this feature should allow cable operators to boost their responsiveness for gaming and other Web applications by moving data packets along the network more swiftly and smoothly than before. In other words, AQM enables the *latency* in packet transport to be reduced significantly. It also allows operators to optimize their cable modem buffer usage and reduce transit time through the cable network by managing queue depth.

Another standout feature of DOCSIS 3.1 is that it offers backward compatibility with DOCSIS 3.0 and earlier versions of the DOCSIS standard. This feature is critical because it will allow cable operators to upgrade to DOCSIS 3.1 equipment and services without needing to upgrade their plant. It also will allow operators to roll out DOCSIS 3.1 incrementally, on a region-by-region, city-by-city, node-by-node or even customer premises device-by-device basis.

Indeed, as noted earlier, the first DOCSIS 3.1 cable modems available are hybrid modems capable of supporting both DOCSIS 3.1 and DOCSIS 3.0 channels and features. As a result, it's likely that most initial deployments of DOCSIS 3.1 will still use DOCSIS 3.0 upstream signaling. Thus, this compatibility between the two specs is critical for a graceful transition to a full DOCSIS 3.1 implementation.

Last but not least, DOCSIS 3.1 includes some new energy management features that will help the cable industry reduce its energy usage. Cable modems may cut their energy requirements during periods of inactivity, shrinking their carbon footprint until needed for higher-capacity times.

Figure 3: Main DOCSIS 3.1 Benefits

Key Benefits	Details
Higher broadband speeds	Support for up to 10 Gbit/s downstream and 2 Gbit/s upstream network capacity.
Improved user QoE	AQM improves responsiveness for gaming and Web.
Fluid deployment strategy	Backward compatibility provides a flexible migration for cable operators.
Cost reductions and greater efficiency	Offers up to 50% more data capacity over the same spectrum relative to DOCSIS 3.0.
Higher capacity over existing HFC network	No upgrade required. Supports more spectrum for even more capacity.
Greater energy efficiency	Cable modems can cut their energy requirements during periods of inactivity.

Source: Heavy Reading

Key Challenges of Deploying DOCSIS 3.1

Despite the new spec's great promise, DOCSIS 3.1 will not exactly be a walk in the park for cable operators to deploy and manage. Indeed, the new broadband spec poses several daunting technical, operational and other hurdles for cable providers to overcome. Specifically, compared to earlier versions of DOCSIS, DOCSIS 3.1 makes the most dramatic change to the physical layer and adds more features than any of its predecessors.

First and perhaps foremost, cable operators must clear enough capacity in their systems to take advantage of the large blocks of spectrum that DOCSIS 3.1 can make available. That can be a tall order for the industry's standard 750 MHz, 860 MHz or even 1 GHz systems clogged with hundreds of analog and digital video channels, scores of HD video channels, dozens of bonded broadband channels, IP video services, voice services, business services and the like. For operators, it means taking costly extensive steps like switching over to all-digital transmission and eliminating all analog video channels, upgrading from the MPEG-2 codec to MPEG-4 for HD video services and/or implementing switched digital video (SDV) technology to make more efficient use of their current spectrum and clear room for DOCSIS 3.1.

Further, switching over to OFDM blocks of subcarriers represents a major operational change for cable providers, who have long relied on single-carrier QAM channels designed primarily for video use. While other industries, such as the mobile sector, have successfully implemented OFDM subcarrier blocks, it is a completely new standard for cable.

While extremely powerful, OFDM also brings larger chunks of spectrum at once (48/96/192 vs 6/8 with SC QAM), which will require new tools and a new approach to analysis. The technology's dynamic aspect also makes it harder to just look at a time and have a good picture of the network's performance.

What's more, moving up to much higher, more advanced orders of QAM modulation for greater spectral efficiencies is never an easy thing to implement. In addition, the move to more complex modulation schemes will create new network performance and signal quality requirements to achieve the highest orders of modulation. Given the same signal-to-noise ratio (SNR), DOCSIS 3.1 performs quite a bit better than DOCSIS 3.0, thanks to LDPC. However, to achieve 4K QAM, higher SNR is needed than before (although multiple profiles mean that not all cable modems have to go to 4K QAM to work.)

Clearing more spectrum for DOCSIS 3.1's greater upstream capacity could be problematic, as well. To create more upstream capacity, cable operators will likely need to conduct "upstream splits," converting some of their lower downstream spectrum to upstream use by pushing out the upstream path from 42 MHz to either 85 MHz or 204 MHz. These kinds of bandwidth conversions are both costly and time-consuming to carry out and can lead to major in-home problems, making it roughly the cable equivalent of a dental root canal.

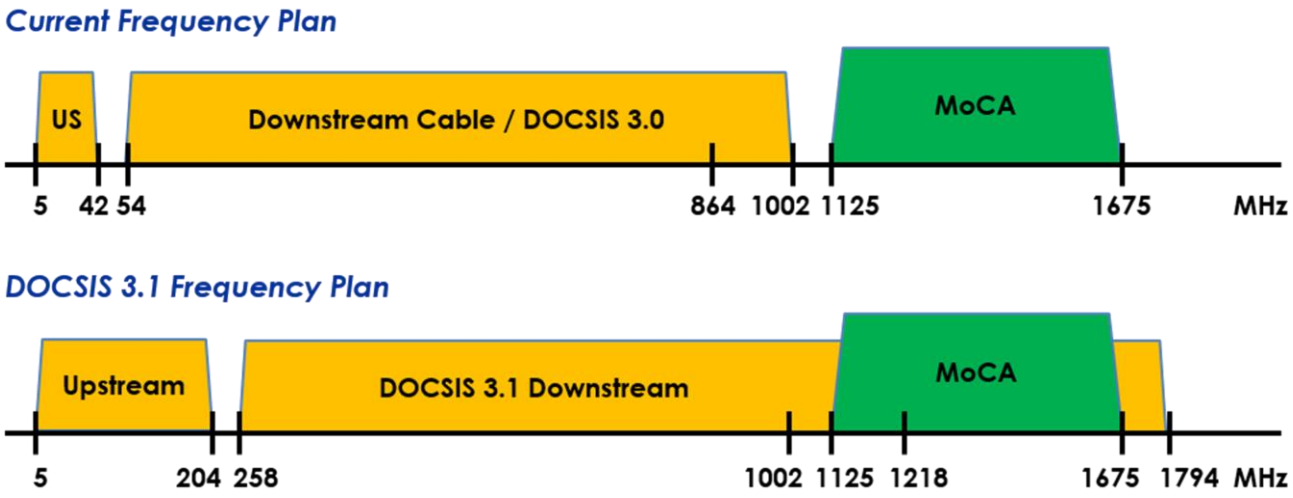
The 85 MHz "mid-split" is significantly less problematic because most existing equipment in the home will continue to work with no issues. On the other hand, the 204 MHz "high-split" will require replacement of a lot of existing customer premises equipment, because the legacy equipment uses out-of-band communications in that frequency range and the isolation of older equipment is not sufficient to prevent interference.

Upgrading a cable system to raise the upper limit of its RF spectrum beyond 1 GHz to 1.2 GHz or higher (1.5 GHz or 1.7 GHz) could prove quite challenging, as well. Expanding a cable system's upper RF frequency bandwidth beyond the current 1 GHz limit will require a host of both new passive and active devices, including taps, amplifiers, optical laser transmitters, nodes and the like. While some of these upgraded devices are already available from manufacturers, they must still be bought and then installed on the HFC plant by operators, consuming both time and money.

Another, lesser-known technical issue presented by DOCSIS 3.1 is frequency interference in the home. That's because DOCSIS 3.1 and such popular home-networking technologies as Multimedia over Coax (MoCA) share some of the same frequencies or at least overlap to some degree. For instance, in a 1.8 GHz plant, both the DOCSIS 3.1 downstream bandwidth and MoCA might use the upper reaches of the spectrum because MoCA can use the 1.1 GHz to 1.6 GHz frequencies.

Even in a 1.2 GHz plant, if MoCA is operating at 1.1 GHz, there would be some overlap. For this reason, the in-house coax wiring would have to be separated from the coax wiring entering the premise. While cable operators may use filters on devices impacted by the overlap, that will require truck rolls or customer training to know where to install the taps.

Figure 4: Coexistence Between DOCSIS 3.1 & MoCA



Source: SCTE

One more great challenge that the cable industry faces with DOCSIS 3.1 is developing and acquiring the proper testing and monitoring tools for deploying and monitoring the spec's implementation and performance. Because DOCSIS 3.1 leverages so many technologies and techniques that are either more advanced or completely new to cable, operators need vastly updated or entirely new sets of probes and other tools to track network performance, identify and report operational problems, and correct issues as soon as they are found. That was not so true for earlier versions of the broadband spec.

Besides the fact that test devices supporting DOCSIS 3.0 will not support DOCSIS 3.1, the plant spectrum divides will also likely change, moving to 85 MHz/204 MHz on the

return and 1.2/1.5/1.7 GHz on the forward end. Further, the complexity of the signal being analyzed will require macro analysis and metrics done at the silicon level and presented in a simpler way to the technician. Before, cable engineers would have looked at 8 QAM on the forward end for DOCSIS 3.0; now they will have to look at several thousand subcarriers for DOCSIS 3.1.

Along with all the various technical and operational challenges presented by the DOCSIS 3.1 spec, there are the corresponding personnel challenges to consider. Namely, cable operators must train or retrain tens of thousands of engineers, installers, technicians, customer service specialists and other staffers to deal with the new spec and the new technologies that it introduces to the cable space. Once again, this represents a significant change of course for the industry, which has never before experienced the need to train so many of its people for a new technology standard before actually deploying it.

Due to these factors and more, the cable industry faces some unprecedented challenges in realizing its multi-gigabit dreams with DOCSIS 3.1. Of course, nobody ever said it was going to be easy.

Figure 5: Main DOCIS 3.1 Challenges

Key Challenges	Details
Clearing enough overall capacity in cable systems	Operators need more capacity to take advantage of the spec's larger blocks of spectrum.
Switching over to OFDM blocks of subcarriers	Major operational change for cable providers who have long relied on single-carrier QAM channels.
Moving up to much higher orders of QAM modulation	Creates new network performance and signal quality requirements to achieve higher QAM.
Clearing more spectrum for greater upstream capacity	Operators will likely need to do "upstream splits," converting downstream spectrum to upstream use.
Raise the upper limit of RF spectrum beyond 1 GHz	Requires host of new passive and active devices, including taps, amplifiers, optical lasers, nodes, etc.
Overcoming frequency interference in the home	DOCSIS 3.1 and MoCA share some of the same frequencies or overlap.
Developing and deploying new testing/monitoring tools	Operators need vastly updated or entirely new sets of tools to track, identify, report and correct issues.
Bringing cable personnel up to speed	Operators must train or retrain thousands of engineers, installers, technicians and other staffers.

Source: Heavy Reading

Overcoming the Prime Challenges

Fortunately, cable operators have plenty of reason for hope as they prepare to face the myriad challenges posed by the new DOCSIS 3.1 spec. In this section, we will lay out some prime ways that operators can overcome the hurdles spelled out in the previous section. We will also discuss key factors that operators should consider when deciding whether, when and how to upgrade to DOCSIS 3.1 and then recommend some key steps that they can take once they decide to move forward.

As such strong DOCSIS 3.1 champions as Comcast's Jorge Salinger and Cox Communications' Jeff Finkelstein have stressed in their public comments about implementing the spec, perhaps the most important thing to know about DOCSIS 3.1 is that it does not have to be deployed all at once. Thanks in large part to DOCSIS 3.1's backward compatibility with DOCSIS 3.0, cable operators can upgrade their plant to the new spec's requirements incrementally on not just a market-by-market, system-by-system or even neighborhood-by-neighborhood basis, but even on a phased node-by-node basis.

This means that operators can introduce new home equipment, network testing tools and new data speeds and other services slowly and deliberately, taking plenty of time to get things right. Cable modems may be installed on a customer-by-customer basis, enabling organic growth based on service tiers purchased.

As Cox's Finkelstein told Cable Congress 2015 in Brussels in March 2015: "The key learning of 3.0 is we had no experience with 3.0, and with 3.1 we are writing test plans but don't have any real life experience yet either. As you take each step, stop and breathe and let your technology guys get some sleep. A lot of this work needs to be done in the maintenance window, which for us is 2 a.m. to 5 a.m."

Anticipating such a careful, incremental rollout strategy, equipment makers have designed the first DOCSIS 3.1 cable modems to be fully hybrid models, capable of supporting both the new spec and the older DOCSIS 3.0 spec. These new modems, which are now rolling off the factory assembly lines for interoperability and certification testing, can support up to 32 downstream and 8 upstream channels under the DOCSIS 3.0 spec and two OFDM channels under DOCSIS 3.1.

As a result, cable operators will be able to leverage these devices for both DOCSIS 3.0 and DOCSIS 3.1 speeds and services without carrying out any immediate plant upgrades. Most notably, they can use DOCSIS 3.1 downstream signals with DOCSIS 3.0 upstream signals, which simplifies the deployment process by focusing on the greatest need for more downstream capacity and bandwidth.

While switching over to OFDM blocks of subcarriers represents a major operational change for cable providers, Proactive Network Maintenance is designed to fill this gap between past and present. Early training of field network technicians in this technology has been ongoing for most operators and will continue through deployments.

As for managing the higher orders of QAM modulation, DOCSIS 3.1 is dynamic and can adjust the depth of modulation based on the SNR of the plant. Cable operators can easily have different modulation depths depending on the specific noise of any part of the spectrum, making it extremely robust against noise. Thus, with the capabilities of mixing modulation profiles, operators possess the tools to manage this issue and learn as they deploy more equipment over larger portions of the footprint. As operators have learned from their earlier DOCSIS deployments, though, the lab and field trials may help them prepare, but it is only at scale that the real learnings occur.

Beyond the spec itself, cable operators should benefit from the extensive research and trials that CableLabs technologists and equipment and testing vendors have aggressively conducted over the past two years in the labs. For instance, as detailed in an earlier section of this paper, CableLabs engineers have so far conducted seven rounds of equipment interops and five rounds of dry run tests to ensure that the new DOCSIS 3.1 gear meets the required standards for certification testing. Previous versions of DOCSIS did not see such intensive waves of testing.

During those tests, CableLabs has reported that multi-vendor interoperability has already been achieved, with maximum download speeds of 4 to 4.5 Gbit/s. These speeds have required two 192Mhz 4K QAM OFDM channels and 32 single carrier QAM channels. In addition, CableLabs has revealed that the tested equipment has realized such higher orders of modulation as 1024 QAM for the upstream path and 4096 QAM for the downstream. Thus, the early DOCSIS 3.1 gear seems to be on track for meeting the spec's requirements.

Most cable operators seeking to launch the new spec should also benefit from the early deployment experiences of such DOCSIS 3.1 pioneers as Comcast, Liberty Global, Cox, Vodafone, Videotron and others. As those early adopters begin to roll out the new equipment commercially in the field this year, the lessons that they learn and share should help other MSOs move ahead and deploy DOCSIS 3.1 with greater speed, ease and effectiveness.

Moving on to the cable HFC plant, clearing enough spectrum to optimize DOCSIS 3.1 over the long term appears to be quite doable even if it may appear to be a daunting task at first. Indeed, several leading cable operators are showing that right now. Consider the case of Comcast, for example. Starting the process several years ago, the biggest U.S. MSO has freed up loads of precious spectrum by switching to all-digital transmission, removing up to 80 analog channels from its systems (and thereby saving an impressive 480 MHz of bandwidth). In addition, Comcast is upgrading its video delivery systems from MPEG-2 encoding to MPEG-4 encoding for its HD channels, thus freeing up about half of the bandwidth it had previously used for delivering HD services.

Creating more capacity for greater upstream bandwidth over the long term is also quite doable. Although it may seem like a painful, costly process, performing mid-splits should actually extend the life of the upstream plant and reduce the need for operators to carry out more node splitting. Initially defined as part of the DOCSIS 3.0 standard, the 85 MHz mid-split (also known as the N-split return bandwidth allocation) could nearly triple the amount of clean spectrum available for the return path with just a relatively small reduction in downstream bandwidth. If coordinated properly, the mid-split move could also enable cable operators to boost their downstream bandwidth by expanding their plant's overall frequency bandwidth to 1 GHz and beyond.

Speaking of overall bandwidth expansion, another key step that cable operators can take to clear more spectrum for DOCSIS 3.1 over time is to raise the spectrum upper limit of their RF plant to 1 GHz and higher. Such a move would enable operators to free up more spectrum for upstream use without cutting into any downstream bandwidth. Plus, if operators can lift their spectrum ceiling beyond 1 GHz, it will allow them to take even fuller advantage of DOCSIS 3.1's speed potential.

For instance, cable technologists estimate that it will take 200 MHz of dedicated bandwidth, or about five times the amount reserved for the return path today, to support the spec's maximum upstream speeds of 2 Gbit/s. Similarly, it will take 1 GHz of dedicated bandwidth, about 1.25 times the amount reserved for the forward

path today, to support the spec's maximum downstream speeds of 10 Gbit/s. Throw in all the other services that cable operators deliver (broadcast video, narrowcast video, voice, other data services and the like) and it's estimated that operators may need 1.5 GHz to nearly 1.8 GHz overall to support everything in their lineups.

Figure 6: DOCSIS 3.1 Spectrum Expansion Options

Downstream Spectrum	Upstream Spectrum
1. Initially use 750/862/1002 MHz plants (> 6 Gbit/s)	1. Use the current sub-split 42/65 MHz (> 200 Mbit/s)
2. Next move up to 1.2 GHz with amp upgrade (> 7 Gbit/s +)	2. Conduct mid-split at 85 MHz (> 400 Mbit/s)
3. Move long-term to 1.7 GHz with tap upgrade (> 10 Gbit/s +)	3. Perform high-split at 204 MHz (> 1 Gbit/s)

Source: Heavy Reading

Tackling the potential frequency interference issue with MoCA, the SCTE has formed a special working group uniting experts from SCTE, CableLabs and MoCA itself to develop a set of recommendations for avoiding problems, primarily through frequency management. The group is also considering longer-term solutions, such as separate F-connectors for the in-home vs. the wide-area cable modem network. Both of these solutions avoid costly add-on filters that would still have difficulty entirely mitigating the potential problems when cable networks expand beyond 1 GHz RF into the MoCA frequency range.

On the network and equipment performance end, testing vendors are working to fill the gap by designing and producing the new software probes and other types of tools needed to monitor the implementation of the new spec. Like the equipment vendors, they have participated extensively in the CableLabs interop and dry run exercises, preparing their products for the certification process and commercial deployments.

Finally, on the people front, cable operators, equipment and testing vendors and, in particular, industry organizations are working furiously to bring their staffers up to snuff on DOCSIS 3.1's numerous intricacies. Fortunately, the SCTE and other organizations and companies are already offering comprehensive DOCSIS 3.1 training programs, and doing so much earlier in the deployment cycle than ever before to accelerate the deployment of DOCSIS 3.1 technology.

For example, SCTE has developed several training courses for cable employees in different job functions. Most notably, SCTE has created an intensive three-week DOCSIS 3.1 "boot camp" for cable engineers to teach them about the new spec's various requirements.

In summary, there are plenty of steps, some short term and some long term, that cable providers can take to prepare for the DOCSIS 3.1 Era and scale the hurdles that the new standard presents. The most critical thing for providers is to start taking at least some of those steps now, rather than waiting another year or two for the era to unfold.

Conclusion

With the first DOCSIS 3.1 devices now getting certified by CableLabs and the first DOCSIS 3.1 cable modems now being deployed by Comcast and other MSOs, the DOCSIS 3.1 Era has clearly begun in earnest. While many, if not most, MSOs do not plan to start deploying the new broadband spec until later this year, 2017 or perhaps even later in the decade, every cable provider undoubtedly has its eyes upon the new multi-gigabit standard as the industry seeks to maintain its competitive edge in the fiercely contested broadband market.

It's easy to see why. As this paper has spelled out, DOCSIS 3.1 offers several major benefits for cable providers, ranging from its support for multi-gigabit downstream and upstream speeds to improved operational efficiencies to greater quality control to reduced transmission costs. In addition, DOCSIS 3.1 is backward-compatible with DOCSIS 3.0, enabling cable operators to upgrade to the new spec carefully and incrementally on a node-by-node basis if they so choose.

As has been widely stated by industry experts, even if cable operators do not wish to boost their data transmission speeds right away, DOCSIS 3.1 brings tremendous performance enhancements. These enhancements are due to its ability to adapt to, correct or avoid noise, eliminate guard bands and leverage even more capable and accurate proactive network monitoring technology. Plus, the new spec can be used today without modifying the plant.

To be sure, cable providers face some major hurdles in deploying this fourth generation version of the industry's broadband spec. As detailed earlier in the paper, these hurdles include mastering new or advanced technologies like OFDM subcarriers and higher orders of QAM modulation, clearing more capacity for DOCSIS 3.1 channels, shuffling around spectrum for greater upstream bandwidth, raising their overall RF plant spectrum limit, deploying new equipment and trying out testing tools and procedures. The industry must also retrain tens of thousands of engineers, technicians, installers and the like to bring the new standard to life.

Nevertheless, as this paper also explains, many, if not most, of these seemingly daunting challenges can be overcome either in the short term or over time if the proper steps are taken. Cable operators can take advantage of OFDM, higher QAM orders and other new technologies, free up more capacity for DOCSIS 3.1 use, create more upstream bandwidth, increase their plant spectrum limits, deploy new cable modems, headend devices and other new gear and make use of new, more advanced testing and monitoring products. And, with the help of SCTE and other industry organizations, operators can train and retrain an entire generation of the industry's workforce.

So, whether they are planning to start rolling out DOCSIS 3.1 right away, later this year, next year or two years or more from now, cable providers must sort through these issues now so that they don't get caught short later on. Cable operators should study DOCSIS 3.1 and start deploying it now, even if just in a small block of downstream channels and not at all on the upstream, to learn as the spec evolves and improves, as all previous DOCSIS specs have done after their initial deployments. In an age of gigabit services, the world is moving faster and faster every day. So it is critical to start learning and playing with the technology today.

"HFC not only has a long life, but a long, useful life, and DOCSIS 3.1 is proof of that," notes Cox's Finkelstein. "DOCSIS 3.1 will serve the cable industry well for many years."