Get Ready -
‘Cause Here it Comes:
DOCSIS 4.0

BROADBAND SUCCESS PARTNERS

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It's time to fasten your seat belt time. *Again.*

Never mind Peak TV, we are experiencing Peak Broadband usage in great part due to exponentially increased streaming combined with 5G roll-outs. All this usage has never been better for the industry as cable ISPs simply have the biggest pipes to carry the burden from backhaul to delivery.

Truth is there is no 5G (generation) without 10G (gigabytes) and if we are going to keep up with our customer demands and needs, its simply time to upgrade our plants. Again.
The following, we hope, explains where we've been, why we need to upgrade and what in blue blazes DOCSIS 4.0 is – and why, without 4.0, we can't get to 10G.

Need to upgrade

Speed on consumer data networks has been increasing at approximately 50% per year since modems were first introduced[1]. There is little sign of this rate of increase changing. Customer demands increase due to the introduction and adoption of newer, higher-bandwidth applications and this drives the increase in network speed. Web browsing pushed the original shift from dial-up to cable modems. VOIP necessitated DOCSIS 2.0 technology, and the wide acceptance of streaming video and High Definition drove DOCSIS 3.0 and 3.1. Now, we see the conversion from HD to 4K and perhaps beyond.

The introduction of Augmented Reality/Virtual Reality adds another network requirement: low latency. While the physical network does not have a major impact on latency, it does help drive operators toward a more distributed, de-centralized architecture.

The desire to service 5G small cells will also drive operators toward lower latency and higher bandwidth networks.

What options do operators have to increase capacity on an existing network? For one, they can reduce the size of service groups by "node splitting". With "node splitting", the plant and customers fed by one node is divided into two or more segments served by new nodes. This usually takes the form of a "segmentable" node, where multiple plant legs leaving a node housing are fed by different modules within the housing.

Unfortunately, many nodes have been split into two or four already, and design architecture and available technology make it difficult to split further at a single housing. That means that if

[1] http://grouper.ieee.org/groups/802/3/ad_hoc/bwa/public/apr12/Comment_25_0412.pdf

plant is to be further segmented, it will need to happen elsewhere. The logical place is at existing amplifier locations which would be converted into new nodes. Replacement of amplifiers with nodes is the basis for cascade reduction, where a plant that was previously Node + 5, for example, is changed to Node + 3. It is also the basis for "Fiber Deep", or Node + 0, when taken to the extreme of replacement of all of the amplifiers with fiber nodes.

By running a higher order of modulation on the QAM carriers that transmit DOCSIS (and other) signals, the throughput for a given bandwidth may be increased. This is only possible if the signal-to-noise ratio is sufficient to support the higher order modulation at an acceptable error rate. Fortunately, when the cascade of amplifiers is reduced or eliminated, the signal-to-noise improves. Further, when transmission is changed from traditional analog laser/receiver nodes to DAA, it improves further. The combination of these with advanced DOCSIS 3.1 error correction capabilities makes 16384QAM downstream possible, yielding a 40% improvement over today's 1024QAM.

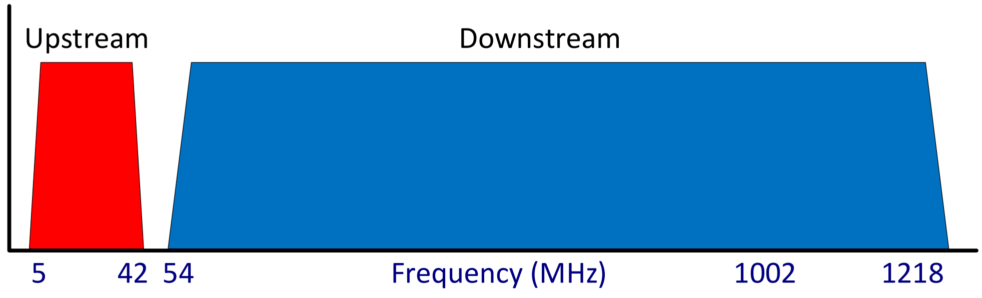
The greatest bandwidth increase comes the way it has traditionally in the cable business – by expanding the RF spectrum carried by the network. As with upgrades of old, the highest RF frequency is extended by replacing active (and possibly passive) elements within the coaxial network. DOCSIS 4.0 is the latest CableLabs specification to address what is possible with HFC.

What is DOCSIS 4.0?

CableLabs Physical Layer Specification - CM-SP-PHYv4.0-I01-190815

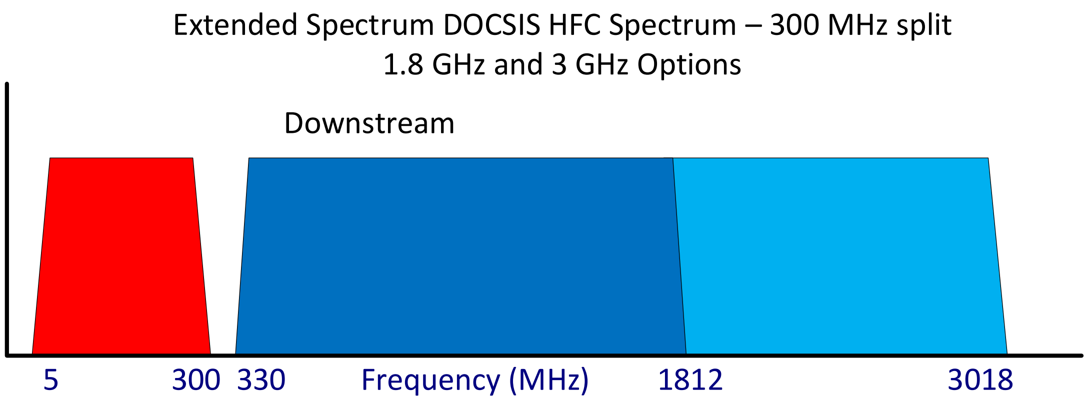
DOCSIS 4.0 builds upon earlier DOCSIS versions. In particular, portions of the DOCSIS 3.1 specification are consolidated into a single new specification and expanded to include greater plant RF bandwidth. Let's take a look at what the new RF bandwidth limits will mean in terms of plant components.

Conventional (Legacy) HFC Spectrum



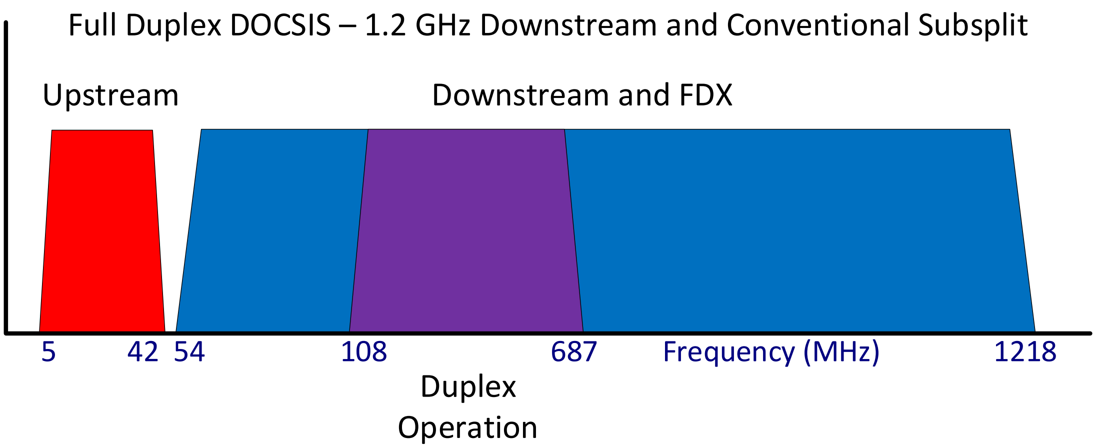
The DOCSIS 3.1 specification has a top frequency of 1.2 GHz. Most operators use this in conjunction with a "sub-split" or "low-split" upstream frequency range of 5-42 MHz and downstream from 54-1200 MHz. This creates a very lop-sided transmission capability limiting upstream speeds to below 300 Mbps. One of the most important changes of DOCSIS 4.0 is to expand the downstream RF frequency range. This is accomplished through two methods: expanded spectrum and Full Duplex DOCSIS.

For Extended Spectrum DOCSIS, the highest plant frequency is increased first to 1.8 GHz and later to 3.0 GHz. Along with extending the highest frequency, the upstream/downstream split may be changed not just to 85 MHz, but to 204, 300, or 396 MHz. Some DOCSIS 4.0 equipment will allow the split to be adjusted to one of several choices remotely, allowing operators maximum flexibility.



Full Duplex Requirements

With Full Duplex DOCSIS (FDX), a portion of the spectrum is set aside for transmission in both upstream and downstream directions by FDX-capable equipment. In order to make this equipment reasonably affordable and easier to design, the lower range of formerly downstream frequencies are selected, using the range 108-687 MHz. Because this range is no longer available for strictly downstream services, the technique is sometimes combined with ESD to make up the difference.

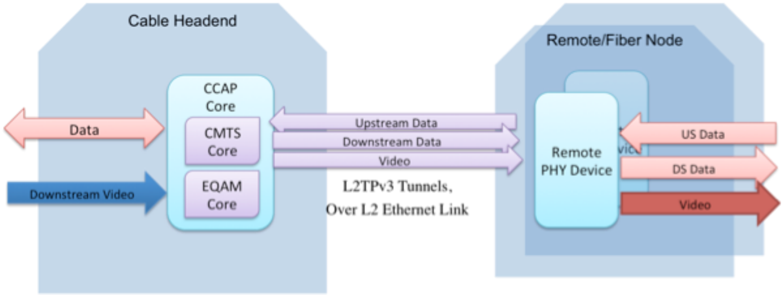


What infrastructure changes are required for DOCSIS 4.0?

Changes to the Fiber Plant

Architecture changes (Distributed Access Architecture, Remote Phy)

The act of changing from an analog HFC architecture to a Distributed Access Architecture (DAA) does not imply any network topology changes on its own. It is only when coupled with other changes, such as node splitting, bandwidth changes, or cascade reduction that the fiber plant will need to be re-worked in some way.



Source: CableLabs

Amplifier cascade reduction (Node + X)

Reducing the cascade requires that fiber is extended such that a new service group can be connected from the headend to each new node. If the plant has plenty of spare fibers available (few do), new cable from a convenient splice location in the existing fiber plant is installed. If spare fibers are few, the only alternative to an extensive construction project is installation of CWDM or DWDM.

Wavelength Considerations

If considering CWDM, it should be noted that the attenuation of the fiber changes as you depart from 1550 nm. This, coupled with the limited number of wavelengths available in CWDM systems, makes DWDM the preferred choice.

To sum up: While the basic fiber architecture of an HFC system does not change to support DOCSIS 4.0, additional fiber will be required to feed new nodes.

Background & History

Existing HFC Networks

Cable operators have been using Hybrid-Fiber-Coax (HFC) networks for more than 25 years. The flexible nature of HFC has permitted transmission of video, voice and data at ever-increasing speeds through a series of plant and terminal equipment upgrades that have provided a robust platform capable of delivering services equivalent to those of Fiber to the Home (FTTH) networks.

The latest round of upgrades promises to enable delivered date speeds well in excess of 1 Gbps, upstream and downstream, through a combination of DOCSIS 3.1 modulation techniques, Full Duplex DOCSIS (FDX), and Extended Spectrum DOCSIS (ESD). Taken together, these form the basis of the DOCSIS 4.0 Specification.

Upgrading to DOCSIS 4.0

Changes to the coaxial plant in a DOCSIS 4.0 network can be profound. These can be grouped into two main categories: supporting ESD and supporting FDX.

In the area of supporting ESD, the bandwidth capability of all active and passive components of the coaxial network must be evaluated. For simplicity, let's look at expansion to 1.8 GHz

Nodes

Nodes themselves must be capable of operating up to 1.8 GHz. If the upstream/downstream split is to be changed, they must also be able to accommodate new diplex filters and upstream transmitters.

Amplifiers

Unless also converting to Node + 0, the amplifiers will need to be able to pass the new 1.8 GHz downstream spectrum and new diplex filters.

Taps

Many of today's taps will perform beyond 1.2 GHz as-is. However, few will go beyond 1.5 GHz. Taps will need to be replaced. The tap replacement might be limited to a plate change, which is less disruptive to service than a change of the entire tap housing. A review of tap specifications and possible lab testing would be in order before considering such an upgrade.

COAX Cable (Hardline and Drop)

Most modern hardline coaxial cable is quite capable of operation to 1.8 GHz and beyond. However, the attenuation at these higher frequencies presents formidable design challenges. An Outside Plant (OSP) cable specified at 1.94 dB/100 ft at 1.2 GHz would instead lose 2.43 dB/100 ft at 1.8 GHz. That same cable would lose over 3 dB/100 ft at 3 GHz.
Drop cable, and in-home cable, is a greater concern. A common RG-6 drop that measures 7.2 dB/100 ft at 1.2 GHz clocks in at 8.97 dB/100 ft at 1.8 GHz and nearly 12 dB/100 ft at 3 GHz. Even larger RG-11 cable loses 8 dB/100 ft at 3 GHz. This could result in a dramatic reduction in signal level at the home – more about that later.

The top frequency of connectors in the network should also be reviewed. A review of several manufacturers shows that new connectors are generally specified to 3 GHz.

CPE

Any modem created using the DOCSIS 3.1 specification has a top frequency of 1218 MHz. Obviously, these would not benefit from an ESD deployment. Legacy TV set-top boxes and tuners in TVs and other devices are also not specified to work above 1218

MHz, and some might be further limited. Much of the CPE would need to be replaced with DOCSIS 4.0 specified equipment in order to take advantage of new plant capabilities. If operated using OFDM signals, devices could operate at much lower downstream RF levels than they do today. This will be a factor, since it is likely that the new higher frequencies will arrive at much lower levels due to higher drop attenuation.

Drop/Home Architecture

One way to get around the lower signal levels at the home would be to convert from a plant-extension architecture to a gateway architecture. In a plant-extension architecture, the entire RF spectrum is split to feed all of the devices in the home. This method requires that the loss of splitters and internal coaxial cable wiring be part of the loss budget for each and every device on the network. As stated above, when operating at much higher frequencies than we do today there might not be enough level to support conventional QAM signals. OFDM would fare better, but would still be a challenge.

In a gateway architecture, plant signals are terminated at a single device. The in-home coaxial network, if used at all, is completely isolated behind the gateway. Signal level to the gateway is the only concern, and is not hampered by splitters and internal coaxial wiring. The gateway device acts as a router and access point for high-speed data services, and connects to customer devices via Wi-Fi and Ethernet. For TV, it connects via Ethernet, MOCA, or Wi-Fi to “mini” set-top boxes.

In FDX, we have the same concerns as ESD if spectrum is expanded. However, whether or not spectrum is expanded there are new challenges added: Node + 0 architecture is required to support FDX. Current technology does not allow an amplifier to be in the line in order for echo-cancelation to function. Work-arounds are proposed that might permit Node + 1 in the future, however these require replacement of amplifiers at a minimum.

Because new FDX modems will be transmitting on frequencies within the passband of legacy devices, such a set-top boxes, interference within the home is a major concern. The high-level RF from a cable modem could pass from port to port on an in-home splitter and be detected in the set-top box, causing video “hits” whenever it transmits.

The problem could be even worse – in some instances the signal from one home could pass from one tap port to another and interfere with legacy equipment in a different home. One way to combat this would be to install filters on the FDX frequency band in front of legacy devices. Another way would be to convert to a gateway architecture as described above.

Bottom line: Support for FDX will require more changes than just adding new FDX modems in the homes that want the expanded upstream speeds that FDX can provide.

Can pieces of DOCSIS 4.0 be used individually?

Because the prospect of high cost and plant disruption associated with a full-on DOCSIS 4.0 deployment is daunting, it is reasonable to ask if portions of it might be used on their own. Some operators have chosen to avoid Node + 0, electing not to reduce service group size. Examination of congestion levels and predicted speed needs could show that higher QAM modulation levels available with a DAA deployment followed by a short cascade of amplifiers would allow enough of an improvement to deliver the required speed increase.

While choosing to avoid Node + 0 would shut these operators out of FDX, ESD is still an option. If the amplifiers are changed in order to allow the upstream/downstream split to be changed, up to 1 Gbps symmetrical service is certainly possible. In order to achieve cascade reduction or a change to a Node + 0 architecture, additional fiber or wavelengths will be required on the existing fiber plant in order to feed them.

Don't Forget: *It's Time to Buckle Up!*

Our industry meets change and disruption HEAD ON! The hurricane/tornedo/tsunami bandwidth storm is upon us. And again, we are ready with incredible home improvement tools from which we can pick and choose. These include the DOCSIS 4.0 HFC toolkit, or the unbeatable Fiber-To-The-Home cure-all.

Doing nothing is simply not an option. Competitor-driven wireless 5G deployments are happening, and we as an industry are not ready to provide the backhaul infrastructure, you can bet someone else will.

While the challenges associated with DOCSIS 4.0 are formidable, from split changes to architecture changes, and from fiber additions to new orders of modulation, it is far from impossible.

Time and again operators have shown that they are up to the task. This time, in this bandwidth weather, it's no different.