The Early Days of Cable Modems

The cable modem of the 1980s wasn’t even called a cable modem. It was designed and used primarily by engineers and was just called a modem, or sometimes, an RF modem. The information was digital—1s and 0s—and these early cable modems were less complex and served limited purposes. Some cable providers would link up various city buildings—the fire and police departments, a library, schools—on what was called an institutional network. With this, the attached buildings could send simple messages to one another over the cable system’s existing plant. The cable television companies themselves recognized the communication abilities of the plant they’d built, and they made use of early cable modems for their own internal communicating.

But despite the early indication of success, the cable modem would have a 15-year wait before it became mainstream.

The hurdle to overcome was the equipment itself. In all cases, it was proprietary to each supplier, and certainly not interoperable. That meant that cable companies risked putting their investment in a technology that might be supplanted by a rival method. It meant that the modems sitting in one warehouse and intended for a particular market might not work two communities away. It was a supplier’s market: What the suppliers had is what cable providers got.

In the early 1990s there were a few “aha!” moments along the way to modem technology having the ability to use the same modem purchased on the west coast with a cable system on the east coast, or anywhere else. And even though the use of the technology was evolving, cable modems still weren’t cheap. Prices ran upwards of $500. Without standards, no manufacturer would see the promise of high volume sales, and the start of competition—the main driver for lowering prices—wouldn’t come about. So the prices remained unreachable for most mainstream users.

Yet cable companies believed they were on to something.

The Next Big Thing

By the mid-1990s, the rise of the World Wide Web nurtured new business opportunities: high-speed Internet access using cable modems.

But equipment interoperability still remained a barrier to overall success. Without a standard, cable modems would never be interoperable. And without interoperability, a thriving market for cable modems was unlikely to take off. The companies developing modems wouldn’t commit to huge volumes for worrying that their equipment would be rendered obsolete by future technology developments. And if volume remained low, prices would remain high—a deal killer for the average consumer.
Big-name suppliers like 3Com, Cisco, HP, among others, entered the scene along with the smaller suppliers. It was a sprint for market share, where everyone moved as quickly as possible in a non-standardized, proprietary environment.

A Standard is Born

Standards, in 1995, were the mantra: Everyone endorsed standards, as long as the standards centered on their technology. But by late 1995, a small group of cable guys began to meet privately to discuss a new chip being made. The chip, unlike every chip used up until then, was completely programmable. That meant the chip could be put inside set-top boxes and cable modems and later as applications changed it could be updated. As the discussions matured, it became clear that the driving motivator was to attract more hardware suppliers into the cable business. The only way to go about it was to insist on interoperability among cable equipment providers. And the only way to garner interoperability was to develop a standard.

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As the enthusiasm for high-speed Internet grew, so did the list of cable modem suppliers, each with a slightly different way of going about it. And the supplier list was growing.

It was common and expected that consumer electronic equipment would work no matter where it was being used. Without interoperable modems, a customer might purchase a whiz-bang cable modem in Tulsa, Oklahoma, only to find it incompatible, and useless, when he moved to somewhere served by a different cable TV company. And retailers, obviously, would never sell a technology that threatened to spawn angry customers who were burned by incompatibility issues.

Figure 1 CableLabs circa 1996
Enter Cable Labs

The Colorado-based research and development arm of the cable television industry, CableLabs, was realizing the strategic importance of cable modems and high-speed Internet services. In November 1996, Data Over Cable Service Interface Specification, or DOCSIS, was put on fast-track status to have a complete specification written by the end of the year. DOCSIS was an immediate shot-in-the-arm to the development of cable modems. It gave the equipment manufacturers a stable, more economical foundation.

By mid-1997, the specification was ready to undergo lab tests of prototype DOCSIS gear at CableLabs. The intent was to provide an ongoing incubator for the vendor community to sample and test the specification. In September 1997, CableLabs released a detailed certification program, and formed a Certification Board to review, and ultimately approve, products that met the DOCSIS specifications.

Certification

Two years and three certification test waves would transpire before any vendors' products became DOCSIS-certified. Not until March 1999 were the first cable modems certified by CableLabs. In ensuing months, dozens of products made the DOCSIS cut. To this day, many of those who follow broadband's development give credit to the cable industry for rallying around a common standard and cite this as the key reason why cable companies currently lead DSL in the U.S. broadband deployment race. DOCSIS itself has continued to develop. In the unfolding story of broadband, cable television has taken the prominent role in the race for prominence with DOCSIS acknowledged undeniable reinforcement.
The Growth Years

The original DOCSIS 1.0 standard offered support for a single channel but as competition with DSL and other forms of broadband surged, a new standard was needed to deliver greater speeds to a greater number of consumers. A standard that offered higher bandwidth was developed and released in December of 2001 and became known as DOCSIS 2.0. DOCSIS 2.0 tripled the upstream performance to 27 Mbps.

Over the next four and a half years the advances made by DSL providers and fiber optics would be the springboard for the birth of DOCSIS 3.0 in 2006.

What made DOCSIS 3.0 different from its predecessors is that it was able to support multiple channels and bind them together to increase performance. More channels means greater speed. And although there’s a 4-channel minimum requirement for hardware to be approved by DOCSIS 3.0, there are no limits to how many channels can be used. This opens up a lot of performance possibilities.

So Now 3.1...

Even years down the road from DOCSIS 3.0 the increasing subscriber demand for bandwidth intensive content and the competition from FTTH providers like Google are raising the bar for cable technology developers to provide operators with new weapons for staying ahead and profitable.

DOCSIS 3.1 is focused on delivering several very specific benefits to cable operators. First and most notably, it enables greater capacity and speed, with support for up to 50 percent more data throughput over the same spectrum already on existing HFC networks. Cable providers will be able to deliver up to 10 Gbit/s speeds in the downstream and 1 to 2 Gbit/s in the upstream. That’s a vast improvement while preserving their investments in the HFC plant.

In addition to the higher data rates, the new standard is expected to provide additional benefits, including improved quality of experience via Active Queue Management. This will decrease the cost per bit for data delivery by decreasing latency in the network and improving the efficiency of spectrum use. It also increases energy efficiency in cable modems.

Finally, DOCSIS 3.1 is written so that new cable hardware will be backwards compatible back to DOCSIS 1.1 making it easier for cable operators to migrate to the new specification. (1)

CableLabs is emphasizing the fact that DOCSIS 3.1 will bring benefits to MSOs, even if they don’t
make any upgrades to their cable plant. The specifications are designed to support the new era in Gigabit data and improve the efficiencies of the available spectrum. The combination of Forward Error Correction (FEC) and Orthogonal Frequency Division Multiplexing (OFDM) technology enables higher-order modulations in existing HFC networks without changes to the existing cable plant.

So Why Move Beyond QAM 256?

Unlike the industry's previous broadband spec, DOCSIS 3.0, which tops out at about 1 Gbit/s downstream and much lower speeds upstream, DOCSIS 3.1 is designed to enable downstream rates as high as 10 Gbit/s and upstream speeds as high as 2 Gbit/s. With increasing demand for business services, Over The Top (OTT) video, 4K video, 3DTV, etc. more capacity is needed. With higher orders of modulation, better forward error correction and the elimination of guard bands, DOCSIS 3.1 has close to 2 times the improvement over DOCSIS 3.0.
The overarching goal is the ability to deploy gigabit speeds over an existing cable plant. So what exactly will DOCSIS 3.1 do for cable providers? Under appropriate conditions, DOCSIS 3.1 will enable providers to achieve up to a 50 percent increase in data throughput in the same spectrum.

- Allow HFC to compete with FTTH
- Achieve 10+ Gbps DS (per-CM speed)
- Achieve 1 to 2+ Gbps US (per-CM speed)
- Continue to be as backward compatible with existing DOCSIS standards back to 1.1
- Minimize cost

Orthogonal Frequency Division Multiplexing (OFDM) is a complex form of multicarrier modulation in which many small QAM channels, like 25 kHz instead of 6 MHz, are placed very close together and each channel then operates independently and transmits at the modulation it is capable of transmitting.
OFDM is a complex form of multicarrier modulation in which many small QAM channels, like 25 kHz instead of 6 MHz, are placed very close together and each channel then operates independently and transmits at the modulation it is capable of transmitting. This offers superior performance and benefits over older, more traditional single-carrier modulation methods because it is a better fit with today’s high-speed data requirements. OFDM has been adopted as the modulation method of choice for practically all the new wireless technologies being used and developed today.

An OFDM signal consists of a number of closely spaced narrowband subcarriers. When modulation of any form - voice, data, etc. is applied to a carrier, then sidebands spread out either side. It is necessary for a receiver to be able to receive the whole signal to be able to successfully demodulate the data. As a result, when signals are transmitted close to one another, they must be spaced so that the receiver can separate them using a filter and with a guard band between them. This is not the case with OFDM. By eliminating guard bands more of the existing spectrum is available for use.

OFDM is based on the concept of the method of transmitting multiple data streams over a common broadband medium such as radio spectrum, coax cable, twisted pair, or fiber-optic cable. Each data stream is modulated onto multiple adjacent carriers within the bandwidth and all are transmitted simultaneously like cable TV. This data stream transmits many parallel channels of video and audio over a single fiber-optic cable and coax cable. However the technique is typically wasteful of bandwidth or spectrum because to keep the parallel modulated carriers from interfering with one another, you have to space them with guard bands or extra space between them. Even then, very selective filters at the receiving end have to be able to separate the signals from one another.

This is not the case with OFDM. What researchers discovered is that with digital transmissions, by eliminating guard bands the carriers could be more closely spaced to one another and still separate, freeing up more of the existing spectrum for use.

- Using close-spaced overlapping sub-carriers, a significant OFDM advantage is that it makes efficient use of the available spectrum.
- Increases modulation options to 512, 1024, 2048 and 4096-QAM and higher
- DOCSIS 3.1 uses a new technology called low density parity check (LDPC) that replaces the older Reed-Solomon FEC for more robust error correction
- 3.0 uses single carrier QAM (SC-QAM), but 3.1 uses OFDM and OFDMA which is multiple subcarriers per channel. Each subcarrier is a QAM signal.
Even though the sidebands from each carrier overlap, they can still be received without the interference that might be expected because they are orthogonal to each other. This is achieved by having the carrier spacing equal to the reciprocal of the symbol period.

Modulation from QAM to OFDM with QAM sub-carriers allows for up to QAM 4096, much higher than today’s max of QAM 256. These multiple narrow subcarriers are time based rather than frequency based meaning longer symbols that make it easier to detect micro-reflections, ingress, and impulse noise.

**How Will Operators Transition to OFDM and Higher QAM Rates?**

Because no plant changes are required to deploy DOCSIS 3.1 equipment and no CPE or infrastructure swap is required to get started, an effective migration strategy can be achieved by Incremental deployments of DOCSIS 3.1 modems over time along with continued use of DOCSIS 2.0 and 3.0 modems even after 3.1 upgrades.

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**DOCSIS DEPLOYMENT THOUGHTS**

- DOCSIS 3.1 specifications have been completed since October 2013
- Products begin to appear in 2015
- Deployments take place in 2016 or 2017
- Cost for new DOCSIS 3.1 CMs expected to be relatively close to DOCSIS 3.0
- Deployments might first focus on CPE then CMTS downstream then CMTS upstream

**CABLE OPERATOR OPTIONS RIGHT NOW**

- Continue on with DOCSIS 3.0
- Use new modulation of DOCSIS 3.1 in existing spectrum
- Make spectrum changes and use new modulation of DOCSIS 3.1 on part of plant

“From my perspective, we are ahead of schedule and fully on track for devices to be ready by the later half of this year and for field trials in early 2016.”

-CableLabs’ President and CEO Phil McKinney
THE FUTURE
The question becomes when or even IF operators should deploy DOCSIS 3.1. Taking the long view, some operators have decided that they will forgo DOCSIS 3.1 and go straight to FTTH when they are ready to upgrade. Others are planning a mix of FTTH in conjunction with equipment upgrades and 3.1 where fiber is not an option. With competitors like Google and telcos moving in with gigabit service, operators are feeling pressure to make decisions. And since it does take time to install fiber, cable operators may still need to deploy 3.1 sooner rather than later in order to keep up with competition.

CHALLENGES
Of course, there are challenges ahead for DOCSIS 3.1 deployments; however many leading cable operators are eager to bring DOCSIS 3.1 to market, which means they will likely do their best to help smooth the transition. The new standards are faster to implement than installing fiber so there is a distinct advantage in time for cable operators. However, the goal to compete with the gigabit speeds from other delivery platforms still has its limitations in that all the benefits of the new 3.1 standards won’t be available without some equipment upgrades.

The ability to deliver gigabit relies on the installation of 3.1 modems. This is due to the fact that OFDM channels can only be used on 3.1 cable modems.

And in order to attain 1gbps speeds operators must retain the 3.0 downstream channels and add one or more 3.1 OFDM channels, each up to 192 MHz wide. This requires more downstream spectrum plus higher core capacity out of the CMTS (3 Gbps and higher per service group).

Remember Before You Buy:
- DOCSIS 3.0 and older cable modems can’t use new 3.1 channels
- DOCSIS 3.1 CMTSs are required for backwards compatibility to support DOCSIS 3.0 (and all others back to 1.1) cable modems. However backward compatibility will only stretch so far and at some point older equipment will necessarily have to be upgraded in order for operators to keep up with increasing subscriber requirements and demand.

Equipment Planning-
What to buy, what to look for over the next few years.

CMTS
If you're considering a CMTS, and you think you may want deploy 3.1 in next 5-10 years, look at options that will support both 3.0 and 3.1. You can go to vendors and buy platforms that will support the cards and CPE.

If you have an older chassis, think hard about upgrades, since there is no future for those older Motorola, Cisco UBR, Arris C4 platforms. Anytime you need to get a new controller card, new line cards, you need to decide whether it would be better to get a new CMTS that will be capable of 3.1. An option is to check with vendors to see if they have trade-in programs.

If you only have 3.1 line cards, they will only work with 3.1 or 3.0. You want a chassis that will work with both 3.1 and 3.0 cards (3.0 is backward compatible to 1.0)

“"The challenge is expanding the plant. We started from the ground up with the 3.1 team and built in full spectrum analysis set up to compete with fiber. Now, 3.1 becomes the tool of choice.”

- Cisco CTO and engineering fellow, John Chapman
VENDOR MODELS THAT SUPPORT 3.1

- Arris E6000 vx C4
- Cisco CBR vs UBR
- Casa 100G

MODEMS
Start thinking about all of the modem lines you’re deploying. Everything should be 3.0 or later if you plan on doing 3.1 relatively soon.

NOTE: If an operator has decided they will never deploy 3.1 and they will eventually have a need for 3.0 equipment, there will be opportunities for hardware at a lower cost. Once the leading MSO’s begin phasing out for 3.1 there will be a lot of used 3.0 equipment available on the gray market.

Final Thoughts
The new DOCSIS 3.1 specification has been crafted by CableLabs to be the roadmap for a generation of DOCSIS technology. Development raced from early concept to completed reality in barely a year, breaking all sorts of standards speed records.

There is also a possibility that we may see cable companies making some level of investment in FTTH. Several of the cable companies that plan to offer gigabit service have said they will rely, at least in part, on FTTH infrastructure. But others have announced plans to upgrade nearly all of their networks to gigabit speeds using DOCSIS 3.1.

At the end of the day though, the pendulum may be swinging and HFC will give way to fiber. Some cable operators are using fiber approaches in their commercial services initiatives and may eventually transition their core consumer business to fiber as well. That likely will happen, but far in the future. But for now cable operators are excited and hopeful that despite the increasing demands for capacity, HFC networks will have enough headroom to keep up at least until 2030, thanks to DOCSIS 3.1.

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Additional Resources

- CableLabs has made the full DOCSIS 3.1 specification available for download on its website.
- Download the DOCSIS 3.1 POCKET GUIDE (PDF, 3MB)
- Find the DOCSIS 3.1 app for your device at Play Store or App Store

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Bibliography

