How cable delivers high speed data: Understanding cable ISPs

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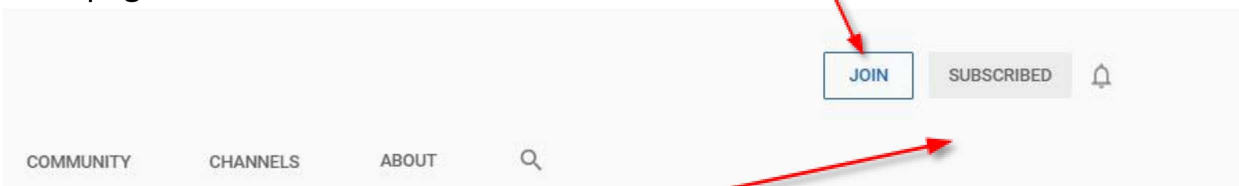

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- The Basic Cable Channel: https://www.youtube.com/@thebasiccablechannel7464
- Excellent Source of Broadband Information: https://broadbandlibrary.com

What type of RF technologies do WiFi 6, cable DOCSIS 3.1, and 5G cellular share

Broadband Access Network Layer 1 Physical

Examples of CPE for cable operators include:

DOCSIS 3.1 Cable Modem Transmit Power

How is DOCSIS 3.1 cable modem transmit power set?

DOCSIS 3.1 at Layer 2

Troubleshooting Slow Performance in Cable Modem Networks

DOCSIS 4.0

How the cable modem “initializes” or “registers” with CMTS

Understanding Coaxial Cables - The Complete Guide

Cable Modem Troubleshooting

DOCSIS Cable Modem Registration

Cable Modem Registration | A Second Look

Cable Physical Layer

What should my Signal Levels be?

Coring hardline coax and installing a tap for service: https://www.youtube.com/watch?v=me4LtGJZl7A

Now all has been heard;
here is the conclusion of the matter:
Fear God and keep his commandments,
for this is the duty of all mankind.
For God will bring every deed into judgment,
including every hidden thing,
whether it is good or evil.

DOCSIS (Data Over Cable Service Interface Specification)

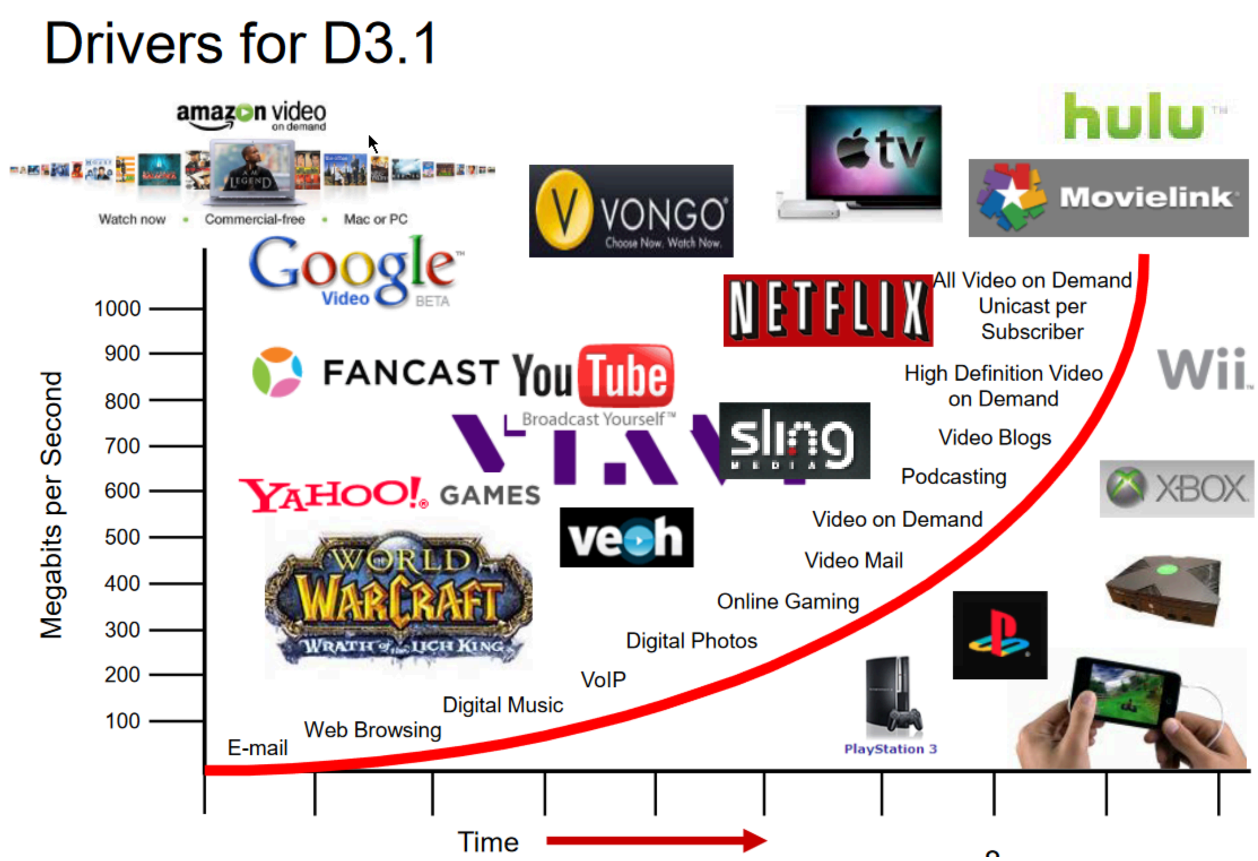
is a standard used for transmitting digital data over coaxial cable systems, primarily for providing high-speed internet access. DOCSIS version 3, also known as DOCSIS 3.0, introduced significant improvements in data transmission capabilities compared to its predecessors.

In a DOCSIS 3.0 network, RF (Radio Frequency) signals are used to carry digital data to the subscriber using Ethernet. Here's a simplified explanation of how this process works:

1. Downstream Transmission:
    - The internet service provider (ISP) sends data from their network to the subscriber's cable modem.
    - The data is first converted into Ethernet frames, which contain the digital information.
    - These Ethernet frames are then encapsulated into IP packets, which are further encapsulated into MPEG (Moving Picture Experts Group) transport streams.
    - The MPEG transport streams are modulated onto specific RF channels, typically in the range of 50 MHz to 1 GHz.
    - Multiple RF channels can be utilized simultaneously to increase the available bandwidth.
    - The modulated RF signals are then combined and sent over the coaxial cable infrastructure.
2. Upstream Transmission:
    - When the subscriber sends data upstream (e.g., uploading files or requests), the process is reversed.
    - The cable modem receives the RF signals from the subscriber's device through the coaxial cable.
    - The RF signals are demodulated and processed to extract the MPEG transport streams.
    - The MPEG transport streams are then parsed to identify IP packets.
    - The IP packets are further stripped to retrieve the Ethernet frames containing the digital data.
    - The Ethernet frames are then sent to the ISP's network for further processing and routing to the intended destination.

It's important to note that DOCSIS 3.0 introduced several enhancements over previous versions to improve data transmission efficiency and increase throughput. These enhancements include channel bonding, which allows the use of multiple RF channels simultaneously, and the use of advanced modulation techniques such as Quadrature Amplitude Modulation (QAM) to achieve higher data rates.

DOCSIS 3.0 has been widely deployed by cable operators around the world to deliver high-speed internet services to subscribers. However, it's worth mentioning that newer versions of DOCSIS, such as DOCSIS 3.1 and DOCSIS 4.0, have been introduced with even greater capabilities, including higher speeds and improved efficiency.



Why are cable operators moving to the new DOCSIS 3.1 version?

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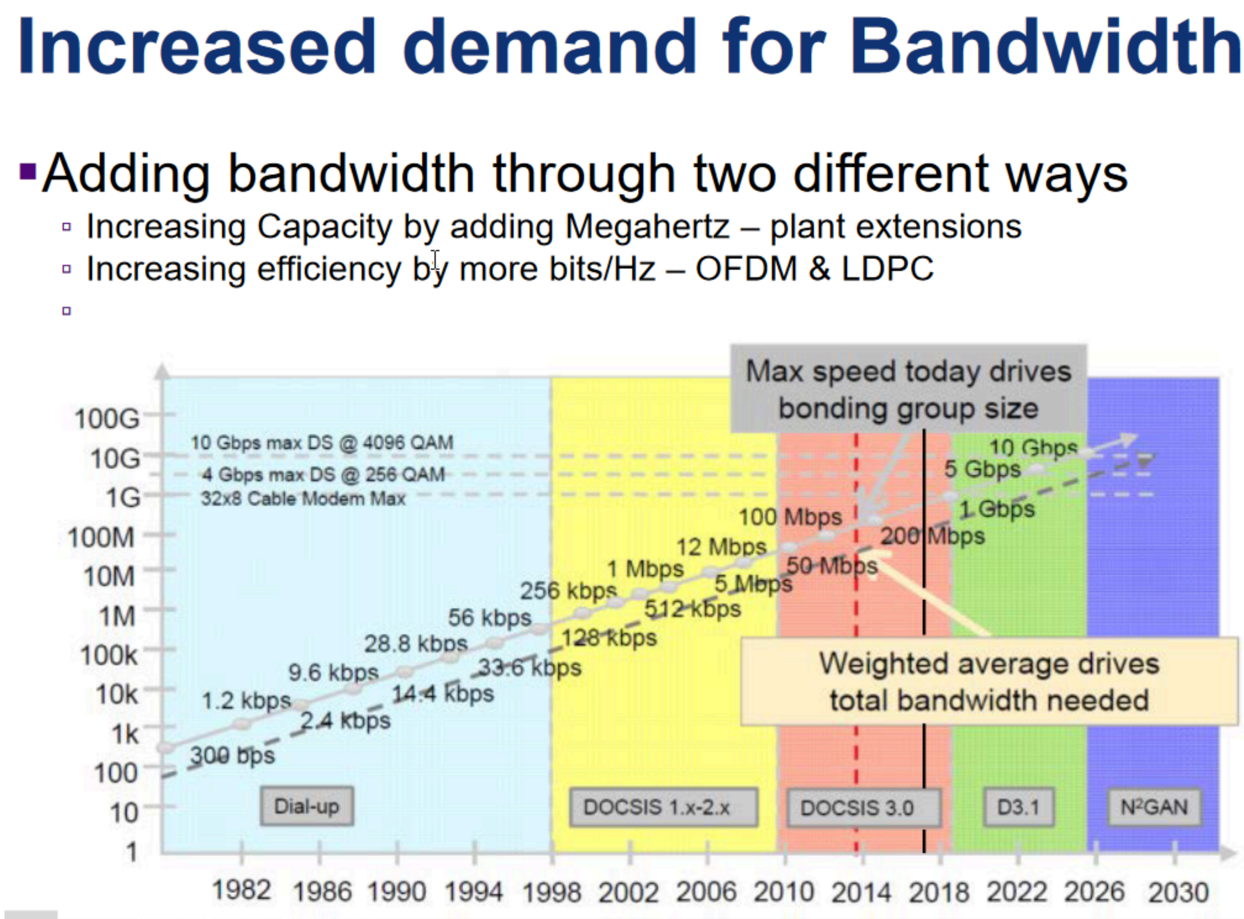
The Evolution of DOCSIS® Technology

	DOCSIS 1.0	DOCSIS 1.1	DOCSIS 2.0	DOCSIS 3.0	DOCSIS 3.1	DOCSIS 4.0
Highlights	Initial cable broadband technology, high speed internet access	Added voice over IP service, gaming, streaming	Higher upstream speed, capacity for symmetric services	Greatly enhances capacity, channel bonding, IPv6	Capacity and efficiency progression, OFDM, wideband channel	**Symmetrical streaming and increased upload speeds**
Downstream Capacity	40 Mbps	40 Mbps	40 Mbps	1 Gbps	10 Gbps	**10 Gbps**
Upstream Capacity	10 Mbps	10 Mbps	30 Mbps	200 Mbps	1-2 Gbps	**6 Gbps**
First Specification Issue Date	1996	1999	2001	2006	2013	**2019**

There are several versions of DOCSIS, each introducing improvements in terms of data transmission capabilities and features. Here are the major DOCSIS versions and the improvements they provide to subscribers:

1. **DOCSIS 1.0:** This was the initial version of DOCSIS, introduced in 1997. It provided a standardized method for delivering internet access over cable television systems. Key improvements included:
    - Support for bi-directional communication, allowing both downstream and upstream data transmission.
    - Data rates of up to 38 Mbps downstream and 9 Mbps upstream.
2. **DOCSIS 1.1:** Released in 1999, DOCSIS 1.1 brought several enhancements to DOCSIS 1.0, including:
    - Quality of Service (QoS) capabilities, enabling prioritization of different types of data traffic.
    - Improved upstream data rates, up to 30 Mbps.

"Darkness cannot drive out darkness; only light can do that. Hate cannot drive out hate; only love can do that." Martin Luther King Jr.



3. **DOCSIS 2.0:** Introduced in 2002, DOCSIS 2.0 offered further improvements over the previous versions:
    - Increased downstream data rates, up to 38 Mbps, and upstream rates, up to 30 Mbps.
    - Support for IP multicast, allowing efficient delivery of multimedia content to multiple users simultaneously.
    - Enhanced security features, including encryption and authentication.
4. **DOCSIS 3.0:** Released in 2006, DOCSIS 3.0 brought significant advancements in data transmission capabilities:
    - Channel bonding: This feature allows multiple RF channels to be bonded together, increasing the available bandwidth and enabling higher speeds. It supports both downstream and upstream bonding.
    - Increased downstream data rates, up to several hundred Mbps, and upstream rates, up to 100 Mbps.
    - Advanced modulation techniques, such as higher-order Quadrature Amplitude Modulation (QAM), providing better spectral efficiency.

5. **DOCSIS 3.1:** Introduced in 2013, DOCSIS 3.1 represents a major leap in performance and efficiency:
    - Support for much higher data rates, enabling Gigabit and multi-Gigabit speeds.
    - Improved energy efficiency and better utilization of the cable spectrum.
    - Enhanced error correction techniques for more reliable data transmission.
    - Support for IP video services and low-latency applications.

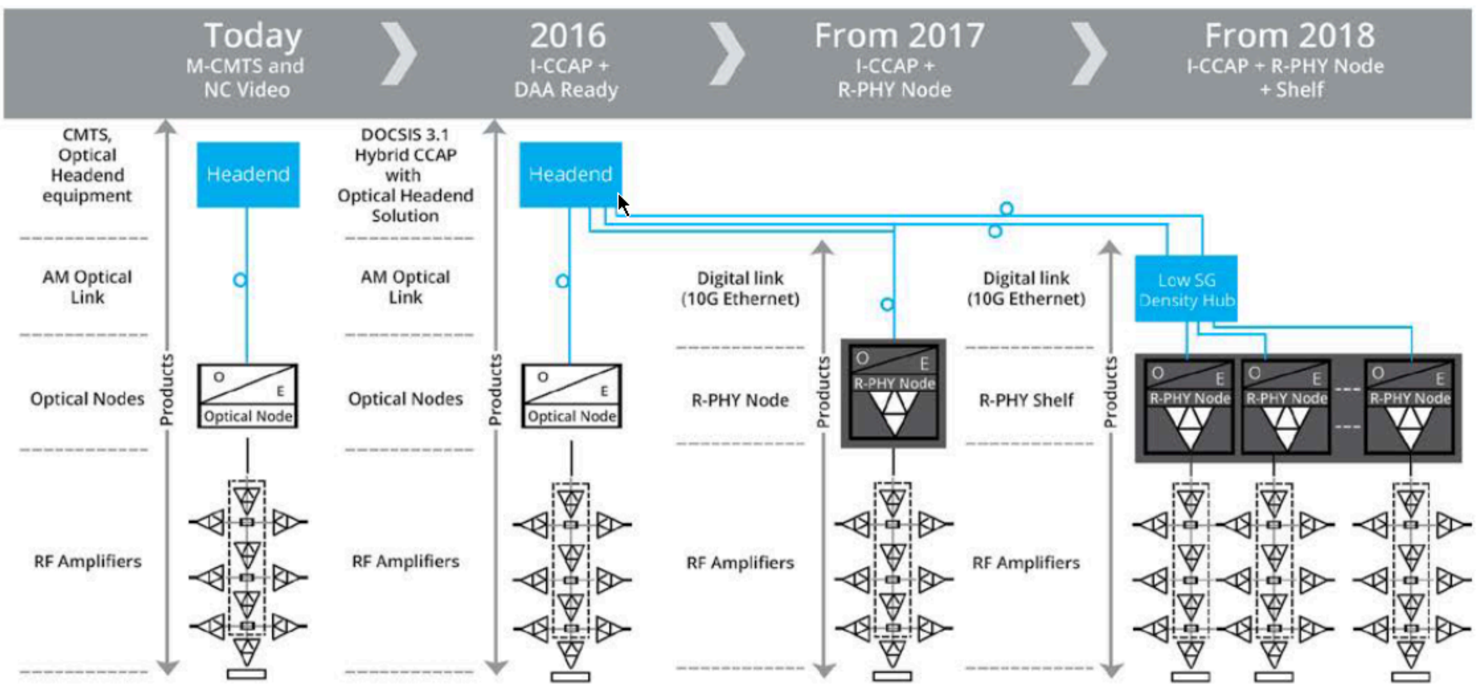


Figure 2 – Final Analysis of the Real-life Customer Example – A Multi-stage Evolution to DOCSIS 3.1

6. **DOCSIS 4.0:** This version, announced in 2020, aims to deliver even higher speeds and improved performance:
    - Support for Multi-Gigabit speeds, potentially reaching 10 Gbps downstream and 6 Gbps upstream.
    - Enhanced capabilities for low-latency applications, such as gaming and virtual reality.
    - Improved network efficiency and scalability.

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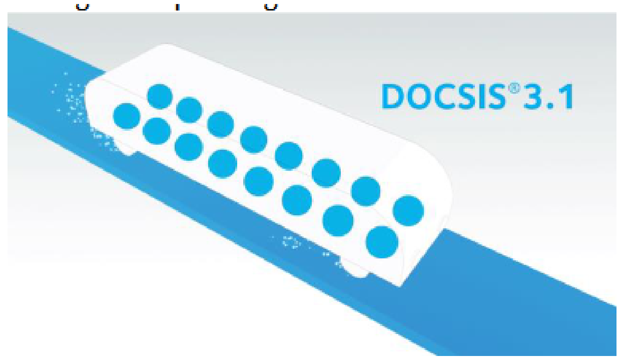
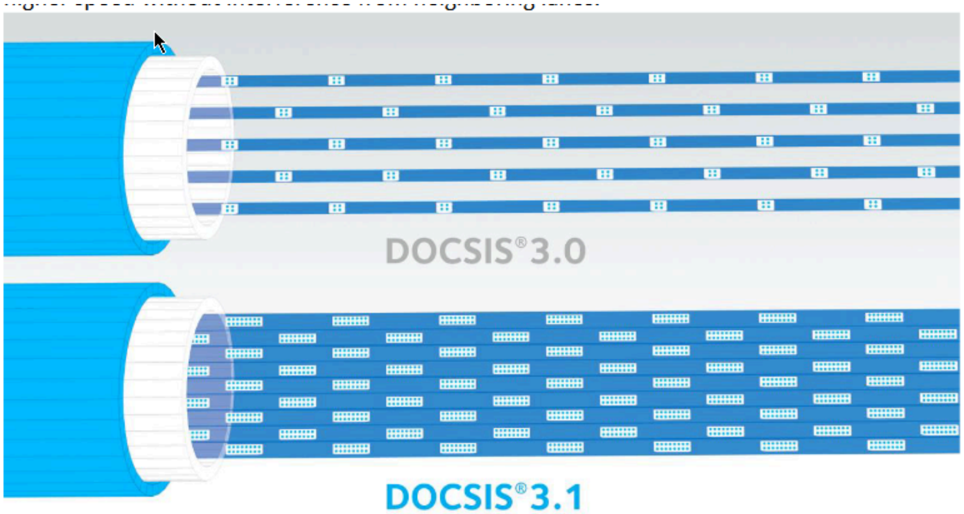
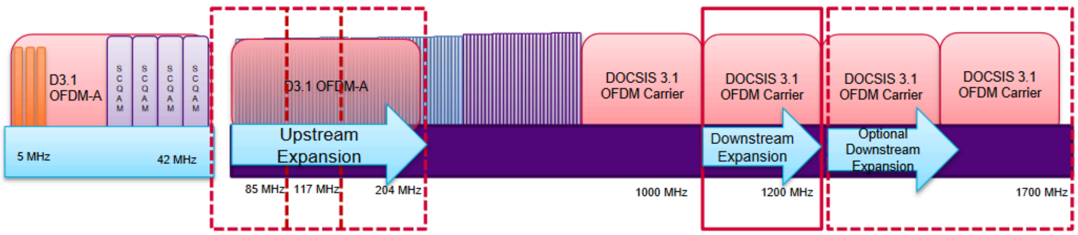
Each DOCSIS version has played a crucial role in advancing the capabilities of cable broadband networks, allowing subscribers to enjoy faster and more reliable internet access. Upgrading to newer versions enables higher speeds, better performance, and support for emerging technologies and applications.





Expansion Summary



- Frequency expansion desirable but not necessary
- Downstream OFDM carriers are from 24 MHz to 192 MHz wide
- Downstream expands to as far as 1.7 GHz
- Upstream OFDMA carriers are up to 2 96 MHz wide carriers
- Upstream expands to as far as 204 MHz
- Coexistence with legacy carriers
- Typically <250 end devices per node

To gain a more detailed understanding of the principles of DOCSIS 3.1 and the conversion between digital and RF signals, you can refer to the following engineering documents:

Whoever of you loves life

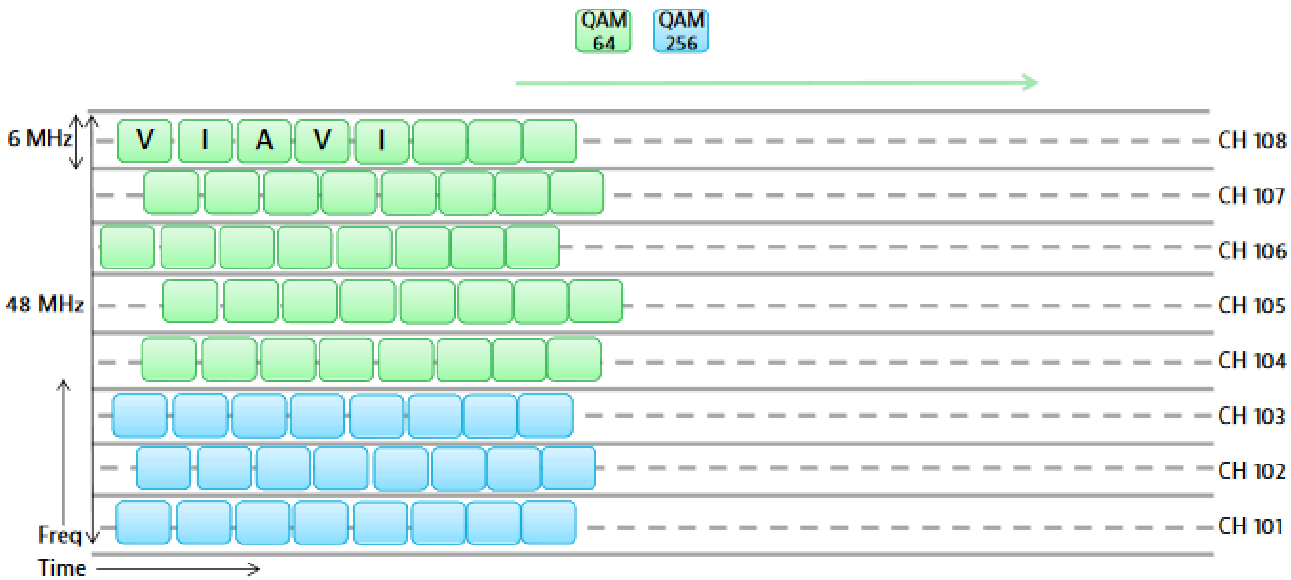
and desires to see many good days,

keep your tongue from evil

and your lips from telling lies.

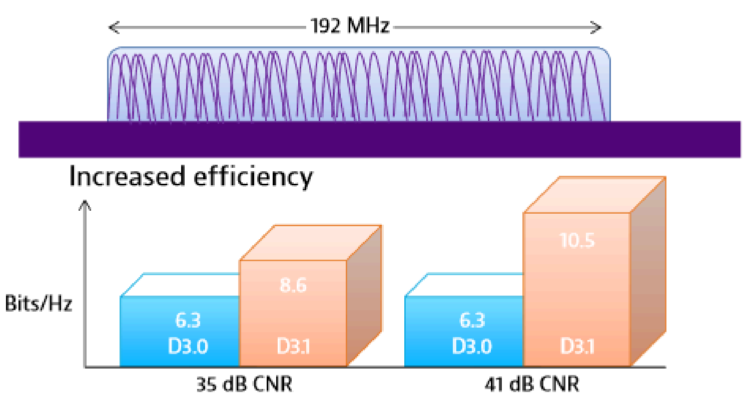
Turn from evil and do good;

seek peace and pursue it.



Dedicated 6 MHz channels (8 MHz in EMEA)
Each frequency behaves independently
Symbols happen sequentially within the channel
Modulation is optimized for the worst part of the plant

Figure 2. Modulation — SC QAM



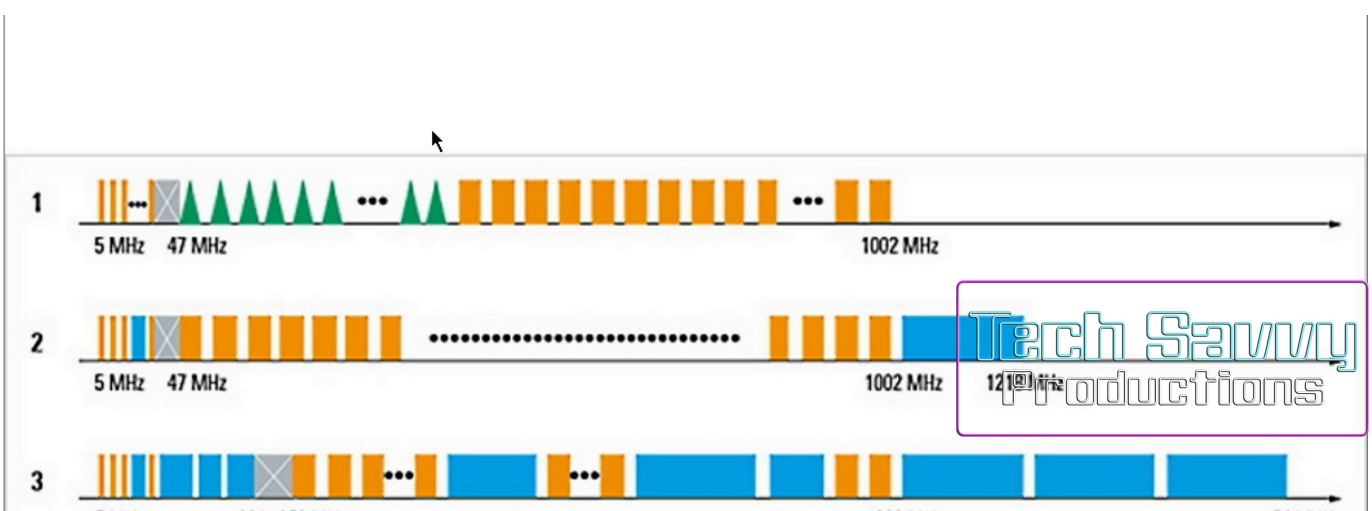
6.3	*Max bits/Hz DOCSIS 3.0*
10.5	*Max bits/Hz D3.1 4096 QAM*
8.5	*Typical bits/Hz DOCSIS 3.1* *(assumes mix of 256, 1024, 2048, 4096 QAM)*
35%	*More Efficient* DOCSIS 3.1 bits/Hz than DOCSIS 3.0

Figure 1. OFDM changes the game, providing more bits/Hz at the same signal-to-noise operating conditions

1. DOCSIS 3.1 Specification:
   - The official DOCSIS 3.1 specification, developed by CableLabs, provides a comprehensive technical overview of the standard. It outlines the principles, protocols, and mechanisms used in DOCSIS 3.1 for digital-to-RF and RF-to-Ethernet conversions. You can find the specification on the CableLabs website.

2. CableLabs Open Specifications:
   - CableLabs publishes a range of open specifications related to DOCSIS and cable broadband technologies. These documents delve into the technical details and implementation guidelines for various aspects of DOCSIS 3.1, including the digital-to-RF and RF-to-Ethernet conversion processes. Visit the CableLabs website and explore the open specifications section to access relevant documents.
3. IEEE Standards:
   - The Institute of Electrical and Electronics Engineers (IEEE) is involved in the development of various standards related to cable broadband, including DOCSIS. IEEE 802.3 standards, which cover Ethernet technologies, can provide insights into the Ethernet aspects of DOCSIS. Specifically, you can refer to IEEE 802.3-2018, which defines the Ethernet standard. These standards can be accessed through the IEEE Xplore Digital Library.
4. White Papers and Technical Articles:
   - Cable industry organizations, technology vendors, and research institutions often publish white papers and technical articles that explain the principles and implementation details of DOCSIS 3.1. These resources can provide valuable insights into the digital-to-RF and RF-to-Ethernet conversion processes. Conduct a search on relevant websites, such as CableLabs, SCTE (Society of Cable Telecommunications Engineers), or technical publications like the SCTE's "Communications Technology" magazine, to find such materials.

When studying these documents, it's important to have a basic understanding of digital communications, modulation techniques, Ethernet, and RF signal

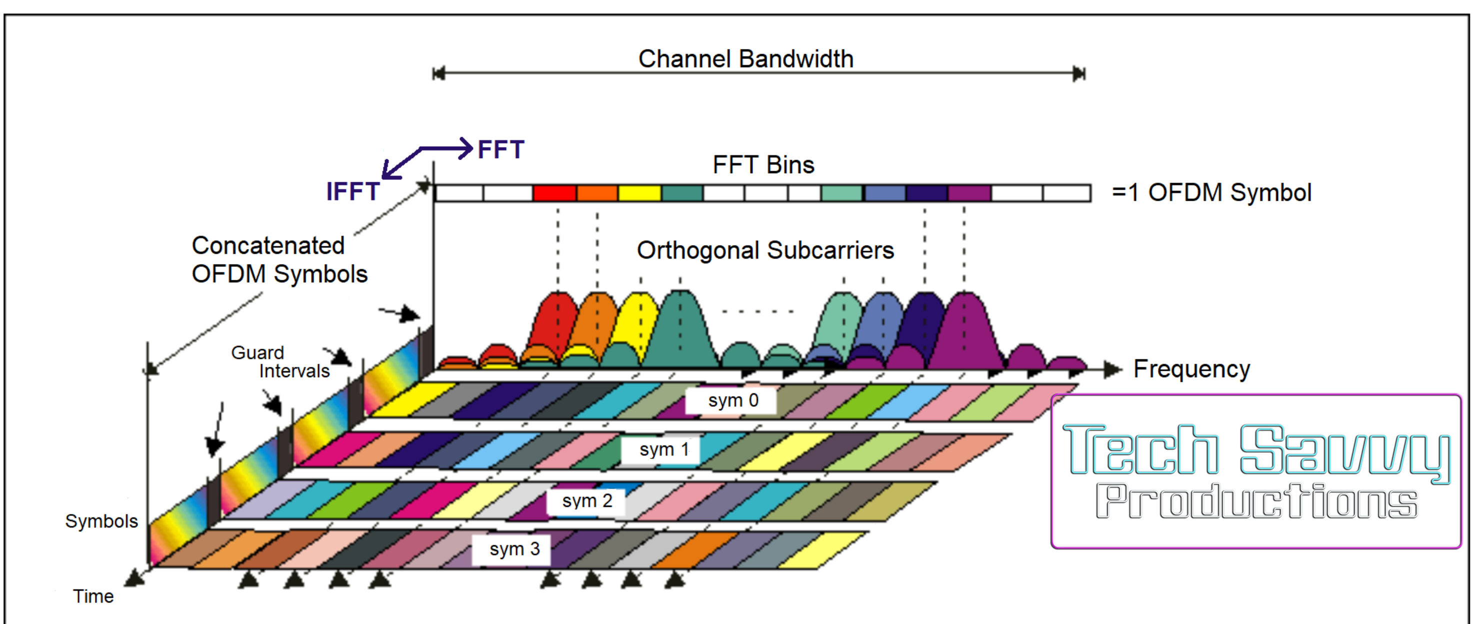


processing. This will help you grasp the intricacies of DOCSIS 3.1 and its conversion mechanisms more effectively.

What type of RF technologies do WiFi 6, cable DOCSIS 3.1, and 5G cellular share

Wi-Fi 6 (802.11ax), DOCSIS 3.1 (Data Over Cable Service Interface Specification), and 5G are all modern communication standards used in different parts of the telecommunication ecosystem, each having unique properties suited for their use-cases. However, they do share some fundamental RF (Radio Frequency) technologies that enhance their performance:

1. **OFDM/OFDMA (Orthogonal Frequency-Division Multiplexing/Multiple Access)**: All three technologies make use of OFDM or OFDMA. These methods involve dividing a single communication channel into multiple orthogonal sub-channels, thereby reducing interference and increasing efficiency. OFDM is used in DOCSIS 3.1, while both OFDM and OFDMA are used in Wi-Fi 6 and 5G. OFDMA, in particular, allows finer resource allocation which improves the efficiency when servicing multiple devices with different data needs.



OFDM and OFDMA

By now you have heard or have been exposed to orthogonal frequency division multiplexing (OFDM). It was the innovative technology introduced in Data-Over-Cable Service Interface Specifications (DOCSIS) 3.1 to increase the efficiency by which DOCSIS networks can transmit data in the downstream.

Additionally, many cable operators are now actively deploying orthogonal frequency division multiple access (OFDMA), which was also introduced in the DOCSIS 3.1 specification in order to increase upstream bandwidth efficiency. So just what is the difference between OFDM and OFDMA?

OFDM uses multiplexing.

- Multiplexing is a method by which multiple digital signals are shared over a common medium, in this case the downstream HFC plant.
- The multiplexed signal is shared across all cable modems in the downstream, which is an especially important concept to keep in mind, particularly when we consider 1 gigabit per second (Gbps) and in the future, 10 Gbps bandwidths.
- The bandwidth is still shared amongst all subscribers. This means if we have an OFDM downstream capable of 1 Gbps or 10 Gbps, that does not mean each subscriber gets 1 Gbps or 10 Gbps, but all subscribers on the node are sharing 1 Gbps or 10 Gbps. Multiplexing = shared bandwidth.

OFDMA is used in DOCSIS 3.1 and DOCSIS 4.0 upstream communication.

- The “MA” at the end of OFDMA stands for multiple access.
- Multiple access is a method by which many users, or in the case of DOCSIS, many cable modems share the same upstream frequency spectrum.

- This same frequency spectrum is shared much the same way one would share a rental house at a beach. I get the house this week, you get the house next week and so on.
- The difference being that the CMTS will allocate time sharing on a microsecond time scale rather than a weekly time scale — size matters (note: frequency allocation and usage comes into play, too, but that's a topic for another day). This is illustrated in Figure 1, from the CM-SP-PHYv3.1 specification, section 7.4.1.

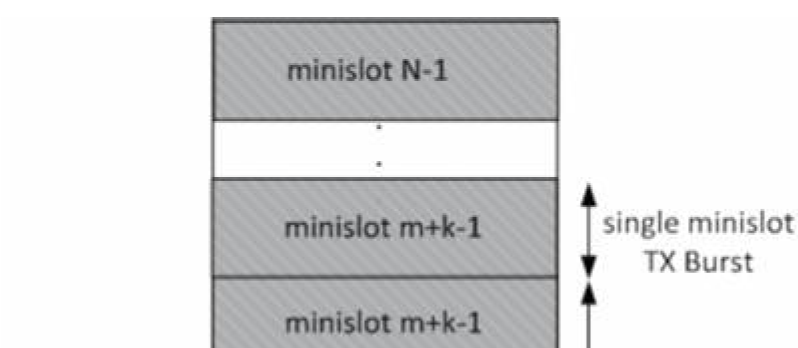
OFDM vs OFDMA

At a high-level, OFDM is for downstream DOCSIS 3.1 communications and is a shared medium for all DOCSIS 3.1 and higher modems. OFDMA is for upstream communications for all DOCSIS 3.1 and higher modems but uses time slot and frequency allocation (like your beach rental) so that each modem is given a time slot or frequency range (group of subcarriers) to send its data. At this high-level, OFDM and OFDMA signals can otherwise be considered similar.

At the technical level, there are many other differences between OFDM and OFDMA signals. While not comprehensive, here is a short-bulleted breakdown of some key differences:

- OFDM includes low density parity check (LDPC) and an extra layer of error correction called BCH (Bose–Chaudhuri–Hocquenghem), while OFDMA supports only LDPC
- OFDM supports bandwidth from 24 MHz to 192 MHz while OFDMA supports bandwidths from 6.4 MHz to 96 MHz
- OFDM requires modulations up to 4096-QAM with optional support to 16384-QAM while OFDMA requires modulations up to 1024-QAM with optional support up to 4096-QAM

Figure 1. OFDMA frame structure showing how minislot timing is allocated to subcarriers



Other considerations

When cable operators begin utilizing DOCSIS 3.1 OFDMA in the upstream they will require advanced software tools to have clear visibility into the OFDMA channel.

OFDMA requires CMTS/CCAP integration in order to have full visibility into the OFDMA upstream.

To do so, CableLabs has created a special set of management information base (MIB) called the upstream triggered spectrum capture (UTSC) MIB which allows for precision control and visibility of OFDMA carriers.

This provides for unprecedented upstream spectrum analysis and the ability to see:

- ingress, "sources of ingress such as amateur radio and broadcast TV stations"
- impulse noise, fast moving noise spikes (noise coming into the cable plant)
- and more within the OFDMA channel in the upstream.

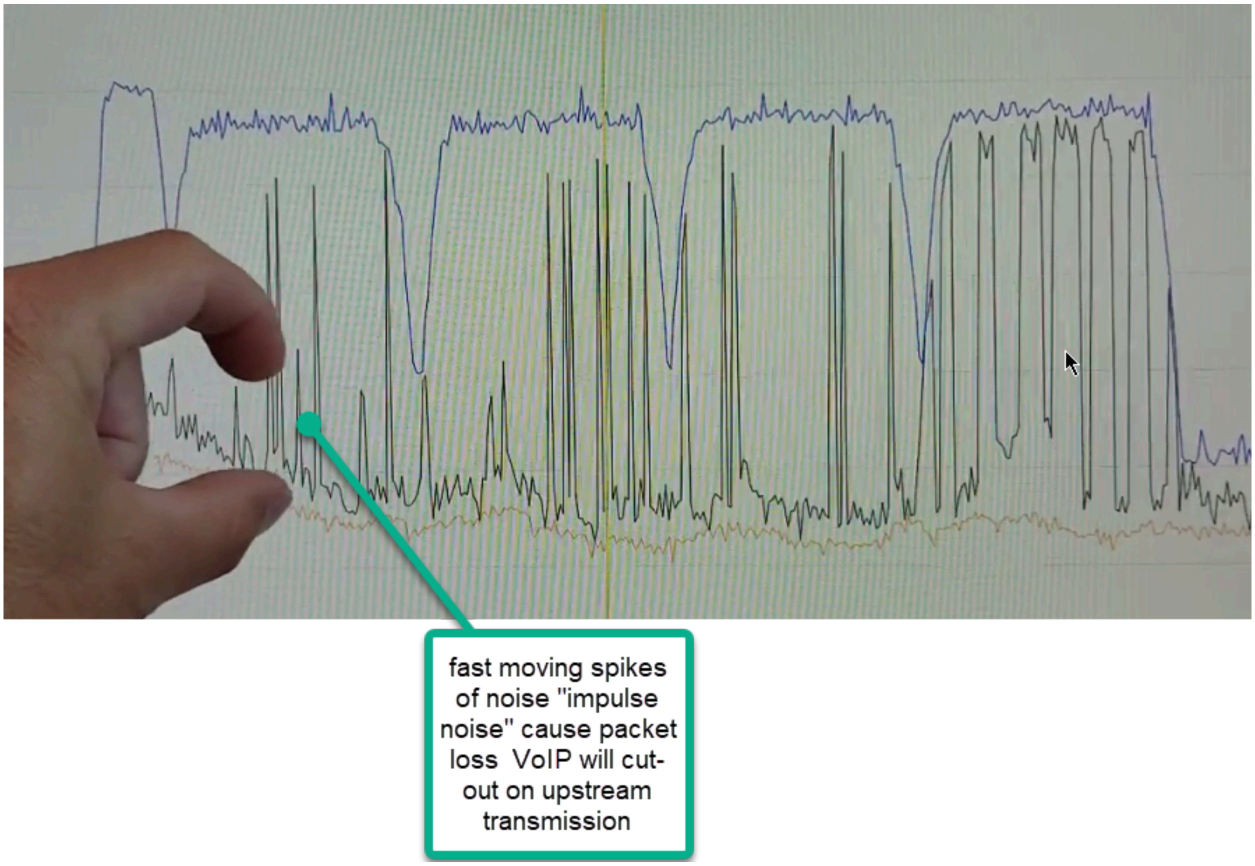


Figure 1 impulse noise from cracked insulators on telephone poles, welding

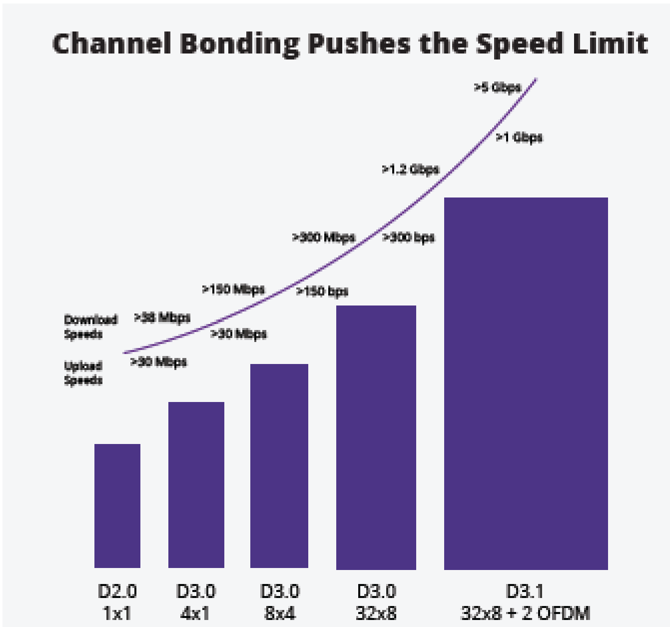
This cannot be done with a traditional external monitoring system without proactive network maintenance (PNM). An operator can use a stand-alone PNM product or one that has been integrated with PNM. Either way you need PNM to see the OFDMA upstream.

The situation only becomes more aggravated with DOCSIS 4.0 where full duplex DOCSIS and/or extended spectrum will be implemented. As operators turn up DOCSIS 3.1 in the upstream they will quickly realize their hardware-based return path monitoring systems are not what they used to be. Of course, not every operator has turned on DOCSIS 3.1 OFDMA but OFDMA channel usage is becoming more common. Technology evolution is normal and with the improvements of OFDMA it is in with the new and out with the old.

2. **QAM (Quadrature Amplitude Modulation):** QAM is used by all three technologies to encode information in both the amplitude and the phase of the carrier signal, increasing the amount of data that can be transmitted. DOCSIS 3.1, for example, supports up to 4096-QAM (12-bit QAM), while Wi-Fi 6 and 5G can also support high orders of QAM (1024-QAM and beyond under good signal conditions).

QPSK	Gross Thoughput	Net Throughput
1.6 MHz	2.56 Mbps	2.24 Mbps
3.2 MHz	5.12 Mbps	4.49 Mbps
6.4 MHz	10.24 Mbps	8.97 Mbps
8-QAM	Gross	Net
1.6 MHz	3.84 Mbps	3.37 Mbps
3.2 MHz	7.68 Mbps	6.73 Mbps
6.4 MHz	15.36 Mbps	13.46 Mbps
16-QAM	Gross	Net
1.6 MHz	5.12 Mbps	4.49 Mbps
3.2 MHz	10.24 Mbps	8.97 Mbps
6.4 MHz	20.48 Mbps	17.95 Mbps
32-QAM	Gross	Net
1.6 MHz	6.40 Mbps	5.61 Mbps
3.2 MHz	12.80 Mbps	11.22 Mbps
6.4 MHz	25.60 Mbps	22.44 Mbps
64-QAM	Gross	Net
1.6 MHz	7.68 Mbps	6.73 Mbps
3.2 MHz	15.36 Mbps	13.46 Mbps
6.4 MHz	30.72 Mbps	26.92 Mbps

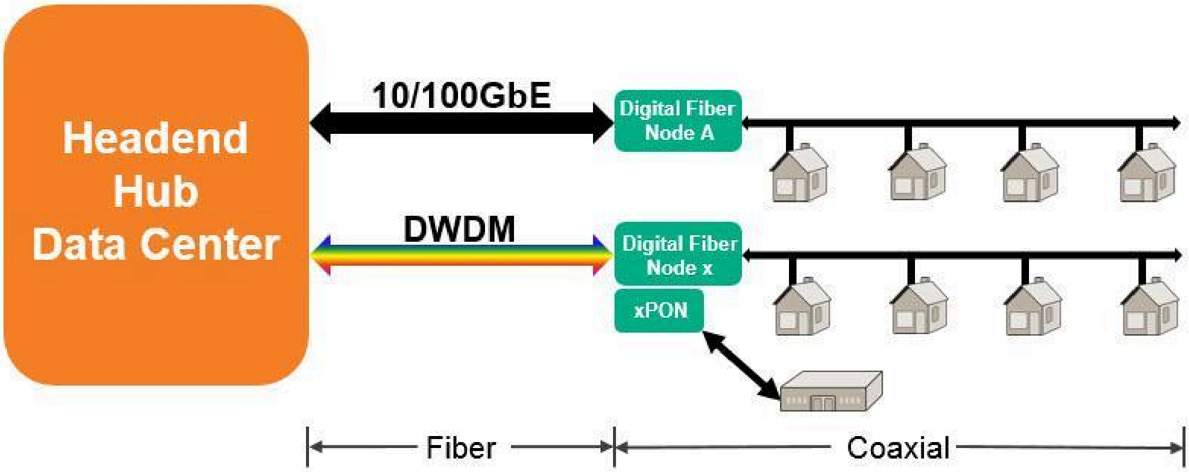
3. **Channel Bonding**: This involves combining multiple smaller channels into a larger one, allowing for increased data rates. DOCSIS 3.1 and Wi-Fi 6 both use forms of channel bonding, although the implementation is quite different due to the difference in medium (wired vs. wireless).

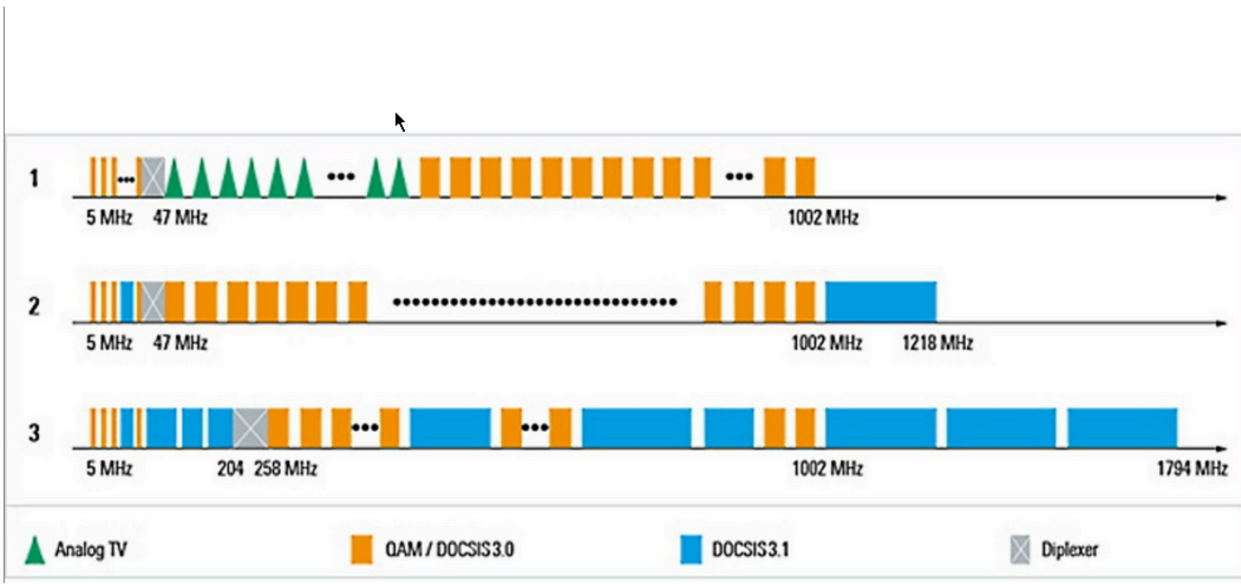


If we consider a standard DOCSIS 3.1 downstream channel width of 192 MHz, and we apply a 4096-QAM modulation scheme, the maximum theoretical data rate for a single downstream carrier becomes:

192,000,000 Hz * 12 bits/Hz = 2,304,000,000 bits per second, or approximately 2.3 Gbps.

It's important to remember that real-world conditions will not achieve this theoretical maximum due to factors such as noise, interference, signal degradation, and the overhead of error-correction coding. In practical terms, under excellent signal conditions, using 4096-QAM you could expect somewhere in the range of 1.89 Gbps per 192 MHz channel after accounting for overheads.





Top of Form

Bottom of Form

Top of Form

cable internet providers

Provider	Speeds	Prices
xfinity	75–1,200Mbps	$25.00–$80.00/mo.[*##‖]
Spectrum	Up to 300–1,000Mbps (wireless speeds may vary)	$49.99–$89.99/mo.[†] for 12 mos.
COX	Up to 100–1,000Mbps	$49.99–$109.99/mo.[‡]
optimum.	300–5,000Mbps	$40.00–$180.00/mo.[§**]
WOW!	50–1,200Mbps	$19.99–$94.99/mo.[‖]
Astound Broadband	Up to 300–1,200Mbps	$20.00–$70.00/mo.[#]

fiber internet providers

Provider	Speeds	Prices
Google Fiber	1,000–2,000Mbps	$70.00–$100.00/mo.*
AT&T	100–5,000Mbps	$55.00–$180.00/mo.†#**‡‡§§
verizon	300–2,048Mbps	$49.99–$119.99/mo.‡
CenturyLink	200–940Mbps	$30.00–$70.00/mo.§
FRONTIER	500–5,000Mbps	$49.99–$154.99/mo.##
optimum.	300–5,000Mbps	$40.00–$180.00/mo.***†††

Cable Service Providers

Comcast
Cox Communications
Cablevision d/b/a Optimum
Charter Communications
(including Time Warner Cable and Bright House Networks)

Satellite Service Providers

AT&T/DIRECTV
DISH Network

Telco Service Providers

AT&T
CenturyLink
Frontier
Verizon

Manufacturers

ARRIS
Technicolor

Energy Efficiency Advocates

Natural Resources Defense Council (NRDC)
American Council for an Energy-Efficient Economy (ACEEE)
Appliance Standards Awareness Project (ASAP)

Broadband Access Network Layer 1 Physical

A coaxial-based broadband access network is assumed. This may take the form of either an all-coax or hybridfiber/coax (HFC) network. The generic term "cable network" is used here to cover all cases.

A cable network uses a tree-and-branch architecture with analog transmission. The key functional characteristics assumed in this document are the following:

• **Two-way transmission**.

• A maximum optical/electrical spacing between the CMTS and the most distant CM of 50 miles (80 km) in each
direction, although typical maximum separation may be 15 miles (24 km).

• A maximum differential optical/electrical spacing between the closest and most distant modems of 50 miles (80km) in each direction, although this would typically be limited to 15 miles (24 km).

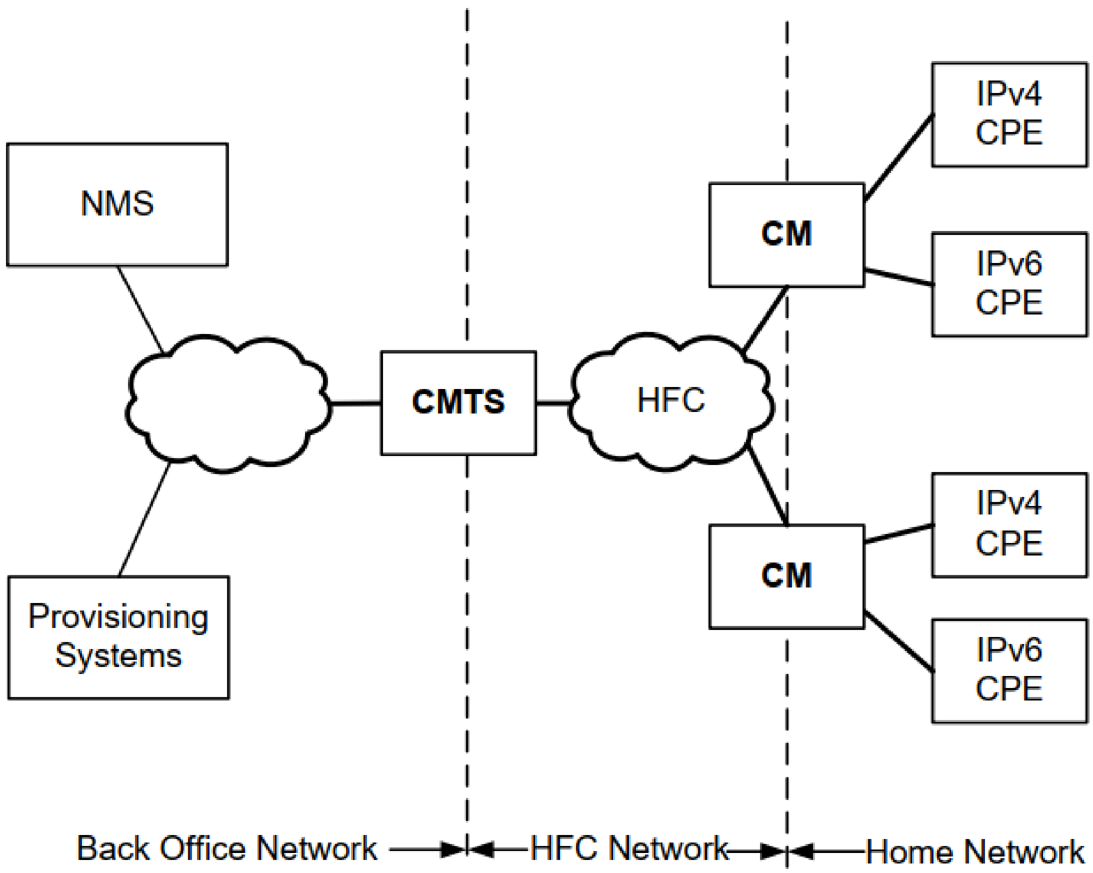


Figure 1–1 - The DOCSIS Network

The CM connects to the operator's HFC network and to a home network, bridging packets between them. Many CPEs can connect to the CMs' LAN interfaces. CPE can be embedded with the CM in a single device, or they can be separated into standalone devices, as shown in Figure 1–1. CPE may use IPv4, IPv6 or both forms of IP addressing. Examples of typical CPE are gateways, home routers, set-top devices, personal computers, etc.

The CMTS connects the operator's back office and core network to the HFC network. The CMTS's main function is to forward packets between these two domains, and between upstream and downstream channels on the HFC network. Various applications are used to provide back office configuration and other support to the devices on the DOCSIS network. These applications use IPv4 and/or IPv6 as appropriate to the particular operator's deployment. The following applications include:

Provisioning Systems:

• The DHCP servers provide the CM with initial configuration information, including the device IP address(es),
when the CM boots.

• The Config File server is used to download configuration files to CMs when they boot. Configuration files are in binary format and permit the configuration of the CM's parameters.

• The Software Download server is used to download software upgrades to the CM.

• The Time Protocol server provides Time Protocol clients, typically CMs, with the current time of day.

• Certificate Revocation server provides certificate status.

NMS:

• The SNMP Manager allows the operator to configure and monitor SNMP Agents, typically the CM and the CMTS.

• The Syslog server collects messages pertaining to the operation of devices.

• The IPDR Collector server allows the operator to collect bulk statistics in an efficient manner.

1

.2.3 Service Goals

As cable operators have widely deployed high-speed data services on cable television systems, the demand for bandwidth has increased. To this end, CableLabs' member companies have decided to add new features to the DOCSIS specification for the purpose of increasing capacity, increasing peak speeds, improving scalability, enhancing network maintenance practices and deploying new service offerings.

The DOCSIS system allows transparent bi-directional transfer of Internet Protocol (IP) traffic, between the cable system headend and customer locations, over an all-coaxial or HFC cable network. This is shown in simplified form in Figure 1–2.

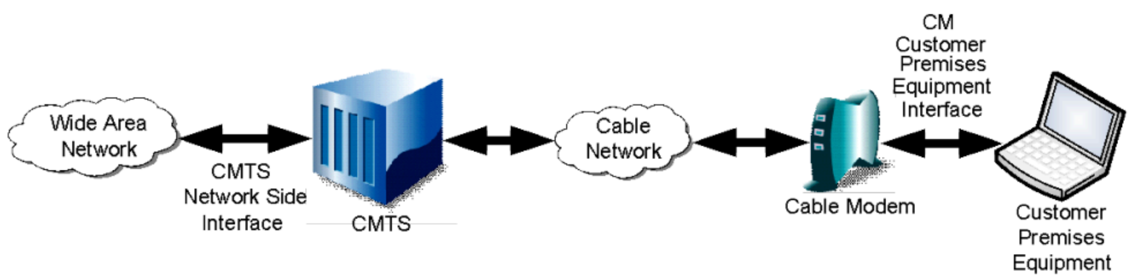


Figure 1–2 - Transparent IP Traffic Through the Data-Over-Cable System

He has shown you, O mortal, what is good.

And what does the Lord require of you?

To act justly and to love mercy

and to walk humbly with your God.

In the context of cable operators, CPE stands for "Customer Premises Equipment." This term refers to any device that is located at the subscriber's home or business and connects to the cable operator's network.

Examples of CPE for cable operators include:

1. **Cable Modems**: These devices connect to the cable operator's network and provide the subscriber with internet access. They use standards such as DOCSIS (Data Over Cable Service Interface Specification) to communicate with the operator's equipment.

2. **Set-Top Boxes**: These are devices that connect to the cable operator's network and provide the subscriber with access to television services. They can provide a range of services including live TV, on-demand content, and recording functionality.

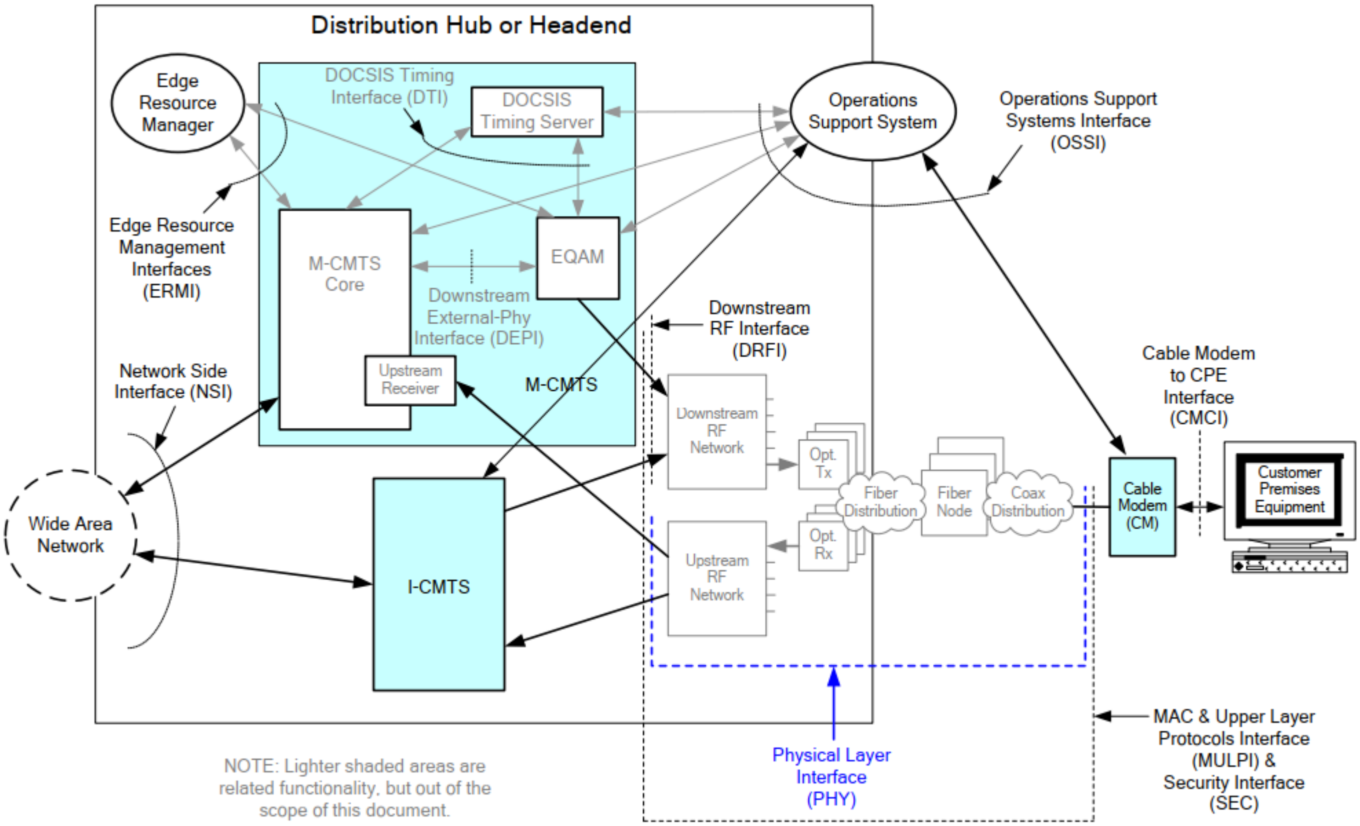
3. **Gateways**: A gateway combines the functionality of a cable modem and a router into a single device. It connects to the cable operator's network for internet access and also creates a local network for devices in the subscriber's home or business.

4. **Telephony Modems**: These are devices that provide the subscriber with telephone services over the cable operator's network. They are similar to cable modems but include additional functionality for voice calls.

If I speak in the tongues of men or of angels, but do not have love, I am only a resounding gong or a clanging cymbal. If I have the gift of prophecy and can fathom all mysteries and all knowledge, and if I have a faith that can move mountains, but do not have love, I am nothing. If I give all I possess to the poor and give over my body to hardship that I may boast, but do not have love, I gain nothing.

Love is patient, love is kind. It does not envy, it does not boast, it is not proud. It does not dishonor others, it is not self-seeking, it is not easily angered, it keeps no record of wrongs. Love does not delight in evil but rejoices with the truth. It always protects, always trusts, always hopes, always perseveres.

Reference Architecture



Data-Over-Cable Reference Architecture

DOCSIS 3.1 operates at the physical layer (Layer 1) of the Open Systems Interconnection (OSI) model, and it includes several significant enhancements over the previous versions. Here are some of the key characteristics:

1. **Increased Bandwidth**: DOCSIS 3.1 increases channel bandwidth from a maximum of 6 MHz or 8 MHz (in DOCSIS 3.0) to a maximum of 192 MHz downstream (towards the user) and a maximum of 96 MHz upstream (from the user). This dramatically increases the data rates supported by the standard.
2. **Orthogonal Frequency Division Multiplexing (OFDM)**: Unlike previous versions of DOCSIS, which use Single Carrier Quadrature Amplitude Modulation (SC-QAM), DOCSIS 3.1 uses OFDM for downstream and upstream data transmission. OFDM allows for more efficient use of the available spectrum by splitting it into multiple smaller subcarriers, each

carrying a portion of the data. This also improves the robustness against interference and signal distortion.

3. **High-Density Modulation Schemes**: DOCSIS 3.1 supports high-density modulation schemes up to 4096-QAM in the downstream direction and up to 1024-QAM in the upstream direction. This allows for higher data rates in the same amount of spectrum.
4. **Forward Error Correction (FEC)**: DOCSIS 3.1 introduces a more robust FEC scheme, known as Low-Density Parity-Check (LDPC). This helps to improve the error correction capabilities and thereby the reliability of data transmission.
5. **Spectral Efficiency**: DOCSIS 3.1 increases spectral efficiency to up to 10 bits per Hz in downstream and up to 5 bits per Hz in upstream, significantly improving the capacity of HFC networks.
6. **Energy Efficiency**: DOCSIS 3.1 includes features for energy efficiency, such as DOCSIS Light Sleep (DLS), a mode that allows cable modems to conserve power when idle.

7. **Frequency Range**: DOCSIS 3.1 increases the maximum downstream frequency range to 1.2 GHz (from 1 GHz in DOCSIS 3.0), allowing for more spectrum to be utilized for data transmission. Upstream frequency range depends on the operator's network configuration but can theoretically go up to 204 MHz.
8. **Full Duplex Capability (DOCSIS 3.1 Full Duplex)**: A future development in the DOCSIS 3.1 specification is Full Duplex capability, which will allow simultaneous data transmission and reception on the same frequency, effectively doubling the available spectrum.

Now all has been heard;

here is the conclusion of the matter:

Fear God and keep his commandments,

for this is the duty of all mankind.

For God will bring every deed into judgment,

including every hidden thing,

whether it is good or evil.

OCSIS 3.1, or Data Over Cable Service Interface Specification version 3.1, utilizes advanced radio frequency (RF) technology at Layer 1 of the Open Systems Interconnection (OSI) model to enable reliable and efficient transmission of data over cable networks. Here are some of the RF technologies used:

Orthogonal Frequency-Division Multiplexing (OFDM): OFDM is a method of encoding digital data on multiple carrier frequencies. DOCSIS 3.1 uses OFDM for downstream (toward the customer) and OFDMA upstream (toward the network) transmission, dividing the entire transmission bandwidth into many narrow subcarriers. These subcarriers are spaced so closely that their spectra overlap, hence the term "Orthogonal". The OFDM system improves bandwidth utilization, allowing for higher data rates and better handling of noise and interference in the cable environment. OFDM splits the signal into multiple sub-channels or sub-carriers, each carrying a piece of the data, all transmitted in parallel. These sub-channels are **'orthogonal**,' meaning they do not interfere with each other, allowing for better use of the available spectrum.

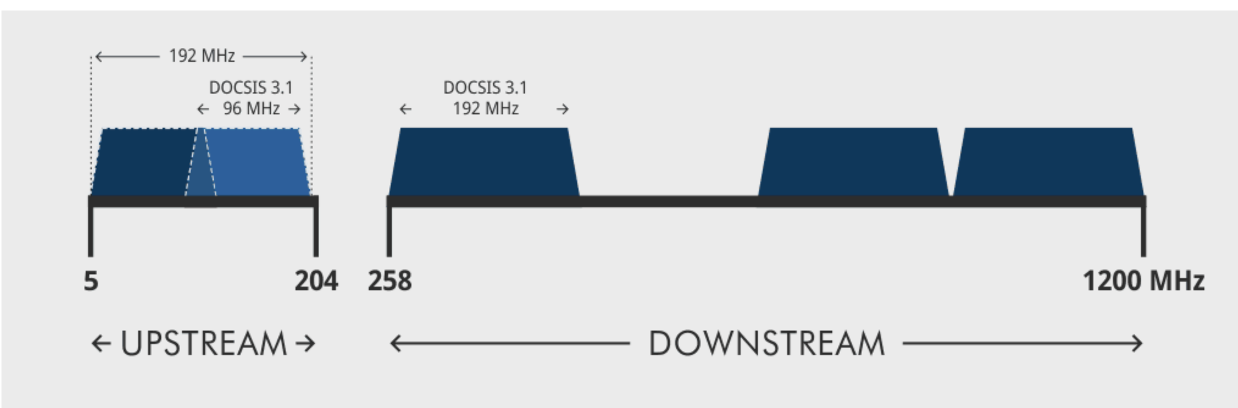
Quadrature Amplitude Modulation (QAM): QAM is a technique for modulating both the phase and the amplitude of a signal. In DOCSIS 3.1, high-density QAM schemes are used (up to 4096-QAM for downstream and 1024-QAM for upstream) for efficient data transmission. Higher order QAM increases the amount of data carried by each subcarrier, thus increasing the overall data rate.

Error Correction and Management: DOCSIS 3.1 introduces a more advanced Forward Error Correction (FEC) mechanism known as Low-Density Parity-Check (LDPC). This helps in detecting and correcting errors that might occur during data transmission over the RF medium, enhancing the reliability and integrity of the data. Also, DOCSIS 3.1 uses a technique known as Active Queue Management (AQM) to reduce network latency.

Profile Management: DOCSIS 3.1 introduces the concept of 'profiles', which are essentially groups of subcarriers with the same modulation and coding parameters. Profile Management enables the system to adaptively change modulation schemes on a per subcarrier basis to better match the channel's RF conditions. This results in a significant increase in the overall spectral efficiency and capacity of the system.

Frequency Division Multiplexing (FDM): In the context of DOCSIS 3.1 Full Duplex, the technology enables Full Duplex communication using the same frequency spectrum for both downstream and upstream communication simultaneously. This is achieved by intelligent management and isolation of echo and interference.

Downstream 1) The direction of RF signal transmission from headend or hub site to subscriber. In North American cable networks, the downstream or forward spectrum may occupy frequencies from just below 54 MHz to as high as 1002 MHz or more. 2) The DOCSIS 3.1 downstream is 258 MHz (optional 108 MHz) to 1218 MHz (optional 1794 MHz).



Downstream Channel A portion of the electromagnetic spectrum used to convey one or more RF signals from the headend or hub site to the subscriber premises.

For example, a single CEA channel's bandwidth is 6 MHz, and a downstream DOCSIS 3.1 OFDM channel's bandwidth can be up to 192 MHz.

Node An optical-to-electrical (RF) interface between a fiber optic cable and the coaxial cable distribution network. Also called fiber node.

Upstream

- The direction of RF signal transmission from subscriber to headend or hubsite. Also called return or reverse. In most North American cable networks, the legacy upstream spectrum occupies frequencies from 5 MHz to as high as 42MHz.
- The DOCSIS 3.1 upstream is 5-204 MHz, with support for 5-42 MHz, 5-65 MHz, 5-85 MHz and 5-117 MHz.

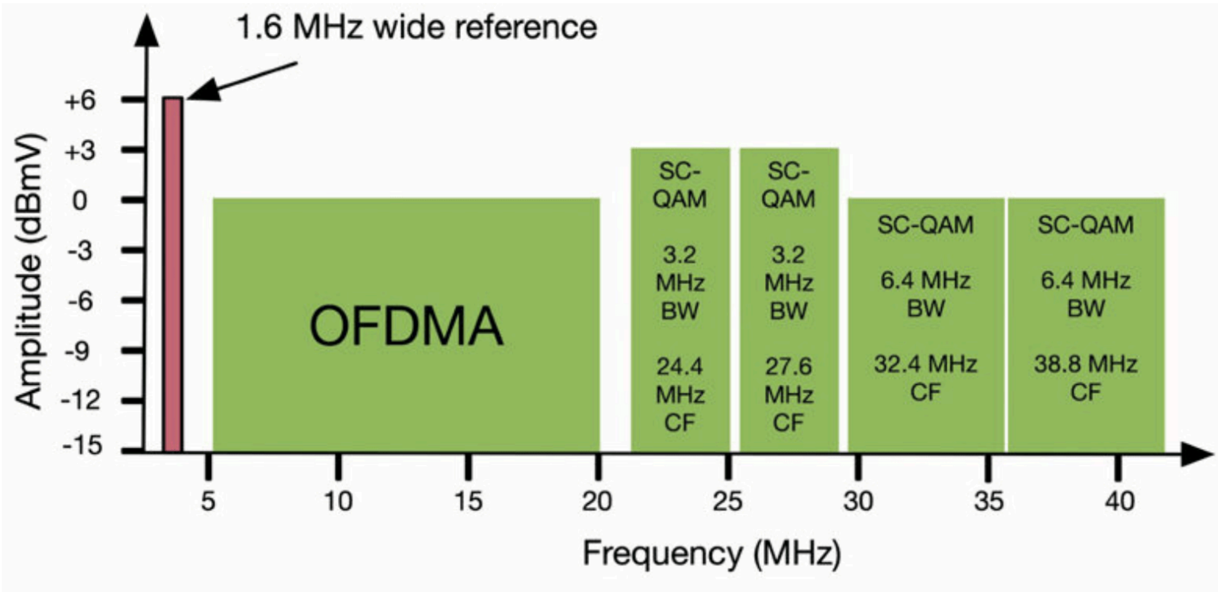
Upstream Channel

- The direction of RF signal transmission from subscriber to headend or hub site. Also called return or reverse. In most North American cable networks, the legacy upstream spectrum occupies frequencies from 5 MHz to as high as 42 MHz.
- The DOCSIS 3.1 upstream is 5-204 MHz, with support for 5-42 MHz, 5-65 MHz, 5-85 MHz and 5-117 MHz

	DOCSIS 1.0	DOCSIS 1.1	DOCSIS 2.0	DOCSIS 3.0	DOCSIS 3.1	FULL DUPLEX DOCSIS 3.1
Highlights	Initial cable broadband technology	Added voice over IP service	Higher upstream speed	Greatly enhances capacity	Capacity and efficiency progression	**Symmetrical streaming and increased upload speeds**
Downstream Capacity	40 Mbps	40 Mbps	40 Mbps	1 Gbps	10 Gbps	**10 Gbps**
Upstream Capacity	10 Mbps	10 Mbps	30 Mbps	100 Mbps	1-2 Gbps	**10 Gbps**
Production Date	1997	2001	2002	2006	2013	**2017**

DOCSIS 3.1 (Data Over Cable Service Interface Specification), an international telecommunications standard, is used to provide internet access via cable television systems. Here is a list of the equipment and components from the Cable Modem Termination System (CMTS) to the cable modem (CM) in a home.

DOCSIS 3.1 Cable Modem Transmit Power



A cable modem's transmit power is extremely important. It not only determines if the cable modem will be able to come online and register with the CMTS (cable modem termination system) but obtaining the optimal transmit power will make or break the subscriber's quality of experience (QoE). A DOCSIS 3.1 cable modem's transmit power introduces some new considerations which are discussed in this article.

Why is DOCSIS 3.1 cable modem transmit power important?

Transmit power per channel is defined as the average RF (radio frequency) power in the occupied bandwidth (channel width).[1] Transmit power per channel of a DOCSIS 3.1 cable modem is important for several reasons. First, every modem has a minimum and maximum transmit power. Having too little or too much attenuation between the modem and CMTS will exceed the minimum or maximum transmit power of the cable modem, which will cause the modem to fail to communicate with the CMTS. Frequently, failure to have enough transmit power to communicate with the CMTS is a key reason that modems are unable to register with the CMTS or the root cause for modems to frequently drop offline and re-register (often called flapping modems).

Next, to achieve the optimal signal quality or receive modulation error ratio (RxMER), the HFC network should be configured to force the cable modem to transmit its signal above the noise floor while leaving headroom to transmit more power when needed. This ideal spot has typically been between 40-50 dBmV.

The lower limit of 40 dBmV elevates the modem's signal out of the noise floor in the HFC plant.

- The upper limit of 50 dBmV assumes four-channel bonding.
- The maximum transmit power per channel of 50 dBmV allows for 1 dB of additional headroom.
- If more than four channels are bonded in the upstream, a cable modem's max transmit may be limited to 48 dBmV if it does not include the extended transmit ECN [MULPIv3.0-N-10.0943-5].
- Recommendations on nodes with more than four channel bonding should be lowered on the high end to a maximum transmit power of 47 dBmV.

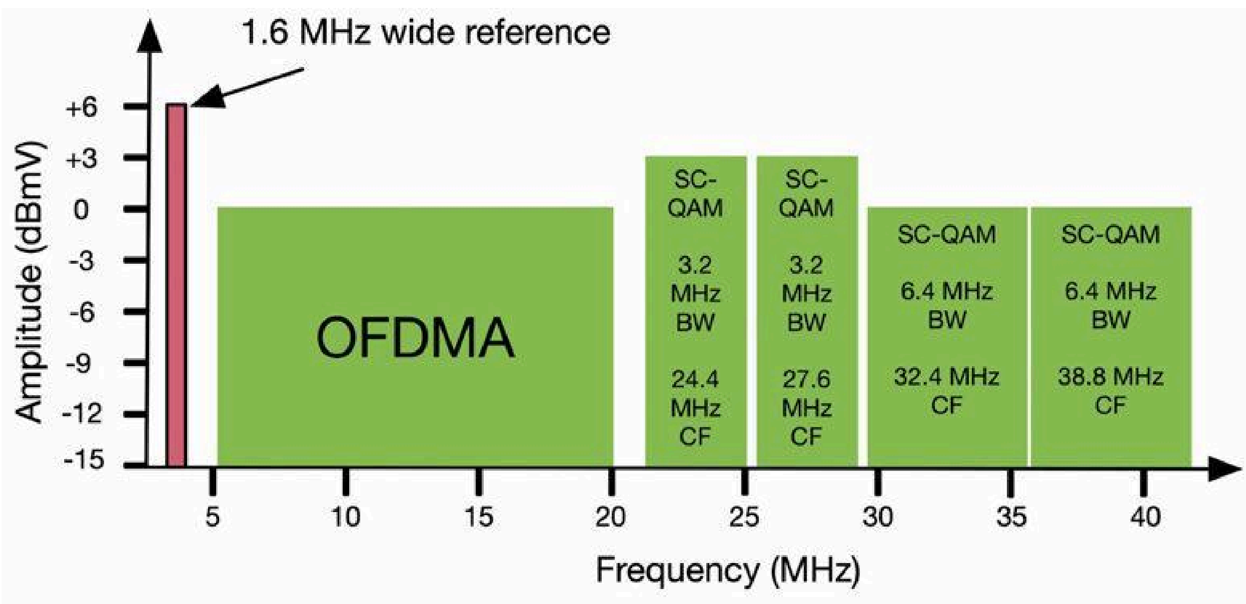


Figure 1. Upstream bonding group (UBG) with one OFDMA and four SC-QAM channels (1.6 MHz wide channel shown in red for reference purposes only

Finally, DOCSIS 3.1 and 3.0 cable modems have a limit on the dynamic range that the modem can have its lowest transmitting channel to its highest transmitting channel. This is called the dynamic range window (DRW) and is limited to 12 dB. While this seems like a large window, return paths have tilt as well as other impairments which can quickly exceed the 12 dB window. In particular, the DRW can easily be exceeded due to degraded in-home wiring. This will result in the cable modem being unable to use all upstream channels, a condition known as **partial mode**. For a deep dive on DRW, please review this YouTube video John Downey and the author created specifically on understanding DRW: https://youtu.be/CJAKmQ2u7pk

How is DOCSIS 3.1 cable modem transmit power set?

A cable modem's transmit power is always controlled by the CMTS. Typically, CMTSs are configured for a constant input power per carrier of 0 dBmV. However, this is vendor specific and can also be changed by the user. As an example, the CMTS used in this article was configured by the author for an input receive power level of 6 dBmV for SC-QAM (single carrier quadrature amplitude modulation) channels and 0 dBmV for OFDMA (orthogonal frequency division multiple access) channels.

Power calculations in a DOCSIS 3.1 CMTS are based on constant power per carrier in the upstream with respect to a 1.6 MHz bandwidth channel. While CMTS vendors may have proprietary methods to set upstream channel power, the DOCSIS 3.1 specification has defined channel power to be measured within a 1.6 MHz bandwidth or $P_{1.6r\_n}$. The "n" in the $P_{1.6r\_n}$, value indicates the number of equivalent DOCSIS channels in the occupied bandwidth as divisible by 1.6 MHz. For DOCSIS 3.1, the **equivalent channel power** for legacy SC-QAM channels is also calculated based on chunks of 1.6 MHz spectrum, again defined as $P_{1.6r\_n}$.[2]

What does all of this mean to upstream receive power at the CMTS? The CMTS upstream channels have been configured as shown in Figure 1 with one OFDMA channel and four SC-QAM channels. Also, added in Figure 1 for visual purposes is a red 1.6 MHz reference channel just below 5 MHz.

The red 1.6 MHz reference channel shown in Figure 1 has a reference power level of +6 dBmV. A DOCSIS 3.1 CMTS that measures power with respect to a 1.6 MHz channel ($P_{1.6r\_n}$) and is configured to have its SC-QAM input level at 6 dBmV would adjust a cable modem's transmit power so that the receive level at the CMTS of the 1.6 MHz channel is set to exactly +6 dBmV. The cable modem is transmitting 3.2 MHz and 6.4 MHz SC-QAM channels. The CMTS will adjust their power based on the 1.6 MHz reference. One can easily calculate the actual level the CMTS will set the 3.2 MHz and 6.4 MHz channels using the following formulas:

Delta = $10\log_{10}$(1.6 MHz / 3.2 MHz) = -3.01 dB

This means the 3.2 MHz channels will be 3.01 dB lower than the 1.6 MHz reference channel or +2.99 dBmV. Similarly, we can do the same for the 6.4 MHz wide SC-QAM channel:

Delta = $10\log_{10}(1.6 \text{ MHz} / 6.4 \text{ MHz}) = -6.02$ dB

This means the 6.4 MHz channels will be 6.02 dB lower than the 1.6 MHz reference channel and 3.01 dB lower than the 3.2 MHz SC-QAM channel.

OFDMA channel power is also measured with a 1.6 MHz bandwidth reference, like the SC-QAM channel. No calculation is required for OFDMA because OFDMA channel power is always configured with respect to the 1.6 MHz reference.

Even though the peak levels in Figure 1 may look different, the total input power for each channel is measured with respect to a 1.6 MHz bandwidth reference. Further, the per-channel power for all of the SC-QAM channels is identical, even though the heights of the "haystacks" are different.[3]

Estimating a DOCSIS 3.1 CableModem Transmit Power

Now that the expected receive power at the CMTS is known, how can one estimate the transmit power of the cable modem?

The cable modem is only aware of its absolute transmit power and is not aware of the receive level at the CMTS. The CMTS sends relative power level adjustments to the cable modem to obtain the desired receive level at the CMTS.

The resultant transmit power of the cable modem represents the loss between the output connector of the cable modem to the input connector of the CMTS. One can think of the HFC network as an attenuator, which the cable modem must overcome. This is illustrated in Figure 2.

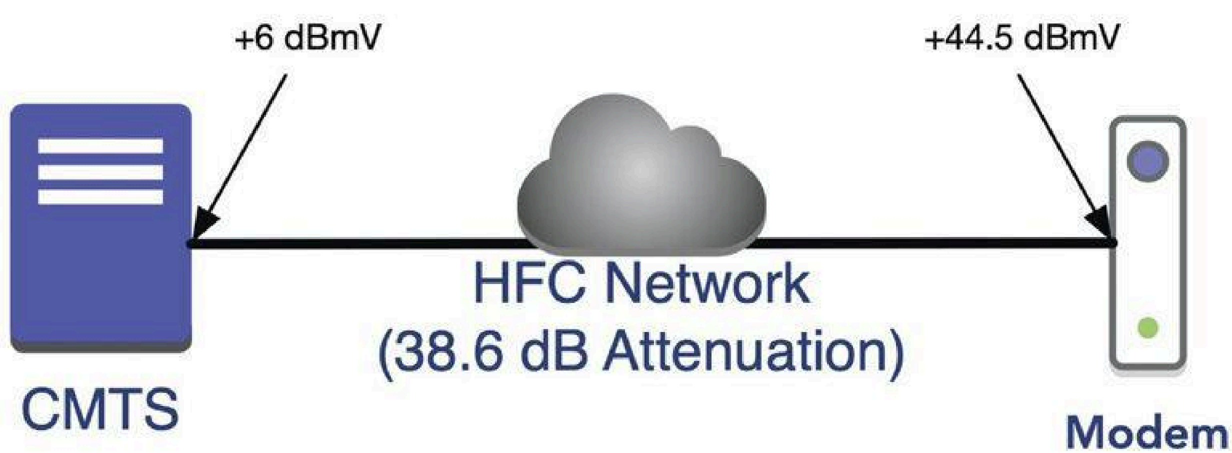


Figure 2. Simplified network diagram, HFC network as an attenuator

DOCSIS 3.1 at Layer 2

The Open Systems Interconnection (OSI) model's Layer 2 is also known as the Data Link Layer. In simpler terms, it is the layer responsible for getting data across the network from one device to another. It deals with things like making sure data gets to the right device and that the data remains intact and uncorrupted during its journey.

Now, when we talk about DOCSIS 3.1 at this layer, we're essentially talking about how it manages to send and receive data over your cable network.

1. **Multiple Devices Support**: DOCSIS 3.1 can manage data for multiple devices in your home or office. It's like a traffic manager, ensuring that every device connected to the network gets its share of the internet speed, whether it's a computer, smartphone, tablet, or smart TV.
2. **Data Delivery**: It makes sure that the data you send and receive (like your emails, video streams, or website data) gets to where it needs to go. It does

this by assigning unique addresses to each data packet and checking them at the destination to ensure the data has arrived correctly.

3. **Error Checking**: DOCSIS 3.1 at Layer 2 has ways to check if any data got corrupted or lost during transmission. If an error is detected, it can request that the data be sent again to ensure you get all the data you need without any errors.
4. **Efficient Use of Network**: DOCSIS 3.1 makes sure that your internet usage is as efficient as possible. It can prioritize certain types of data over others (like giving video streaming data priority over email data) to ensure you get the best experience possible.
5. **Security**: DOCSIS 3.1 also plays a role in network security at this layer. It has measures in place to prevent unauthorized devices from connecting to your network.

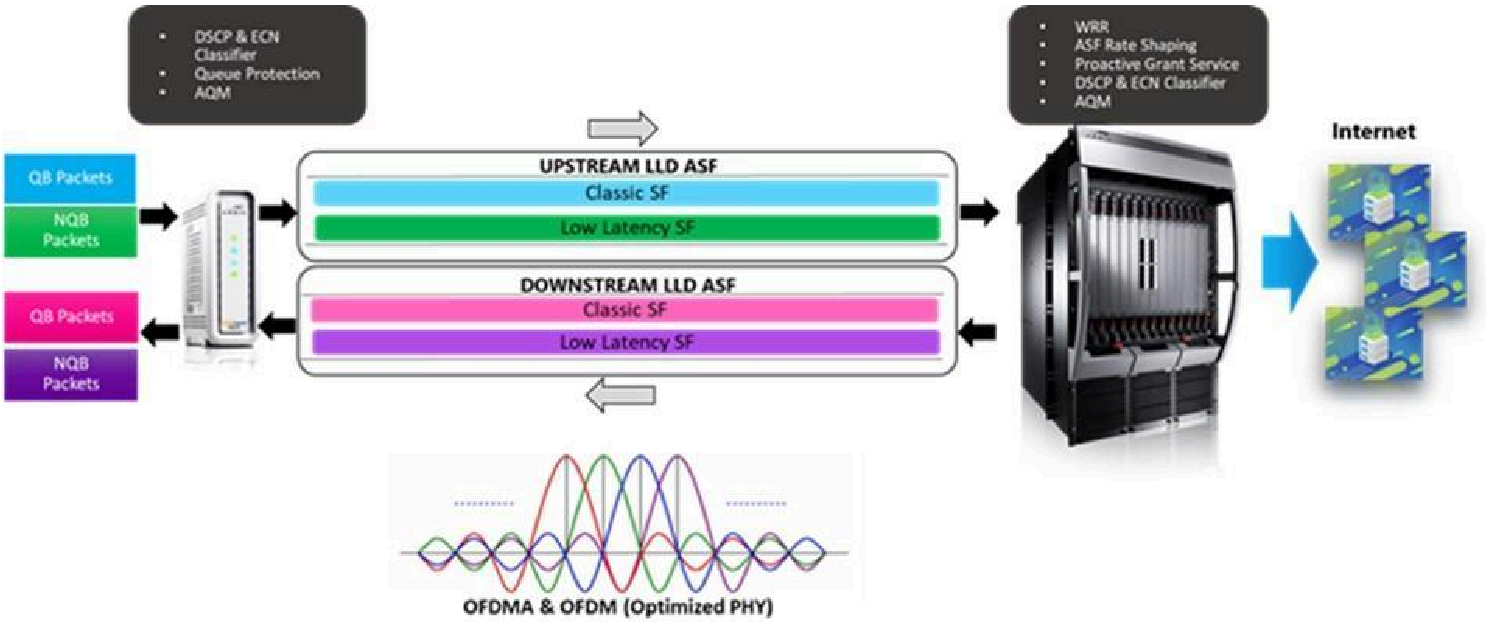
In simpler terms, you can think of DOCSIS 3.1 at Layer 2 as a smart and efficient postman. He knows where each parcel (or data packet) needs to go, he makes sure it gets there intact, he knows how to manage his deliveries for maximum efficiency, and he makes sure only authorized people receive the parcels.

OSI Layer 2 based on the DOCSIS 3.1 specifications

DOCSIS (Data Over Cable Service Interface Specification) 3.1 is a telecommunications standard used for the transmission of data over cable TV systems. It operates at the first two layers of the OSI model - the physical layer (Layer 1) and the data link layer (Layer 2).

At the data link layer (Layer 2), DOCSIS 3.1 carries out various important functions including:

1. **MAC (Media Access Control) Layer Functions**: DOCSIS 3.1 uses a time-division multiple access (TDMA) and frequency-division multiple access (FDMA) scheme for efficient and fair use of network resources. The MAC layer schedules when and at what frequency each modem can transmit data, ensuring smooth and efficient data transmission even with multiple users on the same network.
2. **Frame Encapsulation**: The data link layer encapsulates the network layer data into a frame structure that includes control information such as source and destination MAC addresses and error detection fields.
3. **Error Detection and Correction**: The Layer 2 of DOCSIS 3.1 utilizes an improved error correction mechanism known as Low-Density Parity-Check (LDPC) codes. It checks and corrects for errors that may occur during data transmission, enhancing the overall reliability of data delivery.
4. **Link Security**: DOCSIS 3.1 introduces enhanced security features at Layer 2. Baseline Privacy Interface Plus (BPI+) provides data privacy across the cable network for both downstream and upstream data flows, preventing unauthorized access and eavesdropping.
5. **Quality of Service (QoS)**: The Layer 2 of DOCSIS 3.1 also handles QoS by differentiating types of network traffic and applying different service flows. It can prioritize time-sensitive data such as VoIP or video streaming over other types of traffic.
6. **Active Queue Management (AQM)**: DOCSIS 3.1 introduces AQM techniques to better manage data packet traffic and reduce latency. This is beneficial for applications that are sensitive to delay, like video conferencing or online gaming.



These functions at Layer 2 are crucial to provide reliable, secure, and high-quality data services

1. **Cable Modem Termination System (CMTS)**: This is the first piece of hardware located at the cable provider's end. The CMTS allows the communication between the provider's equipment and the user's equipment.

2. **Coaxial Cable or Fiber Optic Cable**: The CMTS is connected to the user's home through a network of cables. Coaxial cables were traditionally used, but increasingly, providers are using fiber optic cables for better performance. These cables carry the data signal from the CMTS to the cable modem in the user's home.

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3. **Amplifiers/Repeaters**: These devices are used throughout the cable network to boost the signal and prevent degradation over long distances.
4. **Splitters**: These devices are used to split the cable signal into multiple directions to provide service to multiple homes.
5. **Tap**: This is the connection point on the cable line where the user's home service cable connects. This typically is located on a utility pole or in a utility box.
6. **Drop Cable**: This is the individual line that connects from the tap to the user's home.
7. **Network Interface Device (NID)**: This is typically a box located on the outside of the home where the drop cable connects. It's the demarcation point between the cable provider's network and the user's home network.
8. **Home Coaxial Cabling**: This is the internal cabling within the user's home. It connects the network interface device to the cable modem.
9. **DOCSIS 3.1 Cable Modem (CM)**: This is the device that receives the data signal from the cable provider and converts it into a digital signal that can be used by the user's computer or router.
10. **Router**: While not a part of the DOCSIS standard, the router is often a crucial piece of equipment in home networks. It takes the data from the cable modem and distributes it to devices within the home.

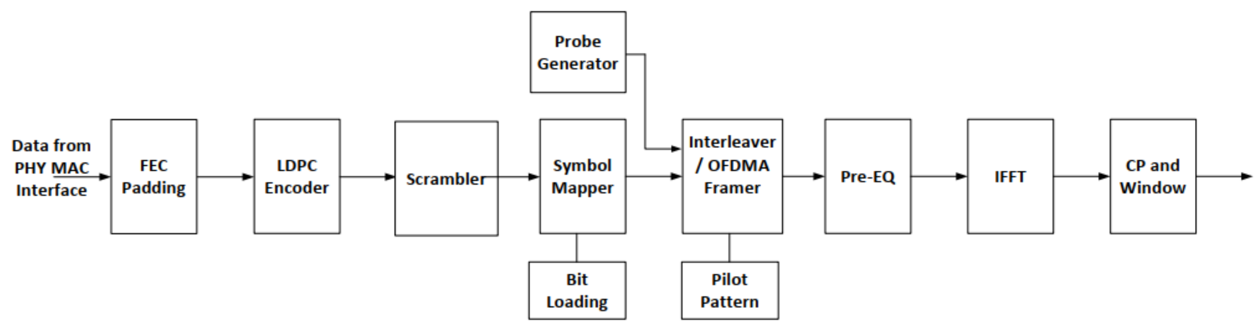


Figure 7–2 - Upstream transmitter block diagram

Framing

Figure 7–3 describes how the received bits from the PHY-MAC Convergence layers are framed before being converted into constellation symbols. The number of FEC padding bits and the number of minislot padding bits are calculated by the PHY-MAC Convergence layer according to the allocation of minislot and the profile received by the grant message.

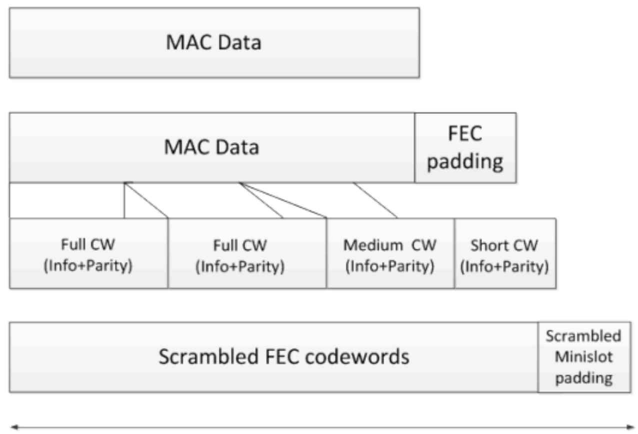
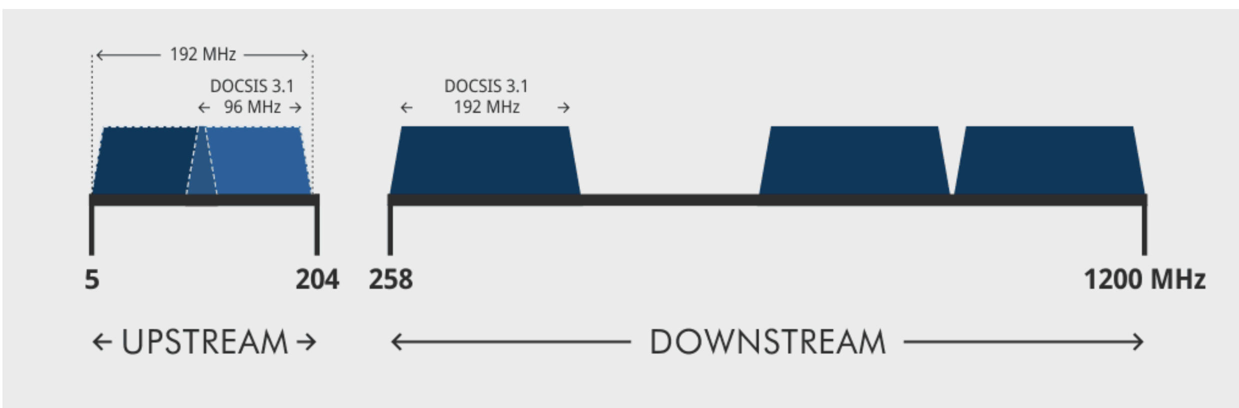
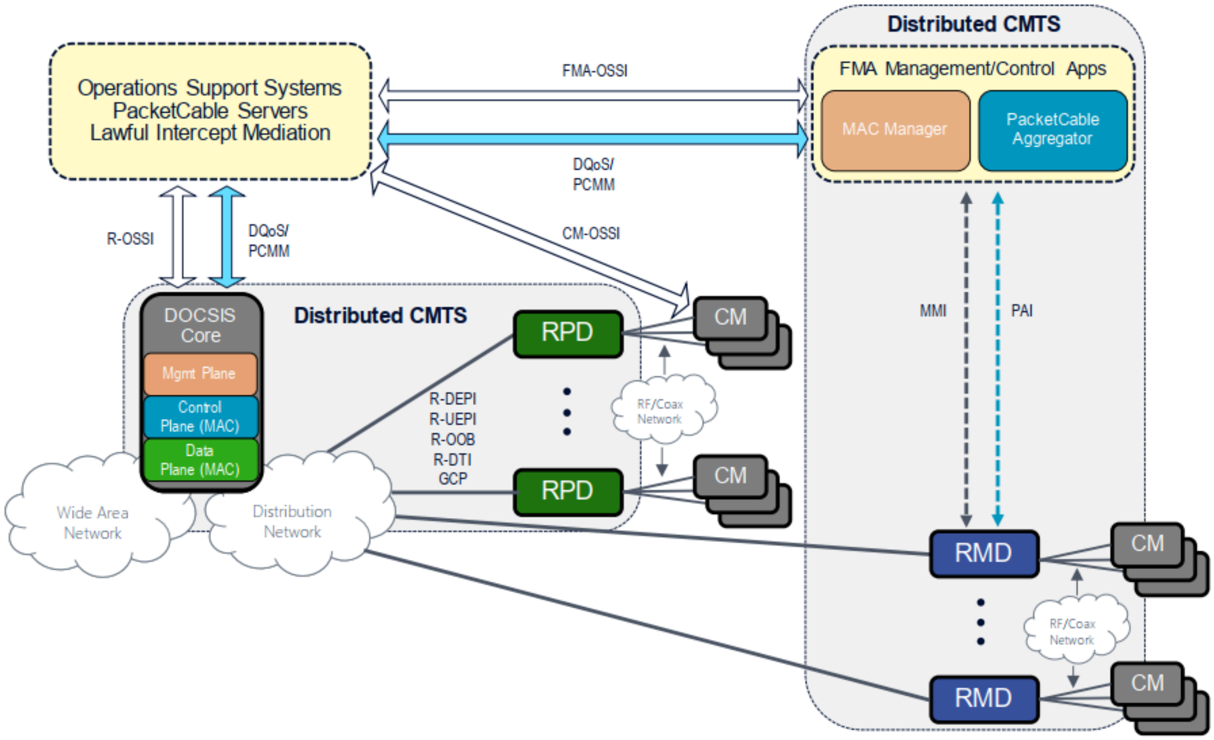


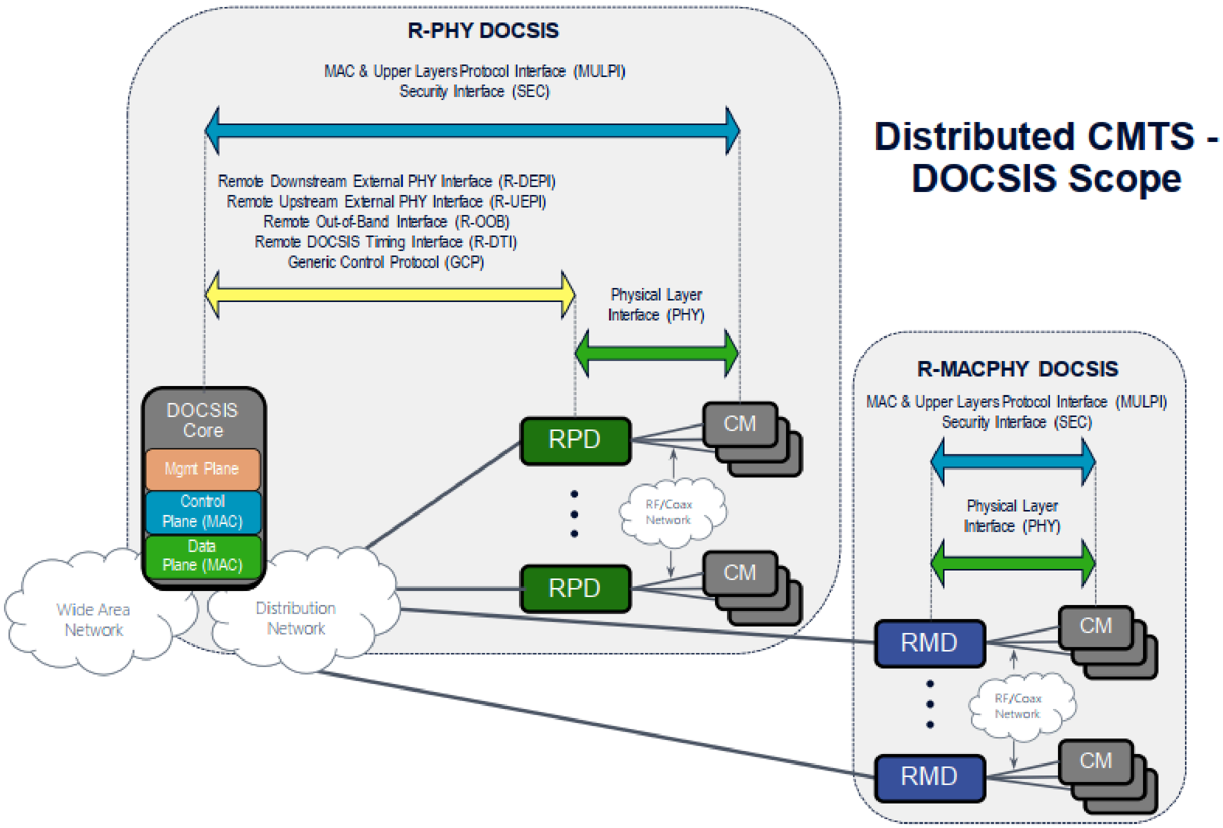
Figure 7–3 - Upstream Transmitter Block Diagram

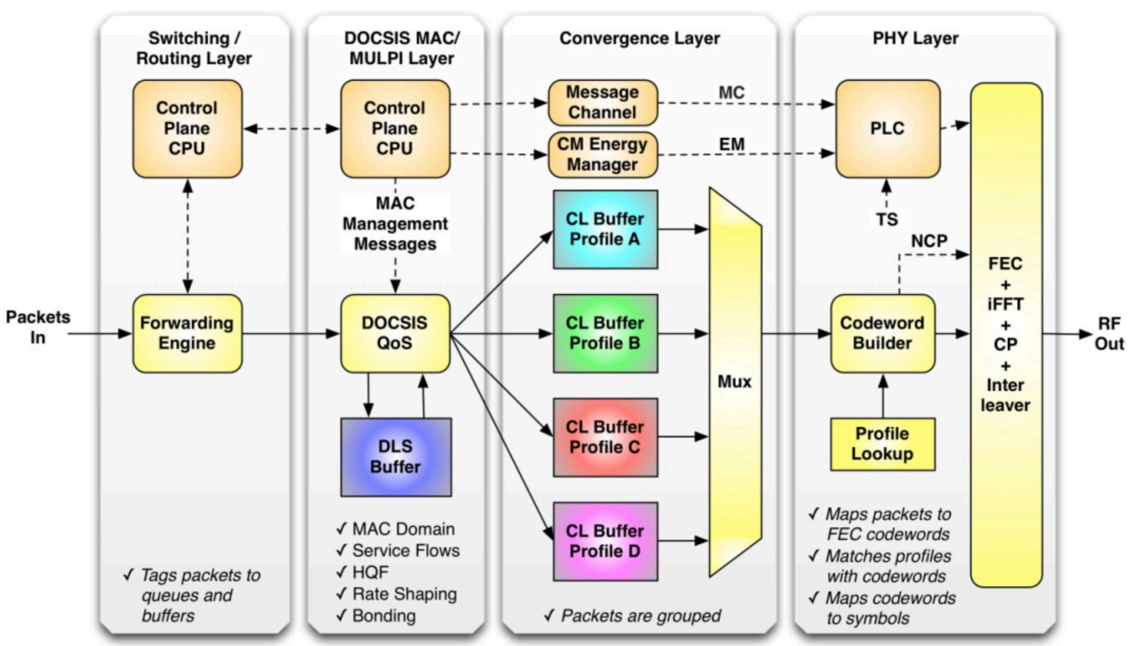


DOCSIS 4.0

DOCSIS 4.0 Distributed CMTS Reference Architecture







Downstream Convergence Layer Block Diagram

Similar to DOCSIS 3.0 CMTS, the DOCSIS 3.1/4.0 CMTS supports autonomous load balancing of CMs.

Multicast Operation

DOCSIS provides support for IP Multicast with features such as Source Specific Multicast [RFC 4607], Quality of Service support for multicast traffic, IPv6 multicast, and bonded multicast. These enhanced IP Multicast features enable cable operators to offer various IP Multicast-based multimedia services, such as Internet Protocol Television (IPTV), over the DOCSIS network.

Troubleshooting Slow Performance in Cable Modem Networks

Accessing diagnostic data from your modem:

192.168.100.1 or 192.168.0.1 are typical IP addresses for most cable modems

Default Usernames and Passwords are found often on a Google search:

Search based on your Cable modem.

- Make and model
- Cable modem login
- Many times the username is “admin”
- Password is “password”

1. **Connect your laptop directly to the back of the cable modem**

Cable Modem

Status | Signal | Addresses | Configuration | Logs | Open Source | Help

This page provides information about the startup process of the Cable Modem. If there is a problem with the startup, the word "Failed" may appear in the Status column. Should this occur, visit the Help area and perform the Checkup procedures listed there. If the problem continues, click on the word "Failed" for more detailed information about the failure, or call your service provider for assistance.

Task	Status
DOCSIS Downstream Channel Acquisition	Done
DOCSIS Ranging	Done
Establish IP Connectivity using DHCP	Done
Establish Time Of Day	Done
Transfer Operational Parameters through TFTP	Done
Register Connection	Done
Cable Modem Status	Operational
Initialize Baseline Privacy	Done

Cable Modem Operation	Value
Current Time and Date	Jan 28 2016 16:12:00
System Up Time	1 days 6h:28m:21s

On the status page of the modem we find a number of valuable pieces of information as follows. At the top of the page we can see that the modem has acquired its downstream channel and locked to it.

This simply means that the modem found a valid DOCSIS channel and was able to obtain a signal lock to it, which is the first stage of the cable modem registration process.

Next we see the connectivity state, which is “operational”, meaning that the modem is online and registered with the CMTS – things are looking good so far. The boot state indicates that the modem’s software booted up without any issues. The configuration file shows “Ok”. The configuration file is a very critical step during modem registration. The cable modem downloads the configuration file from the TFTP server using the trivial file transfer protocol from the cable operators headend. This file contains a plethora of details the cable modem needs to know including the maximum download and upload speeds for your modem.

ARRIS

SB6183

STATUS | PRODUCT INFORMATION | EVENT LOG | ADDRESSES | CONFIGURATION | HELP

Status

The statuses listed show the connection state of the cable modem. They are used by your service provider to evaluate the operation of the cable modem.

Startup Procedure

Procedure	Status	Comment
Acquire Downstream Channel		Locked
Connectivity State	OK	Operational
Boot State	OK	Operational
Configuration File	OK	
Security	Disabled	Disabled
DOCSIS Network Access Enabled	Allowed	

Downstream Bonded Channels

Channel	Lock Status	Modulation	Channel ID	Frequency	Power	SNR	Corrected	Uncorrectables
1	Locked	QAM256	3	801000000 Hz	0.1 dBmV	45.4 dB	6159	823
2	Locked	QAM256	1	789000000 Hz	0.5 dBmV	45.6 dB	11030	3432
3	Locked	QAM256	2	795000000 Hz	-0.4 dBmV	45.6 dB	4758	268
4	Locked	QAM256	4	807000000 Hz	-0.5 dBmV	45.1 dB	4931	512
5	Locked	QAM256	5	813000000 Hz	-0.5 dBmV	44.5 dB	4843	287
6	Locked	QAM256	6	819000000 Hz	0.4 dBmV	45.0 dB	5729	930
7	Locked	QAM256	7	825000000 Hz	-1.3 dBmV	44.2 dB	4608	245
8	Locked	QAM256	8	831000000 Hz	-1.6 dBmV	44.1 dB	5445	484

Upstream Bonded Channels

Channel	Lock Status	US Channel Type	Channel ID	Symbol Rate	Frequency	Power
1	Locked	ATDMA	4	2560 Ksym/sec	15000000 Hz	39.5 dBmV
2	Locked	ATDMA	1	5120 Ksym/sec	35700000 Hz	42.5 dBmV
3	Locked	ATDMA	2	5120 Ksym/sec	29200000 Hz	42.5 dBmV
4	Locked	ATDMA	3	2560 Ksym/sec	20000000 Hz	42.5 dBmV

Current System Time: Sat Jun 13 01:19:22 2020

STATUS | PRODUCT INFORMATION | EVENT LOG | ADDRESSES | CONFIGURATION | HELP

ARRIS

Security is showing disabled on my modem. What security means on the cable modem is Baseline Privacy Interface Specification or BPI+. This security encrypts

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data between the cable modem and the CMTS. This encryption is mostly provided to prevent theft of service by subscribers when enabled. It is very difficult to eavesdrop on another user's modem even when BPI+ is disabled as in the case of my modem because the data being transferred is modulated on an RF signal. To do so one would need a very expensive DOCSIS protocol analyzer and they would need a direct connection to your coax cable. So while not impossible, it is by no means trivial.

DOCSIS Network Access Enabled indicates that while your modem is online, if this setting is not set to "Allowed", you won't be able to access the Internet. This feature is often disabled if you have not paid for service or if you have not paid your bill.

The next two sections show your downstream and upstream channels. If you are having any type of Internet performance issues, this is the place you will want to look. Let's look at each section in detail.

- On the downstream, we see that this modem is bonded to or using 8 downstream channels.
- It is locked to each of the 8 downstream channels. Each channel is using 256 QAM for the modulation.
- In all versions of DOCSIS there are two downstream modulations that can be used for single channel carriers. 64-QAM which will support roughly 27 Mbps per channel and 256-QAM which will support 37 Mbps per channel.
- Since my modem is locked to 8 channels at 256-QAM, my modem could theoretically have a total downstream speed of 8 x 37 Mbps which is a total of 296 Mbps.

Don't worry about the Channel ID, this is used internally for the modem to keep track of the channels. Each channel has its own RF frequency. In broadband we use a cool term called frequency division multiplexing or FDM. This just means we use many RF frequencies and stack them side-by-side. Each channel also has its own receive power, which is the amount of RF signal entering the back of the cable modem.

- The ideal receive powef we want to see coming into the cable modem is between -10 to +10 dBmV. Once your modem's channels start to exceed these values, either too high or too low, the performance of your modem may become degraded.

Next we have the “SNR”, which stands for signal to noise ratio.

- I will digress for just a moment here. SNR is a baseband measurement typically used for measuring the quality of audio and video signals before they are upconverted for transmission. In the cable industry, we have had a history of incorrectly using SNR to label the digital signal quality measurement of signals. The correct terminology for this measurement is modulation error ratio or MER. As a user you will see SNR and MER used interchangeably in cable modems, CMTSs, test equipment, literature and more. If you are a stickler to being technically correct, then please know that MER is the correct term as these measurements are analyzing the quality of demodulated digital signals and not baseband analog signals. I digress no more.
- The minimum MER or SNR as labeled on my modem that we need for an error free reception of 256- QAM signals is 31 dB.
- As you can see with my modem we are more than 10 dB higher than the minimum, so one would believe that everything should be good.

Corrected and uncorrected codewords are likely the most important indicator of your modem's performance.

- First, what are they? To really understand codeword errors you will need to Google Read-Solomon Error Correction which is used for all [DOCSIS] prior to [DOCSIS 3.1] and LDPC (low density parity check) error correction for DOCSIS 3.1 OFDM and OFDMA signals.
- But at a high level, a corrected packet occurs when the modem receives some data, the data has errors, but the error correction is able to repair the errors in the data, so your computer never noticed the error.
- An uncorrected packet occurs when the modem receives a packet of data with some errors, but the error correction is unable to repair the errors, so the modem discards the data.
- When the modem discards the data your computer must either request that the data be retransmitted, in the case of TCP/IP, or if you are using a real-time service like voice or video, you may notice some lost voice or video traffic.

The next section shows your cable modem's upstream channels. These are the channels that your modem uses to transmit data to the CMTS when you send data.

- Similar to the downstream, you can have one to eight channels that your modem can transmit data on, depending on how your cable operator has configured their CMTS. In this example we see there are four upstream channels. Each channel is locked, which means that it is in operation. The upstream channel type is "ATDMA".

Discussion of the channel types is out of scope for this topic, but suffice it to say that the channel type will not have an impact on your modem unless you are looking to purchase your own modem. I'll cover my recommendations on buying your own cable modem in a future video.

Again, you can ignore the channel ID as this is used internally by the modem to keep track of the channels.

The symbol rate indicates the bandwidth of the upstream channel, where 2560 Ksym/sec results in an upstream channel width of 3.2 MHz and 5120 Ksym/sec results in an upstream channel width of 6.4 MHz. Each channel has its own upstream frequency that it transmits on. In the upstream the modems use frequency division multiple access or FDMA, which just means all modems use frequency stacking, but each modem must wait their turn to transmit data. The CMTS allocates time slots to the modems so that your modem doesn't transmit at the same time on the same frequency as your neighbors' modem.

Finally, we see the transmit power for each upstream of the cable modem.

- The ideal transmit power that we want to see for each channel is between 40 to 50 dBmV.
- This is really important. If the transmit power is too low, then your modem's transmitted signal can be lost in the noise.
- If the transmit power is too high, say 52 dBmV or higher, then your modem may run out of transmit power and its signal will not reach the CMTS.

It is usually very difficult for subscribers to do anything about low transmit power. But if you are not experiencing any issues with low transmit power on your cable modem, don't worry about it. High transmit power will many times be caused by bad in-home coax or connectors or the coax and connectors just outside of the house. This is something you can tackle and make a big difference. In my video on T3 timeouts I briefly covered this topic and will do a deeper dive on in home wiring in a future video.

Now, we will look at the event log Figure 2.

- This is where you will see any error the cable modem has experienced, including those T3 and T4 timeouts discussed in other articles. In my event log we see a lot of time of day (ToD) and DHCP renewal error messages. These are completely normal and can be ignored. In fact there will always be many events logged in your modems event log which can look scary, but as long as you are not experiencing any issues these notifications are completely normal and should be ignored.

ARRIS

SB6183

STATUS | PRODUCT INFORMATION | EVENT LOG | ADDRESSES | CONFIGURATION | HELP

Event Log

The table below contains the log of events that the SB6183 has detected. This log can be important to the service provider to help diagnose and correct problems, if any should occur.

Time	Priority	Description
Sat Jun 13 02:11:15 2020	Error (4)	ToD request sent - No Response received;CM-MAC=74:ea:e8:ed:78:4b;CMTS-MAC=00:07:0d:a8:58:54;CM-QOS=1.1;CM-VER=3.0;
Sat Jun 13 02:11:00 2020	Error (4)	DHCP RENEW WARNING - Field invalid in response v4 option;CM-MAC=74:ea:e8:ed:78:4b;CMTS-MAC=00:07:0d:a8:58:54;CM-QOS=1.1;CM-VER=3.0;
Sat Jun 13 02:06:59 2020	Error (4)	ToD request sent - No Response received;CM-MAC=74:ea:e8:ed:78:4b;CMTS-MAC=00:07:0d:a8:58:54;CM-QOS=1.1;CM-VER=3.0;
Sat Jun 13 02:06:00 2020	Error (4)	DHCP RENEW WARNING - Field invalid in response v4 option;CM-MAC=74:ea:e8:ed:78:4b;CMTS-MAC=00:07:0d:a8:58:54;CM-QOS=1.1;CM-VER=3.0;
Sat Jun 13 02:02:42 2020	Error (4)	ToD request sent - No Response received;CM-MAC=74:ea:e8:ed:78:4b;CMTS-MAC=00:07:0d:a8:58:54;CM-QOS=1.1;CM-VER=3.0;
Sat Jun 13 02:01:00 2020	Error (4)	DHCP RENEW WARNING - Field invalid in response v4 option;CM-MAC=74:ea:e8:ed:78:4b;CMTS-MAC=00:07:0d:a8:58:54;CM-QOS=1.1;CM-VER=3.0;
Sat Jun 13 01:58:26 2020	Error (4)	ToD request sent - No Response received;CM-MAC=74:ea:e8:ed:78:4b;CMTS-MAC=00:07:0d:a8:58:54;CM-QOS=1.1;CM-VER=3.0;
Sat Jun 13 01:56:00 2020	Error (4)	DHCP RENEW WARNING - Field invalid in response v4 option;CM-MAC=74:ea:e8:ed:78:4b;CMTS-MAC=00:07:0d:a8:58:54;CM-QOS=1.1;CM-VER=3.0;
Sat Jun 13 01:54:10 2020	Error (4)	ToD request sent - No Response received;CM-MAC=74:ea:e8:ed:78:4b;CMTS-MAC=00:07:0d:a8:58:54;CM-QOS=1.1;CM-VER=3.0;
Sat Jun 13 01:51:00 2020	Error (4)	DHCP RENEW WARNING - Field invalid in response v4 option;CM-MAC=74:ea:e8:ed:78:4b;CMTS-MAC=00:07:0d:a8:58:54;CM-QOS=1.1;CM-VER=3.0;
Sat Jun 13 01:49:54 2020	Error (4)	ToD request sent - No Response received;CM-MAC=74:ea:e8:ed:78:4b;CMTS-MAC=00:07:0d:a8:58:54;CM-QOS=1.1;CM-VER=3.0;
Sat Jun 13 01:46:00 2020	Error (4)	DHCP RENEW WARNING - Field invalid in response v4 option;CM-MAC=74:ea:e8:ed:78:4b;CMTS-MAC=00:07:0d:a8:58:54;CM-QOS=1.1;CM-VER=3.0;
Sat Jun 13 01:45:37 2020	Error (4)	ToD request sent - No Response received;CM-MAC=74:ea:e8:ed:78:4b;CMTS-MAC=00:07:0d:a8:58:54;CM-QOS=1.1;CM-VER=3.0;
Sat Jun 13 01:41:00 2020	Error (4)	DHCP RENEW WARNING - Field invalid in response v4 option;CM-MAC=74:ea:e8:ed:78:4b;CMTS-MAC=00:07:0d:a8:58:54;CM-QOS=1.1;CM-VER=3.0;
Sat Jun 13 01:37:05 2020	Error (4)	ToD request sent - No Response received;CM-MAC=74:ea:e8:ed:78:4b;CMTS-MAC=00:07:0d:a8:58:54;CM-QOS=1.1;CM-VER=3.0;
Sat Jun 13 01:36:00 2020	Error (4)	DHCP RENEW WARNING - Field invalid in response v4 option;CM-MAC=74:ea:e8:ed:78:4b;CMTS-MAC=00:07:0d:a8:58:54;CM-QOS=1.1;CM-VER=3.0;
Sat Jun 13 01:32:49 2020	Error (4)	ToD request sent - No Response received;CM-MAC=74:ea:e8:ed:78:4b;CMTS-MAC=00:07:0d:a8:58:54;CM-QOS=1.1;CM-VER=3.0;
		DHCP RENEW WARNING - Field invalid in response v4 option;CM

So what don't you want to see on your cable modem?

Downstream Channel 3			
Lock Status	Locked	Modulation	256 QAM
Channel ID	4	Symbol rate	5360537
Downstream Frequency	573000000 Hz	Downstream Power	-8.9608 dBmV
SNR	36.8445 dBmV	Correctables	315
Uncorrectables	714		

Upstream Channel 0			
Lock Status	Locked	Modulation	64QAM
Channel ID	1	Symbol rate	5120 Ksym/sec
Upstream Frequency	35800000 Hz	Upstream Power	41.2500 dBmV

Upstream Channel 1			
Lock Status	Not Locked	Modulation	
Channel ID	0	Symbol rate	0 Ksym/sec
Upstream Frequency	0 Hz	Upstream Power	0 dBmV

Upstream Channel 2			
Lock Status	Not Locked	Modulation	
Channel ID	0	Symbol rate	0 Ksym/sec
Upstream Frequency	0 Hz	Upstream Power	0 dBmV

Upstream Channel 3			
Lock Status	Not Locked	Modulation	
Channel ID	0	Symbol rate	0 Ksym/sec
Upstream Frequency	0 Hz	Upstream Power	0 dBmV

Current System Time: Sat Jun 6 22:23:31 2020

Looking at Figure 3, we see a cable modem that is not locked to two of its three upstreams.

- This was sent to me by a colleague who first noticed very slow data speeds.
- They looked at their modem and noticed that the upstream LED on the modem was orange instead of the typical green color.
- Upon logging in to the modems diagnostic page they found what they see in Figure 3.

This is called partial mode. Partial mode occurs when a modem is only using some of its available upstream or downstream channels. In this case the modem could be transmitting on three upstream channels, but two of the upstream channels have become “unlocked”. There are many reasons this can occur, but most are due to some type of impairment. In this scenario, the issue was resolved by simply unplugging the cable modem for a few seconds and plugging it back in.

Once the modem came back online all three upstreams were back online and locked. The orange LED was again green. An easy way to troubleshooting your cable modem by the homeowner without calling the cable operator.

One more cool feature

In most DOCSIS 3.0 and higher cable modems there is a built in spectrum analyzer. To access the spectrum analyzer, append port 8080 to the end of the IP address as follows: http://192.168.100.1:8080. Here you will see a screen as shown in Figure 4:

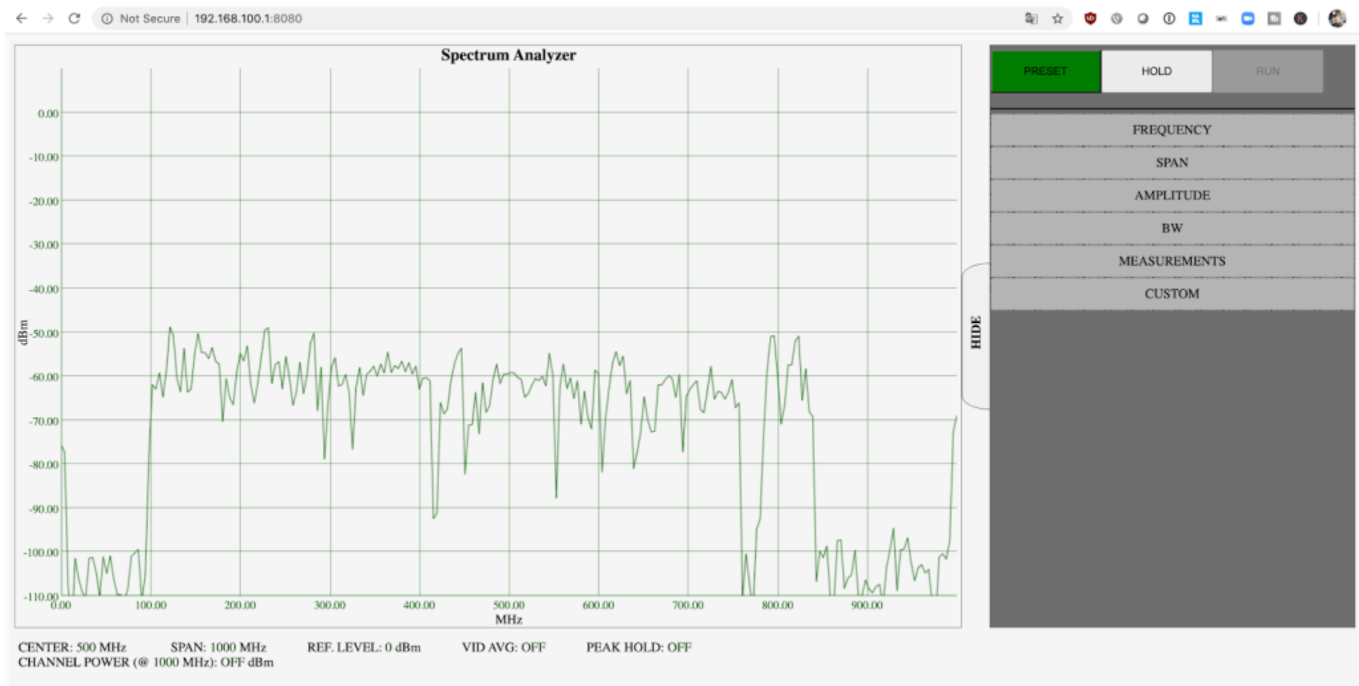


Figure 4: Built-in Spectrum Analyzer

For those who like to play with cool tools, this one's for you.

You can see all of the RF signals coming into your cable modem. There are many features in the spectrum analyzer, but I'll let it up to you to play around with the settings and see what you can find. The spectrum analyzer is also what CableHaunt was built on, which I covered in this video: https://www.youtube.com/watch?v=b0fQ-QTx-aY

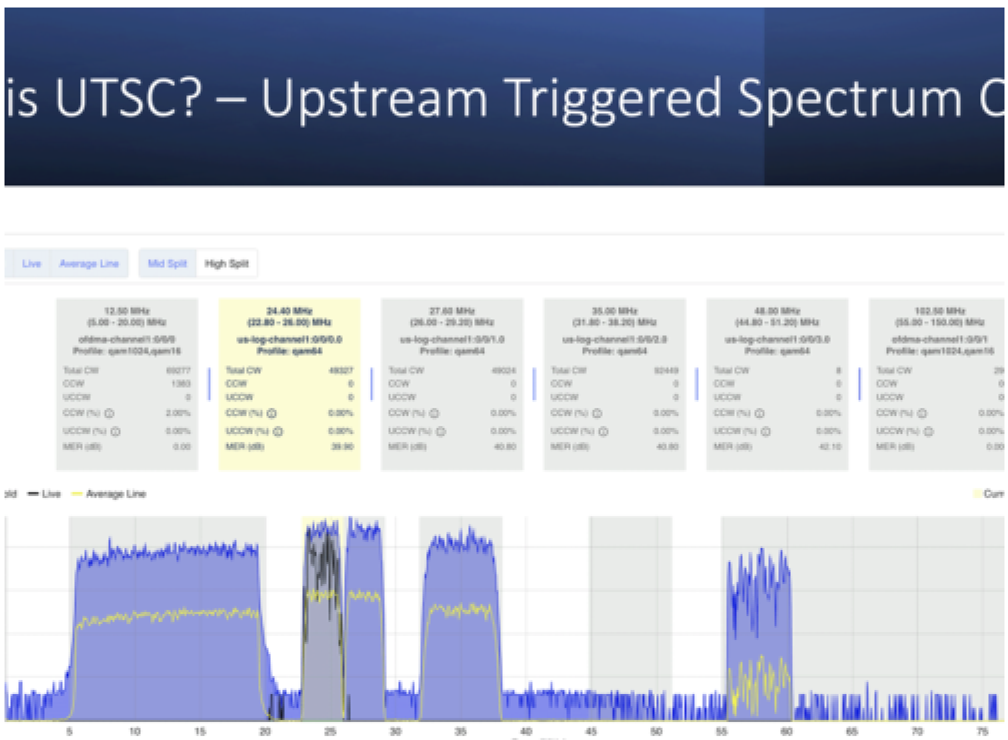
Wrapping it Up – Troubleshooting Your Cable Modem

That was a basic overview of the cable modem internal diagnostic screen. You will find some cable modems contain more or less details. Also, you may find that some cable modems and some cable operators will not give you any access to these diagnostic screens at all.

Unfortunately, subscribers will take this data and abuse their cable operators with it. By that I mean they will constantly harass their cable operators any time a single parameter is out of spec. Please do not do this or you will ruin it for everyone. I am providing you with this information so that you, as a subscriber, can help diagnose and fix issues within your own home. Cable operators and their technicians work very hard to keep networks up and running. I know personally it can be frustrating to have your internet service down or impaired.

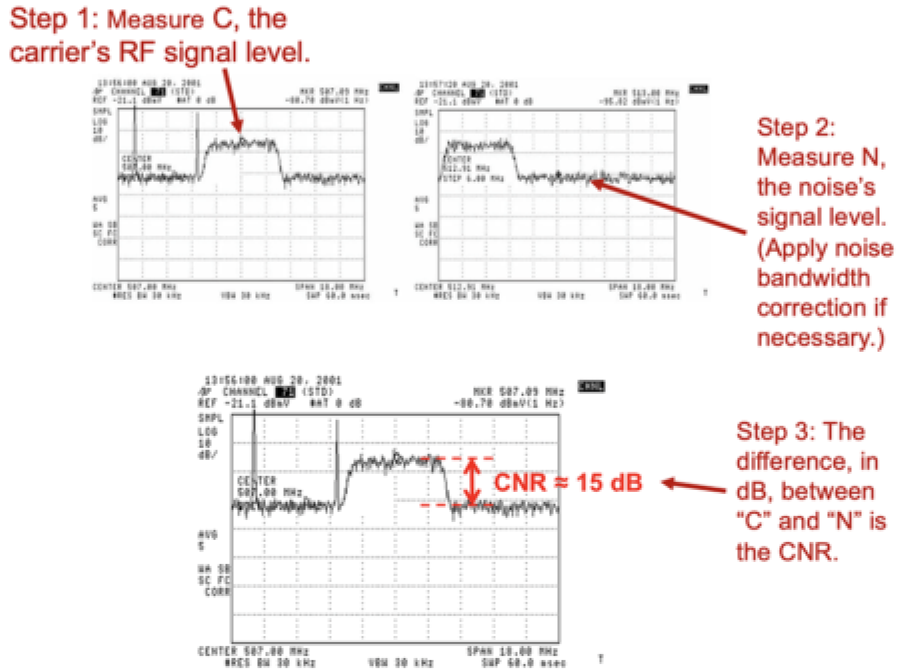
However, many times the issues do start within your own homes internal wiring and things we do without even realizing it, like moving a cable modem around or changing how the coax runs from point A to point B in our house. The cable modem diagnostic screen gives us as end users the ability to self-help. I will be doing more videos on just that – how to fix issues in our homes. Until then, thanks for watching

[Did You Know? DOCSIS: Back to Basics and Clearing Misconceptions]



[UTSC]

Carrier-to-Noise Ratio



How to Read Your Cable Modem's Diagnostic Page When Something Goes Wrong

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Although unknown to and ignored by most people, cable modems have a diagnostic that can help you troubleshoot connection problems.

https://www.howtogeek.com/240575/how-to-read-your-cable-modems-diagnostic-page-when-something-goes-wrong/

What Diagnostic Page?

Unbeknownst to most people, cable modems (and other broadband modems) have diagnostic and logging functions built in, just like routers. While some people do occasionally peek at the control panel of their router, very few people ever look at their modems–or even realize they can do so.

RELATED: ***How to Troubleshoot Your Internet Connection, Layer-By-Layer***

So why look at the diagnostic page and logs of your cable modem in the first place? Think of this familiar scene: something weird is going on with your internet access, so you dutifully unplug your modem and router, start them back up, and things work well again…for a spell. Or maybe your internet connectivity drops out intermittently and no amount of tinkering with your router has solved your problems.

While we all tend to over-focus on the router as the source of potential problems, oftentimes the modem (or the line it's connected to) can be at fault. In those cases, you need to peek into the modem to see what's going on. By accessing the tiny little web server hidden inside your modem and reading the diagnostic pages, you can learn a ton of things about your modem and connection like general status, signal strength, and event history via the system log.

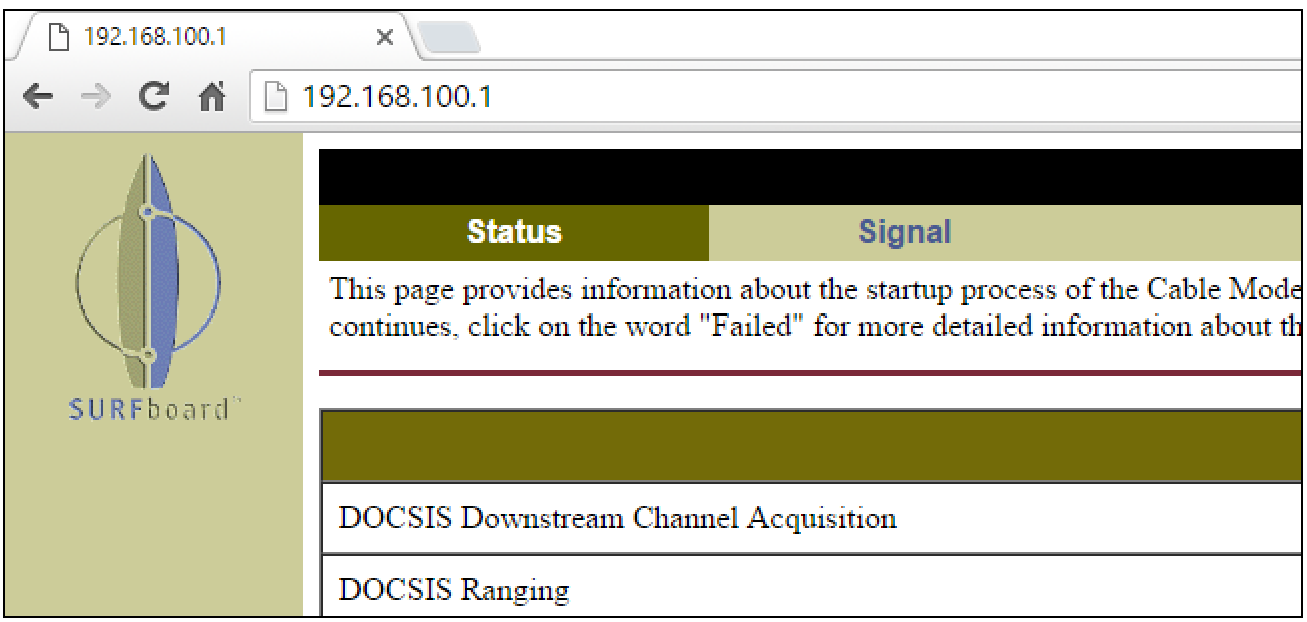
Armed with that information you can then say something like "Okay, it's not the modem or a signal strength issue, so I'll focus on the router and other elements of my network" or "Something is clearly going on with the modem so I'll call the cable company."

We want to emphasize that last part. Even if the diagnostic control panel in your modem does have user-editable settings (which is very rare), you shouldn't mess around with that stuff unless expressly instructed to do so by your internet service provider. While it's unlikely you'll actually break anything if you do wipe your modem in a fit of frustration, you might end up spending the next hour getting it reprovisioned. This is intended to help you *find* the problem, not necessarily fix it.

With that in mind, let's take a look at how you can access the diagnostic page and what to do with the information you find therein. For demonstration purposes, we will be using the using the diagnostic interface of the incredibly common [Motorola/Arris Surfboard 6141] broadband cable modem, but the general layout will be similar across modems.

How to Access Your Modem's Diagnostic Page

In order to not interfere with the common address pools that are doled out by residential routers (such as 10.0.0.X and 192.168.1.X), most modems use an address subnet that falls outside the most commonly used address pools.



Not all modems use the exact same address, but many do. Try typing 192.168.100.1 into your address bar and pressing Enter. If that doesn't immediately pull up a diagnostic page, you should consult the extensive list of broadband hardware at SpeedGuide.net. There you can narrow your search down by brand and model number to find the address of your modem (and any default login information you may need).

What to Look For

Once you have access to the diagnostic panel, there are some basic things you want to look at: the modem status, signal strength, and the activity log. While there may be additional pages to investigate (like the general configuration of the modem), these settings are generally not user-editable. And even if they were, the settings are so arcane and ISP specific that they are of very little diagnostic use to most users.

Modem Status

At the very minimum, this is the page you want to check if you're having connectivity troubles. Everything on the general status page should look positive. You want to see lots of entries that say things like "Done", "Operational", and "OK". You don't want to see entries for things like "Failed" or "Offline". Many modems, the Surfboard series included, will allow you to click directly on a failed/negative entry to access a help file about what that failure means.

Cable Modem

Status | Signal | Addresses | Configuration | Logs | Open Source | Help

This page provides information about the startup process of the Cable Modem. If there is a problem with the startup, the word "Failed" may appear in the Status column. Should this occur, visit the Help area and perform the Checkup procedures listed there. If the problem continues, click on the word "Failed" for more detailed information about the failure, or call your service provider for assistance.

Task	Status
DOCSIS Downstream Channel Acquisition	Done
DOCSIS Ranging	Done
Establish IP Connectivity using DHCP	Done
Establish Time Of Day	Done
Transfer Operational Parameters through TFTP	Done
Register Connection	Done
Cable Modem Status	Operational
Initialize Baseline Privacy	Done

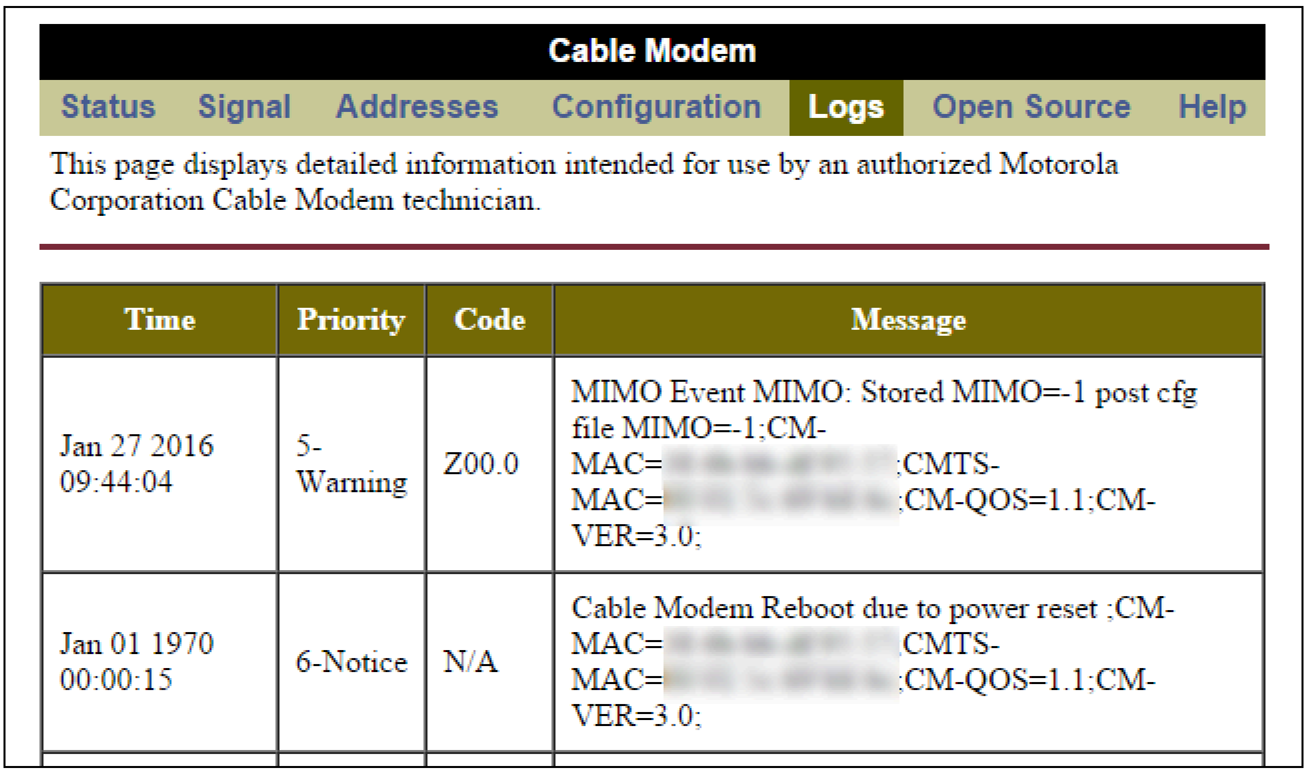
Cable Modem Operation	Value
Current Time and Date	Jan 28 2016 16:12:00
System Up Time	1 days 6h:28m:21s

The other very important thing to look at on the main status page is the system up time. The up time should reflect your experience with the modem. If you reset the modem by power cycling it four days ago, then the up time should reflect four days and change worth of operation. If you haven't reset your modem recently and the up time is a few days (or less) then it's time to dig a little deeper.

In the screenshot above, you can see the general status page for our modem. Everything looks great and the up time, although short, does reflect our interactions with the modem: after this new modem was provisioned a day ago we power cycled the device.

Logs

Modem logs are pretty arcane (like most logs). Your goal in examining the log is not to have a perfect understanding of every single code, but to have a general understanding of what is going on. You can always search online for specifics codes to get a clearer understanding of what is going on if need be.



Time	Priority	Code	Message
Jan 27 2016 09:44:04	5-Warning	Z00.0	MIMO Event MIMO: Stored MIMO=-1 post cfg file MIMO=-1;CM-MAC=[illegible];CMTS-MAC=[illegible];CM-QOS=1.1;CM-VER=3.0;
Jan 01 1970 00:00:15	6-Notice	N/A	Cable Modem Reboot due to power reset ;CM-MAC=[illegible];CMTS-MAC=[illegible];CM-QOS=1.1;CM-VER=3.0;

If we look at the log of our modem, shown above, we can see that everything is currently super smooth sailing. Don't be alarmed by the odd "Jan 01 1970" date–on most devices, the log function activates faster than the time-sync function, so the default hardware date is used during things like reboots.

The log clearly shows that roughly a day and a half ago, the modem was restarted do to a power reset (which we initiated by physically unplugging it), after which there is a MIMO Event (which looks scary because the priority code is "warning" but it's actually just our modem talking to the cable provider as part of a IP configuration/provisioning routine).

What you don't want to see in this log is a bunch of error codes that don't make sense. If you see power resets that weren't caused by you physically resetting the device, that's a problem. If you see a lot of timeout-related errors where the log indicated that the modem has lost connection (often called T3 and T4 errors), that's a problem. Ideally, your log should be boring and you should see very little activity other than the time it boots up, a rare error here or there (because no system is perfect and your modem will occasionally fail to connect), or a rare bit of downtime because your ISP pushed out new firmware.

If your log is packed full of errors and timeouts (and you're experiencing temporary or extended loss of Internet connectivity that correspond with the timestamps of these errors) you'll probably need to contact your internet service provider.

Signal Strength

Barring a defective modem (or issues with your router), the biggest source of broadband connectivity problems is out-of-spec signal strength. Notice that we didn't say "poor" signal strength. It isn't just a weak signal that can cause a problem, but overly strong signals, too. If a bad connection, splitters on the coaxial lines, or even old television amplifiers are dropping the signal below or pushing the signal above the operating range, then you may experience a connection problem.

Downstream	Bondi			
Channel ID	5	6	7	8
Frequency	627000000 Hz	633000000 Hz	639000000 Hz	64500(Hz
Signal to Noise Ratio	39 dB	39 dB	39 dB	39 dB
Downstream Modulation	QAM256	QAM256	QAM256	QAM2
Power Level The Downstream Power Level reading is a snapshot taken at the time this page was requested. Please Reload/Refresh this Page for a new reading	9 dBmV	8 dBmV	8 dBmV	9 dBm

Upstream	Bonding Channel Value
Channel ID	22
Frequency	31000000 Hz
Ranging Service ID	7736
Symbol Rate	5.120 Msym/sec
Power Level	39 dBmV
Upstream Modulation	[3] 16QAM [3] 64QAM
Ranging Status	Success

It's important that you consult with your individual service provider to see what the acceptable range of signal strengths are for your particular service and device. But as a general rule, consider the following values when debating whether or not your physical lines and the connection to the provider are a problem.

The “Downstream Power” reading should be between -15 dBmV to +15 dBmV and, ideally, should be closer to +8dBmV and -8dBmV. In the screenshot above you can see that the individual channels in our modem are all at 8 and 9 dBmV which is acceptable.

The “Upstream Power” reading should be between +37 dBmV to +55 dBmV and, ideally, should be closer to the middle of that potential range. In our screenshot here, the upstream signal squeaks by with a 39 reading (and we’re receiving the full speed we pay for without connectivity issues), but we’ll definitely be keeping an eye on it.

Finally you want to pay attention to your signal-to-noise ratio (SNR). You want this value to be greater than 30 dB. Lower than 25 dB causes signal and packet loss on most systems. The lower the value, the more problems there are with your signal. The higher the value, the less noisy the signal. Ranges from 32 to 55 dB are typical, and our rather-average 39 dB signal-to-noise ratio is more than acceptable.

How to Use this Diagnostic Information

As we noted earlier in this guide, there aren’t a lot of things within the modem that you, the user, can change. Most of the time you need to contact your provider and ask them to either remotely make adjustments or dispatch a tech to your home.

That said, checking your modem’s diagnostic system allows you to quickly save yourself a lot of hair-pulling by ruling out other sources of Internet connectivity issues. You’ll quickly see if your modem is to blame, or the problem lies somewhere else (like your router).

You’ll also be able to use the modem itself as a handy signal checker. If you, for example, have your cable modem plugged into a coax jack in your home office and you’re having connection problems, you could unplug the modem and plug it directly into the coax line coming into your home from the street. By rechecking the signal at the point of entry, you’ll be able to rule out any problems with the wiring in your home as the source of your Internet woes.

Finally (and perhaps most importantly), knowing how to use the diagnostic page makes you an informed consumer. You’ll no longer be at the mercy of a disgruntled tech support worker who says “yeah, everything looks fine on our end…have you tried turning it off and on again?” because you can read your own logs and signal strength to see if everything is, in fact, within acceptable operating levels.

Introduction

There are a number of issues that can affect the performance and speed of cable modems in a Data-over-Cable Service Interface Specifications (DOCSIS) system. This document seeks to address the major causes of slow throughput from the perspective of a cable service provider.

This document first looks at how to determine accurately what kinds of throughput levels an end user is achieving and how to make sure that the performance being measured is that of the cable network, rather than that of the broader Internet.

The next section looks at the most common potential reasons for slow performance and suggested resolutions. These issues include:

- Performance being restricted by the limits in the DOCSIS configuration file.
- Bursty or inconstant download performance caused by using a sub-optimal rate limiting scheme on the cable modem termination system (CMTS).
- Upstream and downstream channel congestion.
- Backhaul network or Internet congestion.
- Noise or errors on the cable plant.
- Under powered end user customer premises equipment (CPE).

Each of these individually or in combination can affect throughput and performance in a cable network.

This document does not discuss troubleshooting a complete loss of connectivity over the cable network or cable modems not coming online. Instead, refer to Troubleshooting uBR Cable Modems Not Coming Online for these kinds of problems.

Before You Begin

Prerequisites

There are no specific prerequisites for this document.

Components Used

The information in this document is based on the software and hardware versions below.

- Cisco IOS® Software Release 12.1(9)EC for the uBR7200 and uBR7100 CMTS.
- The Cisco uBR7100, uBR7200, and uBR7200VXR suite of CMTS products.
- The information in this document is relevant for all other currently available releases of DOCSIS 1.0-based Cisco IOS software for Cisco brand CMTS equipment.

The information presented in this document was created from devices in a specific lab environment. All of the devices used in this document started with a cleared (default) configuration. If you are working in a live network, ensure that you understand the potential impact of any command before using it.

Accurately Determining the Levels of Performance Being Achieved

Measuring the Correct Parts of the System

There are a number of ways to gauge the speed and performance of a system, however it is important to understand exactly what parts of the system are being tested. Consider the diagram below.

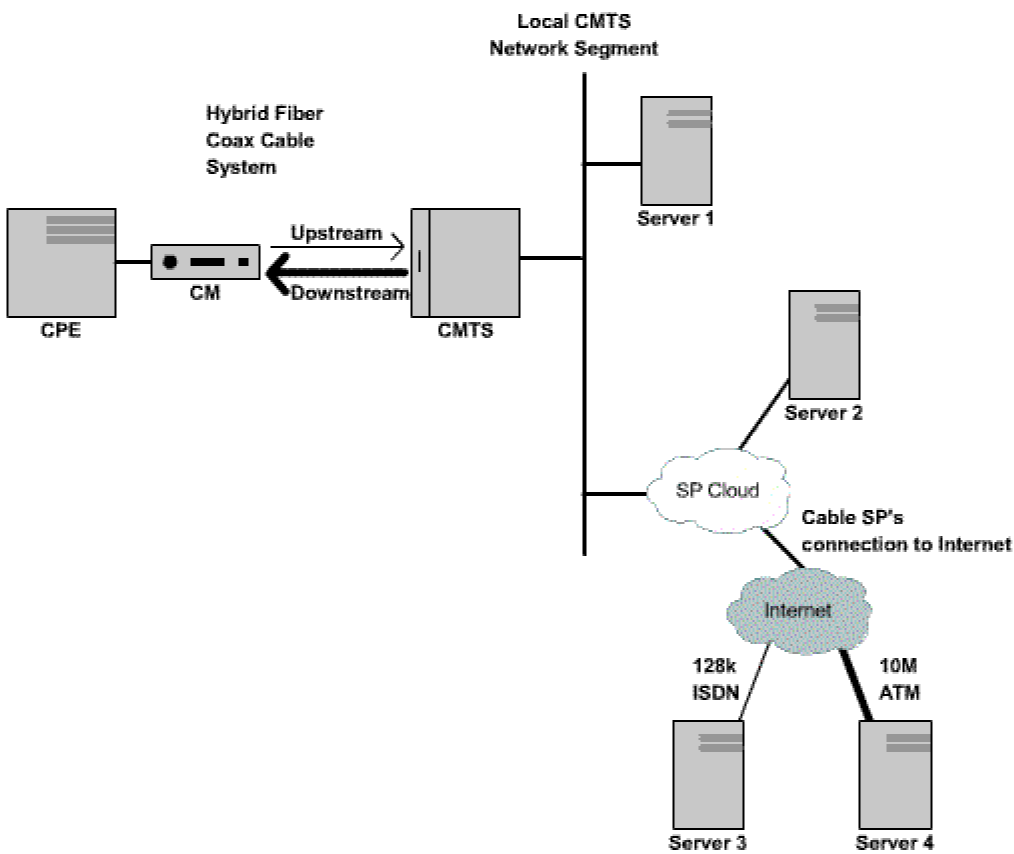


Figure 1 (To see this diagram in video format, click here.)

In this diagram there are a number of components:

- The Hybrid Fiber Coax network between the end user and the CMTS.
- The Local CMTS network segment where the CMTS connects to the cable service provider's network.

- The cable service provider's internal network.
- The public Internet.

When performing a speed test between two points, the speed of all the network components between the two points is being measured.

For example, if performing a speed test between the CPE and Server 3, which is connected to the Internet through a 128 Kbps ISDN line, there never will be speeds of greater than 128 Kbps, even if the available bandwidth on the cable segment is greater then 128 Kbps.

The most accurate way to measure the performance of the cable segment itself is to perform a speed test between the CPE and Server 1, which is connected to the same network segment as the CMTS. This is because the only path data needs to travel over is the coaxial cable segment. The data also must travel across the local CMTS network segment, but it is presumed this segment is of a high bandwidth (FastEthernet or greater) and does not have a high level of congestion.

If for some reason, no server can be connected to the local CMTS network segment, then the next most accurate way to test the performance of the cable segment is to perform a speed test between the CPE and Server 2. This is an accurate measurement as long as there are adequately high speed and uncongested links within the cable service provider's internal network between the CMTS and the CPE.

The most inaccurate way to determine the performance of the cable segment is to perform a speed test between the CPE and a server on the public Internet. This is because there may be congested links in the public Internet between the CPE and the server, or there may be very low speed links in the path between the CPE and the server on the Internet.

It is very important to be able to get an objective measurement of exactly what levels of upload and download throughput are being achieved before any conclusions can be made about whether a performance problem exists in a DOCSIS system.

The easiest way to determine the speed at which uploads and downloads are occurring is to upload or download a large file using FTP or HTTP between a CPE device connected to a cable modem, and a server behind the CMTS. Most FTP and HTTP clients are able to display the speed at which a download or an upload is occurring either during the transfer or once the transfer is complete. The transfer speed seen as a result of the FTP or HTTP operation is typically about 90 percent of the true total throughput attained. This is because the displayed FTP or HTTP transfer speed does not take into account extra IP and DOCSIS overhead that needs to travel between the CPE device and the CMTS.

There are more accurate methods of measuring throughput, for example by using third-party dedicated testing equipment, such as a Netcom Smartbits or a IXIA packet generator, however these systems are not always readily available or easily connected to a production cable network. It is worth noting that if throughput tests are being carried out in a lab environment, then using a dedicated device will reveal much more information than the simple FTP or HTTP download test.

Note: The FTP- or HTTP-based upload and download test is only reliable for testing speeds of around 3 Mbps or less. At higher speeds the processing power of the CPE device, server or Network Interface Cards (NIC) may become a limiting factor in the test. For testing speeds higher than about 3 Mbps, dedicated data throughput testing equipment should be used.

In the following example, a simple FTP download and upload test is performed between a CPE device connected to a cable modem, and an FTP server on the cable service provider's network. The cable modem has downloaded a DOCSIS configuration file that allows a download speed of up to 256 Kbps and an upload speed of up to 64 Kbps. In this test, a 3 Mb file has been placed on the FTP server at IP address 172.17.110.132. The user of the CPE device is given a username and password in order to be able to log into the FTP server so they can download this file from the FTP server, and then upload it back to the FTP server. The command line FTP utility is used to perform the transfer. This utility is available in virtually all versions of Microsoft Windows and UNIX.

A similar test is conducted by having an HTTP web server set up in the service provider's network and performing an HTTP download.

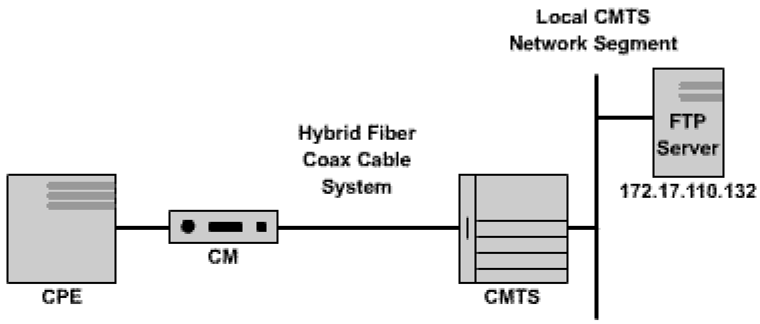


Figure 2

Potential Reasons for Poor Performance

Performance Restricted by DOCSIS Configuration File

The first piece of information that needs to be gathered when troubleshooting slow cable modem performance is the prescribed class of service throughput limitations of the cable modem. When a cable modem comes online, it downloads a DOCSIS configuration file that contains operational limits for the cable modem, including the maximum upload and download rates. Under normal circumstances, the cable modem is not allowed to exceed these rates.

Initially it is necessary to identify the MAC address of a cable modem having problems. Taking a modem with MAC address **0050.7366.2223** that is having problems with slow throughput,. it is necessary to find out what class of service profile this cable modem is using by executing the **show cable modem <mac-address>** command as seen in the example below.

Here it shows this cable modem has a Quality of Service (QoS) profile of 5. In order to find out what downstream and upstream rates this QoS profile corresponds to, use the **show cable qos profile *profile-number*** command, where ***profile-number*** is the QoS profile of interest.

Here it shows that QoS profile 5 corresponds to a service providing 256 Kbps in the downstream and 64 Kbps is the upstream. Any CPE connected to cable modems using QoS profile 5 are not able to exceed these limits. The QoS profile settings are determined by the contents of the DOCSIS configuration files downloaded by cable modems from the provisioning system's TFTP server, therefore QoS profile 5 in the system may not be the same as QoS profile 5 in the example shown above.

If an end user's download and upload performance correlate with the limits shown in their QoS profile, then they are getting the class of service and throughput levels for which the cable modem has been provisioned and configured. The only way to increase the upload and download throughput is to change the DOCSIS configuration file being downloaded by the cable modem to one that has higher throughput limits.

Using a Sub-optimal Method for Rate Limiting

When an end user is trying to download data from the Internet at a rate greater than their cable modem's DOCSIS configuration file allows, the CMTS must rate limit the traffic being sent to that user to ensure that the user does not consume more than their allowed share of bandwidth.

Similarly, when an end user tries to upload or send data to the Internet at a rate greater than what the DOCSIS configuration file allows, the cable modem itself should stop the excess traffic from traveling over the cable segment to the CMTS. If the cable modem, for some reason, fails to perform upstream rate limiting properly, then the CMTS explicitly forbids the cable modem from transmitting higher than the allowed rate. This behavior on the CMTS is to ensure that even a cable modem with "hacked" characteristics is unable to subvert the service provider assigned upload rate limits.

The default rate-limiting scheme used by the CMTS monitors the rate of traffic to or from each cable modem over every one-second period. If the cable modem sends or receives more than its per second quota in less than a second, then the CMTS does not allow any more traffic to flow to that cable modem for the rest of the second.

As an example, take a cable modem with a QoS profile allowing a download rate of 512 Kbps. If the cable modem downloads 512 kilobits (64 kilobytes) within the first half of a second, then for the next half of the second, the cable modem is not allowed to download anything. This type of rate limiting behavior may have the effect of a bursty download pattern that seems to stop and start every second or two.

The best downstream rate-limiting scheme to use is the **token bucket** rate-limiting algorithm with **traffic shaping**. This rate-limiting scheme has been optimized to allow for a smooth web browsing experience at a steady rate, while at the same time ensuring that end users are not allowed to exceed the prescribed download rate as specified in the DOCSIS configuration file.

The way this scheme works is to measure the rate at which a cable modem is downloading or uploading data each time a packet is sent to or from the cable modem. If sending or receiving the packet in question causes the modem to exceed its allowed transfer rates, then the packet is buffered or cached in CMTS memory until the CMTS can send the packet without exceeding the downstream bandwidth limit.

Note: If the downstream traffic rate consistently exceeds the allowed downstream rate for the cable modem, then packets are eventually dropped.

By using this smoother method of rate limiting and shaping, most TCP-based Internet applications such as HTTP web browsing and FTP file transfers operate more smoothly and efficiently than when using the default rate-limiting scheme.

The token-bucket with traffic shaping scheme also can be applied to upstream ports, but since it is the responsibility of the cable modems to perform upstream rate limiting, the upstream rate-limiting scheme applied to the CMTS normally will not have any impact on the performance of a system.

Users can view how severely the CMTS is rate limiting traffic to a particular cable modem by using the **show interface cable X/Y sid <Z> counters** command, where cable X/Y is the cable interface to which the cable modem is connected, and Z is the SID number of the modem being observed. This command shows the number of times the CMTS has dropped a downstream packet or refused to allow an upstream packet due to the modem exceeding its allowed throughput limits. If no value is specified for Z, then counter information for all cable modems connected to interface cable X/Y are displayed.

The **Ratelimit DSPktDrop** field shows how many times the CMTS has dropped packets destined for the cable modem due to the modem trying to exceed its allowed downstream throughput.

The **Ratelimit BWReqDrop** field shows how many times the CMTS has refused to let a cable modem send a packet in the upstream path due to the modem trying to exceed its allowed upstream throughput. In most circumstances this counter always should remain at 0. If it rises significantly above zero, it may be that the cable modem being observed is not performing upstream rate limiting properly.

Upstream Channel Congestion

The upstream channel is normally the most precious resource in a cable system. Currently, most cable service providers use a 1.6 MHz channel width and Quadrature Phase Shift Keying (QPSK) modulation in the upstream path. This equates to approximately 2.5 Mbps in total available upstream bandwidth for all users connected to the one upstream channel. It is important to ensure that the upstream channel does not become over used or congested, otherwise all users on that upstream segment suffer poor performance.

The upstream usage for a particular upstream port can be obtained by executing the CMTS command **show interface cable X/Y upstream <Z>**, where *cable X/Y* is the downstream interface number and *Z* is the upstream port number. If Z is omitted, information for all upstreams on interface cable X/Y will be displayed.

If upstream channel usage is consistently above 75 percent during the peak usage time, end users begin to suffer issues such as latency, slower "ping" times, and a generally slower Internet experience. If upstream channel usage is constantly above 90 percent during the peak usage time, end users experience an extremely poor level of service because a large portion of the end user's upstream data will have to be delayed or discarded.

Upstream channel usage changes during the day as different users have an opportunity to use their cable modem, so it is important to monitor the upstream usage during the busiest times of the day rather than at low usage times.

Ways of relieving upstream congestion include:

- **Reducing the number of cable modems per upstream** – If there are too many cable modems connected to a particular upstream, or if users on a particular upstream are heavy users of upstream bandwidth, the best solution is to move some users on the congested upstream port to an under used upstream port, or to a completely new upstream port. This is typically accomplished by moving a fiber node from one upstream combining group to another, or splitting an upstream combining group into two separate combining groups. For more information, refer to What is the Maximum Number of Users per CMTS.

- **Increasing the upstream channel width** – This involves a **rigorous and thorough** analysis of the upstream spectrum to find a wide enough band with adequate Signal-to-Noise Ratio (SNR) characteristics to support the increased channel width. The upstream channel width should not be changed without careful planning because this change potentially can affect other services in the user's cable system.
- **Changing the upstream digital modulation scheme to 16-Quadrature Amplitude Modulation (QAM)** – Once again, this requires a **rigorous and thorough** analysis of the upstream spectrum in order to verify whether there is a frequency band in the upstream available that can support 16-QAM modulation. If this analysis is not performed properly, there is a risk that performance is further decreased or a complete upstream outage may occur. The upstream modulation scheme may be changed by creating an upstream modulation profile that uses 16-QAM modulation and then applying that to an upstream port.
- **Reducing the allowed upstream throughput per cable modem** – By reducing the maximum upstream transmit rate in the appropriate DOCSIS configuration files, cable modem users are not able to transmit at as high a rate in the upstream direction and upstream congestion is relieved. The negative aspect of this course of action is that cable modem users are limited to a slower class of service.
- **Note:** The measures discussed in this section do not significantly increase the performance of an already uncongested system.

Downstream Channel Congestion

The downstream channel has significantly more bandwidth to share than an individual upstream channel, therefore the downstream is not usually as subject to congestion as the upstream. Still, more users typically share a downstream channel than any single upstream channel, so if the downstream channel becomes congested, all users connected to the downstream segment experience reduced performance.

The following table shows the total available downstream bandwidth associated with the four possible downstream modulation schemes available in DOCSIS systems.

Downstream Modulation Scheme	Available Downstream Bandwidth
64-QAM North American DOCSIS	27 Mbps
256-QAM North American DOCSIS	38 Mbps
64-QAM Euro DOCSIS	38 Mbps
256-QAM Euro DOCSIS	54 Mbps

The majority of DOCSIS cable systems currently deploy 64-QAM North American DOCSIS and therefore have 27 Mbps available per downstream channel.

Downstream channel usage can be determined by issuing the **show interface cable X/Y** command, where *cable X/Y* is the cable interface being observed. The displayed output rate in bits per second should be compared to the available downstream bandwidth as seen in the table above.

The first component of this output to note is the bandwidth of the interface indicated by the **BW** parameter. In Cisco IOS Software Releases 12.1(8)EC and later, this value is adjusted automatically according to the downstream modulation scheme and version of DOCSIS being used. In revisions earlier than Cisco IOS Software Release 12.1(8)EC, this value must be configured manually using the cable interface command **bandwidth <bandwidth-in-kilo-bits-per-second>** or otherwise it remains at the default value of 27000 Kbps.

The second component to note is the transmission load as indicated by the **txload** parameter. This parameter gives a metric out of 255 where 0/255 means that no traffic is flowing in the downstream direction to 255/255, which means data is traveling in the downstream at the maximum possible rate (in this case at 27000 Kbps). If this parameter is running consistently at greater than approximately 75 percent during the peak usage time (for example, greater than 191/255), end users start to experience slower Internet access and higher latency.

The third component to note is the **output rate**, which shows the average downstream throughput rate in bits per second. If this number consistently exceeds approximately 75 percent of the available downstream bandwidth during the peak usage time, end users start to experience slower Internet access and higher latency.

By default, these statistics are calculated over a five-minute moving average. (Refer to Understanding the Definition of bits per second (bits/sec) from the show interfaces Command Output for details of how the average is calculated.) The period over which this average is calculated can be reduced to as little as 30 seconds by issuing the **cable interface** command **load-interval 30**. By lowering this period to 30 seconds, a more accurate an up-to-date value is calculated for each of the parameters discussed in this section.

Downstream channel usage changes during the day as different users have an opportunity to use their cable modem, so it is important to monitor downstream usage during the busiest times of the day rather than at low usage times.

Ways of relieving downstream congestion include:

- **Reducing the number of cable modems per downstream** – If there are too many cable modems connected to a particular downstream, or if users on a particular downstream are heavy users of downstream bandwidth, then the best solution is to move some users on the congested downstream channel to another downstream channel. This typically is accomplished by splitting a group of downstream fiber nodes associated with the downstream into two separate groups and assigning each of the new groups separate downstream channels. Refer to What is the Maximum Number of Users per CMTS.
- **Changing the downstream digital modulation scheme to 256-QAM** – This action requires a **rigorous and thorough** analysis of the downstream spectrum in order to verify whether the system can support a 256-QAM

signal. If this analysis is not performed properly, there is a risk that performance will be further decreased or a complete downstream outage may occur. The downstream modulation scheme may be changed by issuing the cable interface command as seen below.

- **Reducing the allowed downstream throughput per cable modem** – By reducing the maximum downstream transmit rate in the appropriate DOCSIS configuration files, cable modem users are not able to download at as high a rate in the downstream direction and downstream congestion is relieved. The negative aspect of this course of action is that cable modem users are limited to a slower class of service. Refer to Building DOCSIS 1.0 Configuration Files Using Cisco DOCSIS Configurator.

  Note: The measures discussed in this section do not significantly increase the performance of an already uncongested system.

Backhaul Network or Internet Congestion

In some cases, performance problems may not be a result of issues on the cable plant or the CMTS, but may be related to congestion or problems in the backhaul network that the CMTS uses to connect to the Internet, or within parts of the Internet itself.

The easiest way to determine if backhaul network congestion is a problem is to connect a workstation to the same network segment as the CMTS and try to browse the same websites as end users behind cable modems are trying to reach. If performance is still slow, there is a performance problem in the network not related to the CMTS or the cable segment. If performance from the local CMTS network segment is significantly better than for users connected to cable modems, then focus efforts back on the CMTS and the cable segment.

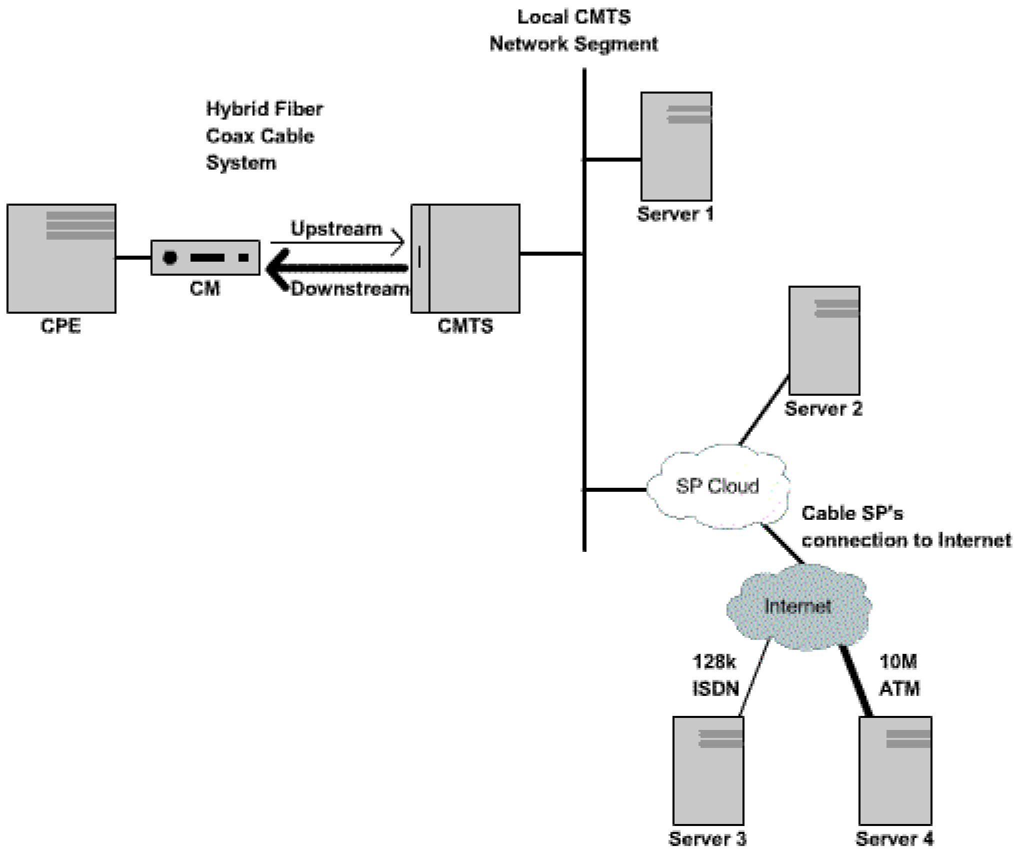


Figure 3

In the above network, if Server 1, which is connected to the same network segment as the CMTS, is getting slow performance when browsing the Internet, then the source of the problem is not the CMTS. Instead, the bottleneck or performance issue somewhere else. In order to determine where the problem is, performance tests are carried out between Server 1 and various other servers within the Internet Service Provider (ISP) network and the public Internet.

Noise and Errors on the Cable Plant

If there is an excessive amount of noise or ingress in a cable system, then packets between cable modems and the CMTS can be corrupted and lost. This can lead to a significant degradation in performance.

Aside from a degradation in performance and throughput, some of the prime indicators of noise or radio frequency (RF) issues include:

- Cable modems sporadically dropping offline or getting stuck in the init(r1) or init(r2) states.
- A low estimated SNR as seen in the output of a **show controller cable X/Y upstream Z**, where *cable X/Y* is the cable interface being observed and Z is the upstream port being observed. The DOCSIS specification requires a Carrier-to-Noise Ratio (CNR) of at least 25 dB for all upstream signals. This equates to an SNR of approximately 29 dB. The Cisco CMTS is able to detect coherently QPSK upstream signals at much worse SNR levels, however all cable service providers should strive to meet the DOCSIS CNR requirements in their system.
- In the example above, the estimated SNR reading is 28.628dB. This is adequate for QPSK upstream operation. Note that the SNR figure given in the output of this command is only an estimate and is no substitute for an SNR figure derived from a spectrum analyzer or other appropriate testing equipment. See the Cisco Broadband Cable Command Reference Guide for more information about the **show controllers cable upstream spectrum** command.
- A quickly incrementing number of **Corr Forward Error Correction (FEC)** and **Uncorr FEC** errors in the output of a **show cable hop** command. **Corr FEC** errors indicates data that was corrupted by upstream noise but was able to be recovered. **Uncorr FEC** errors indicate data that was corrupted by upstream noise and was not able to be recovered resulting in lost data and slower performance. In the example above, each active upstream port on cable 3/0 seems to have experienced packet loss due to noise. Upstream port 0 seems to be the least affected and upstream port 2 seems to be the most heavily affected. The important factor to note is how quickly the FEC Errors are incrementing rather than the total number of errors. See the Cisco Broadband Cable Command Reference Guide for more information about the **show cable hop** command.
- A high number of "flap" events in the output of a **show cable flap-list** command. The flap statistics most pertinent to possible RF or noise problems are the **Miss** column, which indicates missed ranging requests, and the **P-Adj** column, which indicates rapidly varying upstream power levels.

- Cable modems displaying a "* "or a "!---" in the output of a **show cable modem** or **show cable flap-list** command. A "*" indicates a cable modem that is rapidly varying its upstream power levels. This is indicative of a poor connection to the cable plant, a faulty reverse path amplifier, or rapidly changing cable plant attenuation due to temperature or other environmental effects. A "!---" indicates a cable modem that has reached its maximum upstream power level. This is indicative of too much attenuation between the cable modem and the CMTS, or a poor connection between the cable modem and the cable plant. In the example above, the cable modem with MAC address 005a.73f6.2213 is transmitting at its maximum output power. This results in that modem not being able to transmit at the correct level. Consequently, this modem's upstream transmissions are not heard as clearly as transmissions from other modems. The cable modem with MAC address 009c.96d7.3831 has a rapidly varying power output due to varying cable system attenuation. See the Cisco Broadband Cable Command Reference Guide for more information about the **show cable modem** and **show cable flap-list** commands.

High CPU Usage on the CMTS

In some circumstances a Cisco CMTS can become overloaded due to a sub-optimal configuration, over use of certain management functions, or a very high number of packets being routed by the CMTS.

The best way to determine the CPU usage of a Cisco CMTS is to execute the **show process cpu** command. The current CPU usage is indicated on the first line of the output of the command.

In the lines of output shown below the first line, each process running on the CMTS is shown along with the portion of the CPU being used by that process. This section of the **show process cpu** output is useful for determining if one particular process or function is the cause of high CMTS CPU.

In the example above, the current CPU load on the CMTS is 45 percent/21 percent. This means that the total CPU usage is at 45 percent of the capacity of the system. In addition 21 percent of the CPU is being used to service interrupts. This second figure typically equates to the portion of the CPU being used to route packets and switch traffic through the CMTS.

If the five minutes CPU usage consistently is more than 80 percent during the peak usage time in the system, then end users may start to experience slower performance and increased latency. If the five minutes CPU usage is constantly more than 95 percent during the peak usage time, then take urgent action to ensure that the CMTS remains in a stable state.

Common strategies for reducing high CPU usage on the CMTS include:

- Upgrading to Cisco IOS Software Release 12.1(9)EC or later, activating the global configuration command **ip cef**, and making sure no interfaces on the CMTS have the command **no ip route-cache** configured. This typically leads to a 10 percent to 15 percent reduction in traffic-related CPU usage. Make sure that all of these steps are taken in conjunction.
- Making sure that Simple Network Management Protocol (SNMP) management stations are not being too aggressive in polling the CMTS. This leads to a high CPU usage in the IP SNMP process.
- Not running the **show tech** command several times in succession. This leads to an artificially high CPU usage in the Virtual Exec Process.
- Making sure that no **debug** commands are running on the CMTS.

For more information about High CPU usage on Cisco routers, including Cisco CMTS products, refer to Troubleshooting High CPU Utilization on Cisco Routers.

Under Powered or Malconfigured CPE Equipment

In many cases, the cause of slow access to a cable network is a problem in the end user's CPE equipment. If only one or a handful of users are experiencing slow throughput, and the rest of the user population are experiencing no problem, then this is a strong indication that there may be a unique problem within that user's environment.

- **Under powered or overloaded CPE**—If the end users complaining of difficulties are using antiquated CPE equipment, or equipment that may not be powerful enough to run their chosen operating system or Internet access software, then this end user will have difficulties. The only resolution if this is the case is for the end user to upgrade their CPE equipment.
- **Firewall or performance measurement software**—If the end user is running any firewall, network performance measurement, or other similar software, a good troubleshooting step is to have the user turn off this

software to see if it has any effect on performance. Often, these kinds of software can have a negative impact on performance.
- **Misconfigured TCP/IP settings**—Most service providers require that end users have their CPE equipment acquire an IP address, network mask, default gateway, and DNS servers by way of Dynamic Host Configuration Protocol (DHCP). Ensure that any end users experiencing problems have their CPE devices configured to use DHCP to acquire all of these parameters.

If an end user claims to have none of the problems listed above, then confirm that the end user is not exceeding their maximum download or upload rate as per the sections above.

Conclusion

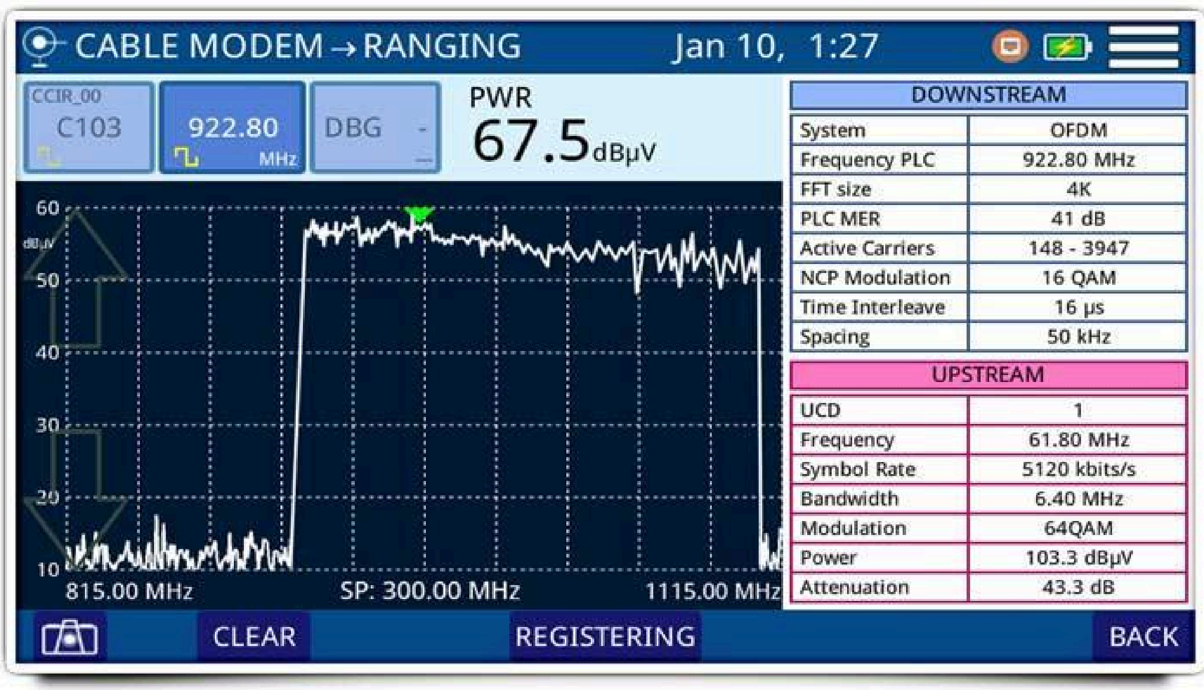
A DOCSIS cable network is a sophisticated system requiring proper planning and maintenance. Most performance issues in DOCSIS cable systems are a direct result of proper planning and maintenance not being performed. In today's Internet access market, where there are a variety of broadband Internet access alternatives, it is important that cable service providers quickly address any performance or congestion issues in their system before the problems become significant enough for end users to be affected noticeably, and, consequently, consider an alternative means of broadband access.

Related Information

- **Troubleshooting uBR Cable Modems Not Coming Online**
- **Determining RF or Configuration Issues On the CMTS**
- **Connecting the Cisco uBR7200 Series Router to the Cable Headend**
- **Troubleshooting High CPU Utilization on Cisco Routers**
- **Technical Support & Documentation - Cisco Systems**

How the cable modem “initializes” or “registers” with CMTS

In the first stage of CM initialization, topology resolution and physical layer initialization, the CM acquires a single downstream channel (either via a stored last-known-good channel, or by scanning the downstream channel map) and receives broadcast information from the CMTS that provides it with enough information to identify what set of downstream channels are available to it, as well as what upstream channels might be available.



The CM then attempts to initialize the upstream physical layer by "ranging" on a selected upstream channel. Via a series of attempts and alternative channel selections, the CM succeeds in contacting the CMTS and completing the ranging process.

At this point, the CMTS has located the CM in the plant topology (i.e., is aware of what downstream channels and upstream channels physically reach the CM) and has established two-way communication via a single downstream/upstream channel pair.

While this section has referred to the first stage in terms of physical layer initialization, a provisional MAC layer initialization has been performed, with the full initialization of the MAC layer being deferred to the final stage.

The second stage, authentication and encryption initialization, involves the CM sending its **X.509 digital certificate** (including the CM's RSA public key) to the CMTS for validation.

- If the CM has sent a valid certificate, the CMTS will respond with a message that triggers the exchange of AES (or DES) encryption keys that are used to encrypt the upstream and downstream data transmissions from this point forward.
- This "Early Authentication and Encryption" can be disabled. If so, the CM will attempt authentication and encryption initialization after the registration stage.
- The details of the authentication and encryption initialization process are provided in [DOCSIS SECv4.0].

In the third stage, IP initialization, the CM acquires an IP address in the cable operator address space, as well as the current time-of-day, and a binary configuration file.

DOCSIS 3.0 defines use of IP version 4 and IP version 6 and four provisioning modes: IPv4 Only, IPv6 Only, Alternate, and Dual-stack. For IPv4 Only provisioning, the CM uses DHCPv4 to acquire an IPv4 address and operational related parameters. To facilitate compatibility with existing provisioning systems, this process is identical to the DOCSIS 2.0 CM provisioning process.

For IPv6 Only provisioning, the CM uses DHCPv6 to acquire an IPv6 address and operational parameters. The CM uses the IPv6 address to obtain the current time-of-day and a configuration file. For Alternate Provisioning Mode (APM) the CM combines the first two provisioning modes, IPv6 Only and IPv4 Only, in sequential order, attempting IPv6 provisioning first and, if this fails, attempting IPv4 provisioning next. In the first three provisioning modes, IPv6 Only, IPv4 Only, and APM, the CM operates with only one IP address type (v4 or v6) at any given time, and thus these modes are called single-stack modes. For Dual-stack Provisioning Mode (DPM), the CM acquires both IPv6 and IPv4 addresses and parameters through DHCPv6 and DHCPv4 almost simultaneously, prioritizing the use of the IPv6 address for time-of-day and configuration file acquisition. In this mode, the CM makes both the IPv4 and the IPv6 addresses available for management.

The fourth stage, registration, involves **a three-way handshake** between the CM and the CMTS in which the CM passes certain **contents of the configuration file** to the CMTS, the CMTS validates the contents, reserves or activates MAC layer resources based on the service provisioning information that it received, and communicates MAC layer identifiers back to the CM.

Once the CM acknowledges receipt of the CMTS's response, the MAC layer initialization is complete.

After the CM completes initialization, it is a manageable network element in the operator's IP network.

- The CM supports SNMP (as mentioned above) and responds to queries directed to the IP (v4 or v6) address that it acquired during initialization.
- DOCSIS 3.1/4.0 also supports a dual-stack operational mode in which the CM is manageable via both IPv4 and IPv6 addresses simultaneously.
- This mode is initialized (i.e., the CM acquires a second IP address) after the CM is operational. This feature is also intended to help provide a streamlined migration from IPv4 to IPv6 in DOCSIS networks.

Understanding Coaxial Cables - The Complete Guide

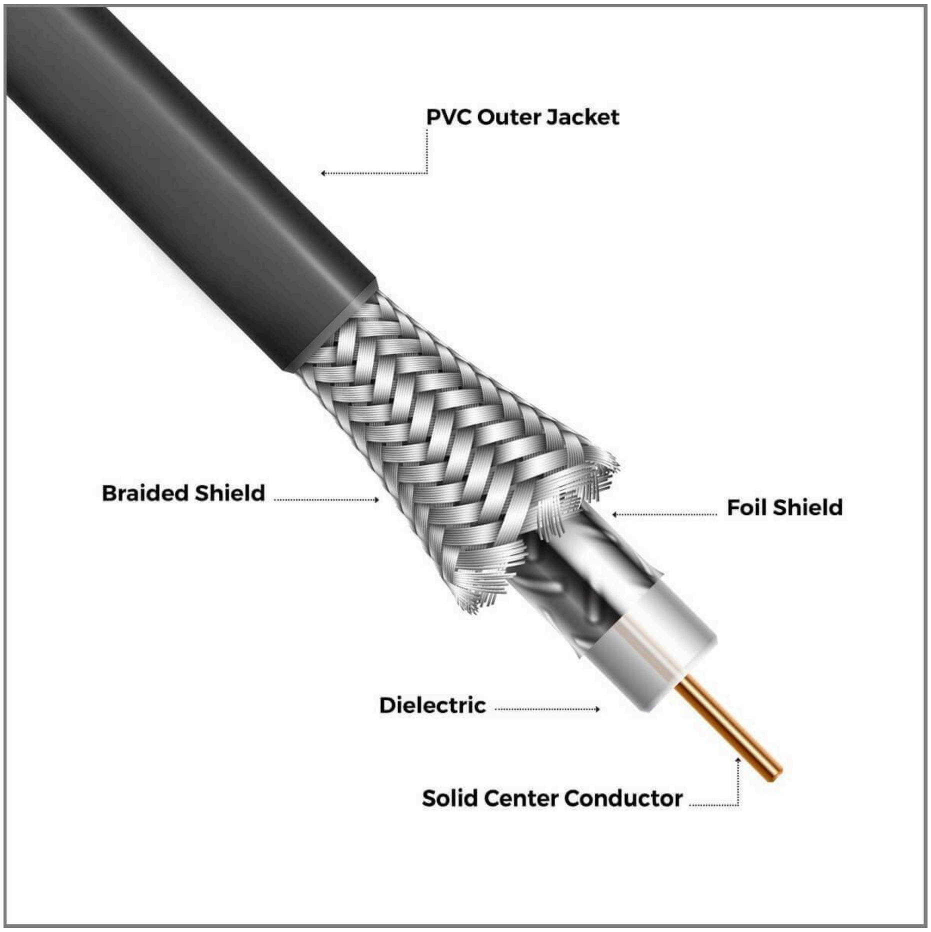
Written by **Wilson Amplifiers**
31st Jan 2023

What is Coaxial Cable?

Coaxial cables are electrical transmission lines used to pass high radio frequency (RF) signals from one point to another with low signal loss.

They have many applications, including phone lines, cable TV, internet, cell boosters, and more. Coax cables come in many sizes and lengths, each designed for specific uses.

What Does A Coaxial Cable Look Like?



Before we get into how coax cables work, you need to know how they're constructed.

As you can see from the above image, there are four main parts to a coax cable:

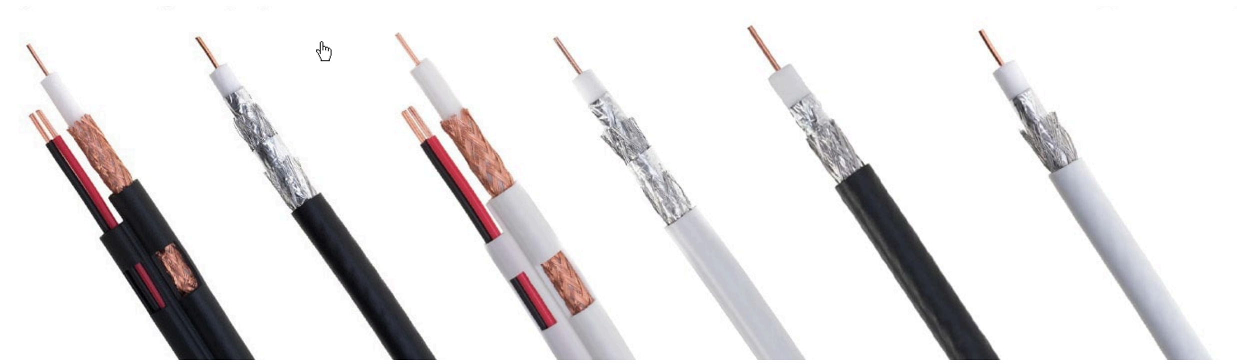
1. Center Conductor/Core
2. Dielectric Insulator
3. Shield(s)
4. Jacket (Rubber Wrapper)

At the **core**, coaxial cables consist of a single copper or copper-coated steel wire. It's what carries the RF signals. A **dielectric insulator**, often made of plastic, surrounds the wire. It keeps a constant distance between the center conductor and the next layer.

The **metal shield**, made of woven copper, aluminum, or other metals, wraps around the insulator. It cancels outside electromagnetic interference. Some coaxial cables are constructed with multiple shields for extra protection. The final layer is a **jacket** that protects the whole configuration. Its rating (more on this later) lets you know where the cable can be installed.

Outdoor-rated cables need extra insulation and special jackets to protect the wires from sun and moisture.

How Do Coaxial Cables Work?



Coaxial cables transmit signals through the center wire. To ensure a quality signal travels the length of the cable a metal shield is needed. Both components receive a current simultaneously, generating a magnetic field. This allows the signal to remain intact and not bleed out like it would without the shield.

The metal shield also helps protect the signal from electromagnetic interference. Thus, coax can be placed near other electronic equipment without any issues.

For optimal performance, the distance between the core and shield must be consistent throughout. The dielectric insulator makes that happen. It also prevents the two signals from coming in contact and canceling each other.

All components are further insulated and protected from damage by the outer jacket.

As a result, RF signals can be carried over long distances with little interference or loss. Depending on your application, the signal is then converted into images, audio, WiFi, or amplified cell reception.

Top Featured Manufacturers and Suppliers of Coaxial Cables

Company	Location	Year Founded	No. of Employees
Dacon Systems, Inc.	Corona, CA	1973	10-49
New England Wire Technologies Corp.	Lisbon, NH	1898	200-499
ABA Industry, Inc.	Carson, CA	1996	10-49
Micro-Tek Corp.	Cinnaminson, NJ	1965	10-49
AIR802	Aurora, IL	2005	10-49
ICB Electronics, Inc.	Scottsboro, AL	2001	1-9
American Wire Group	Miami, FL	2001	1-9
TTI Inc.	Fort Worth, TX	1971	1000+
Connectronics Corp.	Toledo, OH	1988	50-99
Precision Mfg. Co., Inc.	Dayton, OH	1967	

What are the Uses and Applications of Coaxial Cables

Coaxial cable is used by cable operators, telephone companies, and internet providers. They're necessary for applications requiring radio frequency transmissions, such as:

Cable TV

If you have cable television, coaxial cable is used to carry video and data from the cable company to your TV. They're also used to connect your television or digital converter box to a personal antenna.

Signal Boosters

Wilson Amplifiers is the leading provider of cell phone boosters. These devices use an outdoor antenna, an amplifier, and an indoor antenna. Coaxial cables are used to connect the three components. It also bypasses signal blocking material. We have a full guide on how a signal booster works for more information.

With this technology, you can boost your weak outside cell signal and enjoy stronger signal inside your home, office, or vehicle.

Cable Internet (Copper-Based)

Cable internet uses coax cable to provide your home with internet. The copper-based cable is piped into your house from the cable service provider. Your router or cable modem connects to a coax or ethernet outlet to receive the signal. You can then wire your devices to the router or connect via WiFi for speedy internet access.

Ham Radio

Ham radio is a means for people to communicate over airwaves. Coaxial cable connected to the antenna provides a stronger signal. Ham radios can be set up in the middle of nowhere and do not require internet or cell phone technology.

Basic RF Systems

RF (Radio Frequency) waves are generated when an alternating current goes through a conductive material. Coax cables carry radio frequency signals. They can be used with any RF system.

Are All Coax Cables the Same?

While all coaxial cables are used to transmit signals, they are not all the same. Coaxial cables vary in size, material, and shielding. Each type of coax cable works best with specific applications.

Coaxal Cable Types

There are many different types of cables to choose from. They fall within two categories, RG and LMR type. Your application will determine which one has the best characteristics. Here are the most common coax cable types:

Coaxial cable, often referred to as coax, is a type of transmission line used to carry high-frequency electrical signals with low losses. It is used extensively in computer networks, cable TV systems, and various types of radio frequency communication.

Here's a detailed explanation of how it works:

1. **Structure of Coaxial Cable**: Coaxial cable is made up of several layers. At the center is a conductor, often copper or a copper alloy, which carries the actual signal. This central conductor is surrounded by an insulating layer made from a material such as polyethylene. The insulator is then covered by a metal shield, often made of braided aluminum or copper, which is used to protect the central conductor from electromagnetic interference. Lastly, the entire cable is enclosed in an outer insulating layer that provides physical protection.
2. **Transmission of Signals**: The signals carried by coaxial cables are electromagnetic waves. These waves propagate along the cable by reflecting off the cable's internal walls. The central conductor carries the signal, and the surrounding metal shield provides a return path, creating an enclosed circuit. The insulating layer between these two components ensures the signal stays within this path and doesn't escape or get interfered with.
3. **Signal Quality and Interference**: Coaxial cables are well suited for carrying high-frequency signals, which are more susceptible to noise and signal loss. The shield prevents outside electromagnetic signals from interfering with the signal being carried in the central conductor. It also prevents the signal within the cable from radiating outwards. This construction helps maintain the quality of the signal over long distances.

4. **Impedance Matching**: For optimal signal transmission, the cable's characteristic impedance should match the source and load impedance. This prevents signal reflection, which can cause interference and loss of signal. For many applications, coax cables are designed with a characteristic impedance of 50 ohms or 75 ohms.
5. **Bandwidth and Data Rate**: Coaxial cables can carry a substantial amount of data due to their ability to support a wide range of frequencies. They have a higher bandwidth than other types of transmission lines like twisted pair cables, which makes them suitable for applications that require high data rates.

RG Coax Cables

RG, short for Radio Guide, is the original military specification for coaxial cables. The RG number refers to the cable's diameter. However, measurements do vary. Generally, a higher RG numbers means a thinner central conductor, and vice versa.

RG-6/U
Impedance: **75 Ohm**
Core size: **1.024 mm**
Dielectric Type: **PF**
Nominal Attenuation per MHz (dB/100 ft):**850/8.5dB; 1900/13.6dB**

RG-6/U is a common type of coaxial cable. It has an impedance of 75 Ohm. It's used in a wide variety of residential and commercial applications, including cable television, home internet, and more.

RG-8
Impedance: **50 Ohm**
Core size: **2.17 mm**

Dielectric Type: **PF**
Nominal Attenuation per MHz (dB/100 ft): **850/6.4dB; 1900/10.4dB**

RG-8 is similar to RG-6, but unable to carry pure video signals. It has an impedance of 50 Ohm. It's used in audio control rooms, radio stations, and external radio antennas.

RG-11
Impedance: **75 Ohm**
Core size: **1.67 mm**
Dielectric Type: **PF**
Nominal Attenuation per MHz (dB/100 ft):**850/6.25dB**

RG-11 is a higher gauge cable used for CATV, HDTV, TV antennas, and video distribution. It has an impedance of 75 Ohm and covers up to 3 GHz.

RG-59
Impedance: **75 Ohm**
Core size: **0.64 mm**
Dielectric Type: **PF**
Nominal Attenuation per MHz (dB/100 ft):**N/A**

RG-59 is a 75 Ohm coax cable best used for CCTV, audio video, and other low-frequency applications. They are flexible and easy to install. Though, they are not meant for long runs.

LMR® Coax Cable

LMR® is the newer generation of RF coaxial cables. They provide greater flexibility, ease of installation, and lower cost. They're used as transmission lines for antennas on missiles, airplanes, satellites, and communications. The LMR ® number is a rough estimate of the cables thicknes.

LMR®200
Impedance: **50 Ohm**
Core size: **1.12 mm**
Dielectric Type: **PF**
Nominal Attenuation per MHz (dB/100 ft): **850/9.6dB; 1900/14.6dB**

LMR®200 is an outdoor-rated flexible low loss communications coax. It has a 50 Ohm impedance and is great for short antenna feeder runs. This cable also features low-PIM.

LMR®240
Impedance: **50 Ohm**
Core size: **1.42 mm**
Dielectric Type: **PF**
Nominal Attenuation per MHz (dB/100 ft): **850/7.2dB; 1900/11.2dB**

LMR®240 is also an outdoor rated flexible low loss communications coax with an impedance of 50 Ohm. It's designed for short feeder runs for applications like GPS, WLAN, and mobile antennas.

LMR®400
Impedance: **50 Ohm**
Core size: **2.74 mm**
Dielectric Type: **PF**
Nominal Attenuation per MHz (dB/100 ft): **850/3.8dB; 1900/5.8dB**

LMR®400 is a flexible communications coax with an impedance of 50 Ohm. It's used for jumper assemblies in wireless communications systems and antenna feeder runs. If you need a cable that requires periodic or repeated flexing, choose this one. LMR®400 was designed to replace the RG-8 cables.

LMR®600
Impedance: **50 Ohm**
Core size: **4.47 mm**
Dielectric Type: **PF**
Nominal Attenuation per MHz (dB/100 ft): **850/2.4dB; 1900/3.8dB**

LMR®600 or “Half-Inch” is designed for outdoor use as well. It's more flexible than air-dielectric and hardline cables in terms of bending and handling. It also has an impedance of 50 Ohm.

LMR®900
Impedance: **50 Ohm**
Core size: **6.65 mm**
Dielectric Type: **PF**

Nominal Attenuation per MHz (dB/100 ft): **850/1.6dB; 1900/2.6dB**

LMR®900/1200/1700 are larger cables. They're designed for medium antenna feeder runs with any application needing an easily routed, flexible low loss cable.

LMR®200
Impedance: **50 Ohm**
Core size: **8.66 mm**
Dielectric Type: **PF**
Nominal Attenuation per MHz (dB/100 ft): **850/1.2dB; 1900/1.9dB**
LMR®1700
Impedance: **50 Ohm**
Core size: **13.39 mm**
Dielectric Type: **PF**
Nominal Attenuation per MHz (dB/100 ft):**850/0.9dB; 1900/1.5dB**

How to Identify Coaxial Cable Types?

The numbers and letters printed on the cable jacket tell you everything you need to know. The type of cable it is, who manufactured it, rating, and more.

Coaxial Cable Signal Loss (Per 10 Feet)

Signal loss happens with all types of coaxial cable. As signal travels through the cable, it loses energy. It's inevitable. With increased cable length more signal loss occurs.

Signal gain and loss are measured in decibels (dB), which are measured exponentially. A loss of 3 dB means a weakened signal by 2x!

Per the image, the Wilson400 (and the equally powerful RG-11) has the least loss per 10ft. It's almost twice as effective compared to the RG-6 for home installations. The only mightier cable is the pricey LG600 and even pricier Half-Inch.

The RG-174 should never be installed in any unit that needs more than 6 feet of cable. It does a poor job of carrying signal at 10 feet.

Signal loss doesn't end there. Mixing and matching 50 Ohm and 75 Ohm cables and systems (more on this later) can lead to further signal loss. While you can customize your installation with connectors and adapters, it's best to stay consistent.

To calculate the amount of loss you should expect, use an online calculator. For example, the QSL Loss Calculator. We don't endorse this one specifically. Simply fill in the blanks and loss will be calculated in seconds.

There are many online calculators you can use as well as formulas for manual calculation.

Important Coaxial Cable Features to Consider Before You Buy

Coaxial Cable Length and Thickness

Coaxial cable comes in varying lengths and thicknesses. These features will determine the strength of the signal transmitted.

As mentioned, the longer the cable the more loss occurs when transmitting signal across long distances. Thick cable features lower loss than thin cable, making it ideal for long cable runs. For optimal transmission, you'll want the shortest and thickest cable appropriate for your application.

In radio systems, cable length is comparable to the wavelength of the signals transmitted. You can study the math involved in deciding the best cable length to use. Characteristics of the cable, such as outside diameter of the inner conductor, inside diameter of the shield, dielectric contact of the insulator, and magnetic permeability of the insulator, all affect the quality of the wavelength going through your cable.

Coaxial Cable and dBm

dBm represents your signal strength. The type of coaxial cable used will determine how strong a signal your cable can handle. To learn the difference between dB and dBm, click here.

Coaxial Cable Impedance (Ohms)

Impedance is the amount of resistance waves moving through the coaxial cable encounters. The lower the impedance, the easier the waves flow through the cable. Each type of cable has an impedance rating. Factors affecting this are the size and materials of the cable.

Standard coax impedances are 50 and 75 Ohms. When tested, these impedance ratings were deemed a great balance between power handling and low loss.

What is the difference between 50 and 75 Ohm cables? This analogy might help. Think of signal as a drink and cables as straws. 75 Ohm cables are your typical soda straws, and 50 Ohm cables are jumbo straws.

While 50 Ohm cables transmit signal better, it doesn't mean you need 50 Ohm cable.

50 Ohm cables tend to be better for high power handling applications. These could be commercial boosters, broadcasting TV transmitters, and ham radios. 75 Ohm cables are the popular choice for home and office applications. They're used for residential signal booster installations, cable TV boxes, internet routers, and the like. These are general rules and do not apply to all types of cable.

When choosing cable, avoid mixing and matching 50 Ohm and 75 Ohm cables and systems. You should aim to use the same impedance throughout to prevent additional signal loss.

Coaxial Cable and PIM

PIM stands for Passive Intermodulation. When you connect two metals, the result is nonlinear elements, and distortion in the signal may occur.

As signal amplitude goes up, the effects will be more significant. This often happens when connecting antennas, cables, and connectors. PIM problems occur most often in cellular networks. To mitigate PIM issues, consider low-PIM cables, connectors, and adapters.

Coaxial Cable Rating

All coaxial cables are rated for different applications. The rating tells you everything you need to know about where the cable can be SAFELY installed. The most common are:

- **Communications Multipurpose Plenum (CMP) Cable**: Plenum cable is designed to be used in plenum air spaces. The jacket is fire-retardant and low smoke. In the event of a fire, plenum cables release the lowest level of toxic fumes. They are the safest to use in spaces designed for air circulation.
- **Communications Multipurpose Riser (CMR) Cable**: Riser cable is mainly used to run cable between floors through risers or vertical shafts. The jacket is also fire retardant to prevent fires from spreading between floors. Though, they are not as heavy-duty as plenum cables.
- **Communications Multipurpose (CM) Cable**: CM cable, sometimes referred to as PVC cable, is the most commonly used cable rating. It's rated for general-purpose applications, such as connecting a computer to the wall. It's not as fire-retardant and will release toxic fumes. They are not to be used in riser or plenum spaces.

Coaxial Cable Connectors

Connectors are on each end of the cable. They are designed to maintain the integrity of the cable as it transmits signal. They are usually plated with high-connectivity metals, such as tarnish-resistant gold or silver. The type of connector you need depends on what you are connecting to.

Coaxial Cable Connector Types:

SMA Connector

SMA stands for Subminiature Version A. It's a minimal connector interface for coaxial cable with a screw-type coupling mechanism. It has an impedance of 50 Ohm and is designed for use from DC (0 Hz) to 18 GHz. Applications include microwave systems, handheld radios, and mobile telephone antennas.

SMB Connector

SMB stands for Subminiature Version B. SMBs are smaller than SMAs and feature a snap-on coupling design. They are available in 50 and 75 Ohms and operate up to 4 GHz. Less robust than SMA, they can't be used in harsh environments. Common applications include base stations, antennas, GPS, and computer systems.

F-Type Connector

F-Type connectors are mid-size connectors designed for common use. They are commonly found on RG-6/U cable. F-Types are the most widely used connector for residential wiring. They're used with cable television, satellite television, and cable modems.

N-Type Connector

N-Type connectors are larger connectors designed to be used with thick, commercial cable.

FME Connector

FME (For Mobile Equipment) is a 50 Ohm miniature coax connector that offers performance from DC to 2000 MHz. It's mainly used in cellular communication devices and data applications.

TNC Connector

Threaded Neill–Concelman (TNC) connectors are commonly used in mobile phones and RF/antenna connections. They are weatherproof and operate up to 11 GHz.

UHF Connector

UHF connector, also known as Amphenol coax connector, is a 50 Ohm connector for low-frequency RF applications. It's widely used in amateur radio, citizens' band radio, and marine VHF radio. It's suitable for use up to 300 MHz.

Connectors are either standard or reverse polarized male or female.

Standard polarized male connectors have threads on the inside of the shell and a pin. On the other hand, standard polarized female connectors have threads on the inside of the shell and no pin. The hole and pin are switched in reverse polarized connectors. In other words, the female connector has the pin, and the male connector has the hole.

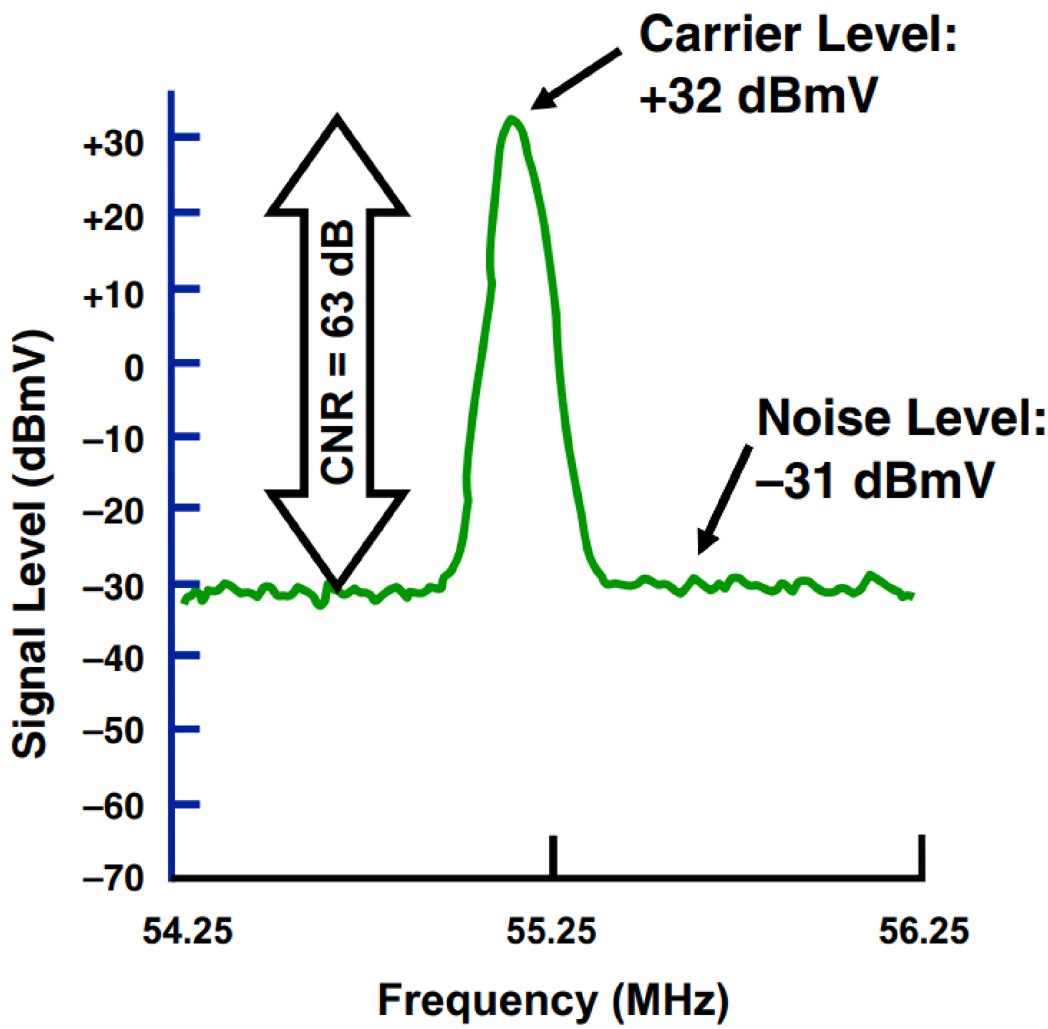
The only way to connect a male to male or female to female is with a coax cable adapter, which also causes signal loss. Signal attenuation from an adapter will depend on the quality.

Check the plug on your device to avoid unnecessary signal loss. If it's a standard female, you need a standard male plug and vice versa. Getting a coaxial cable with the correct connector from the get-go is recommended.

Cable Modem Troubleshooting

Cable modem termination systems (CMTSs) can report a variety of operating parameters to the end user.

For example, CMTSs that use Broadcom® BCM3137, BCM3138, or BCM3140 or Texas Instruments® TNETC4522 series upstream burst receivers can provide an "upstream SNR" estimate.



- This function is a very useful tool, but it has resulted in much confusion.
    - It is not unusual for a cable company's network operations center (NOC) staff to report an alarm condition when the reported upstream signal-to-noise ratio (SNR) of the CMTS drops below a defined threshold.
    - A headend technician follows up by checking the upstream RF performance with a spectrum analyzer or similar test equipment, only to find that everything appears normal.
    - Data personnel in the NOC insist there must be a problem, while outside plant technicians see nothing amiss on their test equipment. What is going on here?
- The discrepancy occurs from a lack of understanding about just what the CMTS upstream SNR estimate is—and what it is not.

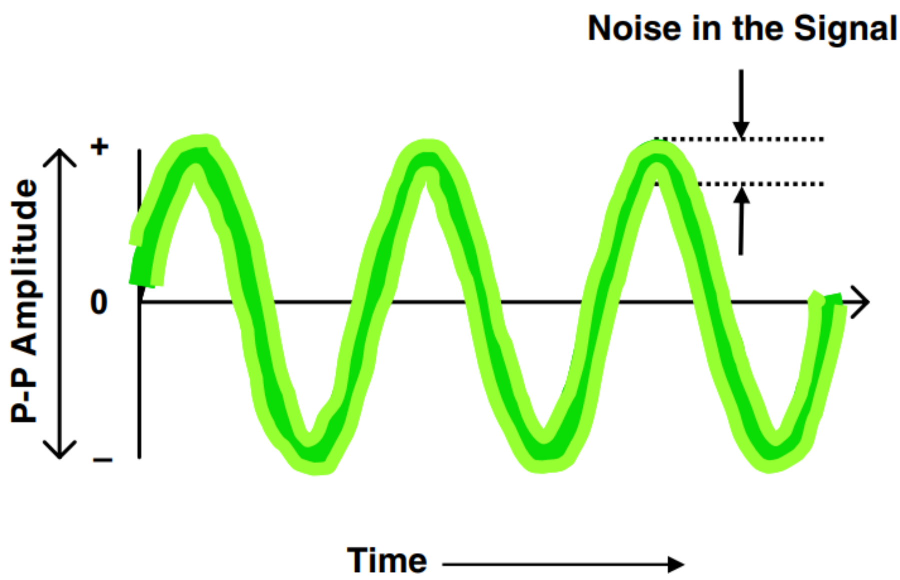


Figure 2: Baseband SNR Measurement

- Further confusion comes from the fact that cable modems and digital set-top boxes (STBs) can provide digitally modulated signal operating parameters such as RF signal level and SNR.
    - These are downstream parameters at the customer premises, not upstream parameters as is sometimes incorrectly assumed.
    - In addition, test equipment used by cable operators to characterize digitally modulated signals can measure downstream—and in some cases upstream—modulation error ratio (MER).
    - Some of these instruments call this parameter SNR. Also, because of the time-shared nature of the upstream, most of today's CMTSs can measure parameters on a per-channel basis or a per-cable-modem basis.
    - Per-channel measurements provide an average of all cable modems or simply a snapshot of the most recently active cable modem(s).
    - It is important to distinguish which type of measurement is presented. This paper provides a background on several signal quality metrics applicable to CMTS and cable network operation and how they relate to overall performance.
    - The CMTS upstream SNR and cable modem or STB downstream SNR estimates are explained.

- Noise, as discussed in this paper and unless defined otherwise, refers to additive white Gaussian noise (AWGN), or simply white noise, also known as thermal noise.
- Interference such as narrowband ingress and burst or impulse noise is usually treated separately.
- First, what the CMTS upstream SNR estimate is not: the SNR estimate from a cable modem or CMTS is not the same thing as the carrier-to-noise ratio (CNR) that one measures with a spectrum analyzer.
- Here is what the upstream SNR estimate is: an operating parameter provided by the upstream burst receiver used in DOCSIS® CMTSs.
- Similar information for downstream signals is provided by the quadrature amplitude modulation (QAM) receiver in a cable modem or STB.
- The SNR estimate, which is derived after the data is demodulated, is more accurately called receive modulation error ratio (RxMER), a term recently defined in the DOCSIS MIB.

- RxMER includes the effects of the cable network downstream or upstream noise floor, in-channel frequency response (including amplitude tilt and ripple, group delay variation, and micro-reflections), oscillator phase noise, receiver imperfections, and all other impairments that affect the receive symbol constellation.
- Because it measures the end-to-end performance of the communications link, RxMER is useful for tracking long-term system performance trends

Broadcom Delivers End-to-End Portfolio of Devices for DOCSIS 3.1

Broadcom Corporation (NASDAQ: BRCM), a global innovation leader in semiconductor solutions for wired and wireless communications, today announced three new DOCSIS 3.1-based devices for Converged Cable Access Platform (CCAP) equipment. The BCM3047, BCM31442 and BCM3222 enable CCAP vendors to build and deploy DOCSIS 3.1-compliant equipment that supports multiple Gigabit cable broadband speeds over coax to deliver new content and services to home subscribers. For more news, visit Broadcom's Newsroom.

Broadcom's new silicon for DOCSIS 3.1 CCAP equipment works in conjunction with Broadcom's recently announcedBCM3390 device for cable modems to provide the industry's only end-to-end DOCSIS 3.1 solution. The platform enables cable operators to leverage the existing cable plant to compete with fiber optic service. Early adopters of Broadcom'sDOCSIS 3.1 technology include both major cable operators such as Comcast and Liberty Global, and CCAP equipment suppliers such as ARRIS and Harmonic.

"The performance improvements offered by Broadcom's end-to-end DOCSIS 3.1 platform enables cable operators to cost effectively upgrade their head-end equipment for the delivery and use of a new range of subscriber content," said Dan Marotta, Broadcom Executive Vice President and General Manager, Broadband & Connectivity Group. "Today's new CCAP infrastructure devices, combined with the BCM3390 cable modem platform, provide a complete DOCSIS 3.1-based silicon solution with advanced capabilities that effectively compete with speeds offered by fiber deployments."

"End-to-end DOCSIS 3.1 technology, in both cable infrastructure and cable modems, is critical for subscribers to receive Gigabit speeds in the home," said Balan Nair, Liberty Global Executive Vice President and CTO. "DOCSIS 3.1 is making it possible for Liberty Global to deliver enhanced services to consumers later this year."

"DOCSIS 3.1 will allow Comcast to cost-effectively deliver faster and more reliable data speeds to our subscribers over our existing HFC network," said Tony Werner, Comcast Executive Vice-President. "Having DOCSIS 3.1 technology for both CCAP and home equipment will allow us to offer more and better speed options to more customers in 2015 and beyond."

"The evolutionary nature of DOCSIS technology continues with the introduction of the DOCSIS 3.1 specification, enabling an elegant and rapid upgrade of the growing installed base of ARRIS CCAP equipment around the world," said Tom Cloonan, ARRIS CTO, Network Solutions. "The efficiency gains enabled by DOCSIS 3.1 will ensure cable operators remain at the forefront of the Broadband industry and meet consumers' ever-increasing demand for richer, more interactive media experiences."

"DOCSIS 3.1 opens the door to a new generation of cable services," said Nimrod Ben-Natan, Harmonic Senior Vice President and General Manager, Cable Edge Business. "Broadcom's complete end-to-end solution in support of this standard enables Harmonic to provide cable operators with CCAP equipment that cost-effectively leverages their existing infrastructure to deliver Gigabit speeds today."

Broadcom's new chips provide a complete physical (PHY) and media access control (MAC) layer solution for operators deploying DOCSIS 3.1 in CCAP infrastructure equipment. The new PHY devices include the BCM31442 upstream burst receiver which receives transmissions from the home toward the network and BCM3047 downstream transmitter which supports transmissions from the network to the home. The new MAC device, the BCM3222, supports rapid and efficient cable modem access to network resources.

Key Features of the BCM3047 Transmitter

- Industry's first single-chip transmitter with integrated high-speed digital to analog converter (DAC) enabling transmission out to 1.2 GHz on the cable plant
- Supports up to 160 SC-QAM and up to 6 OFDM transmitters

Key Features of the BCM31442 Receiver

- Industry's first DOCSIS 3.1 burst receiver with integrated analog to digital converter (ADC) supporting up to 300 MHz of upstream spectrum
- Supports 2 upstream ports across 24 SC-QAM and 4 OFDMA receivers

Key Features of the BCM3222 MAC Device

- Capable of supporting up to 25 GbpsAvailability

  Broadcom's BCM3047, BCM31442 and BCM3222 are currently sampling.

  For ongoing Broadcom news visit our Newsroom, read our B-Connected Blog, or visit us on Facebook or Twitter. And to stay connected, subscribe to our RSS Feed.

  About Broadcom Broadcom Corporation (NASDAQ: BRCM), a FORTUNE 500® company, is a global leader and innovator in semiconductor solutions for wired and wireless communications. Broadcom® products seamlessly deliver voice, video, data and multimedia connectivity in the home, office and mobile environments.

With the industry's broadest portfolio of state-of-the-art system-on-a-chip solutions, Broadcom is changing the world by Connecting everything®. For more information, go towww.broadcom.com.

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BCM3390 Broadcom

BCM3390 DOCSIS® 3.1 modem/gateway SoC

- Overview
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DOCSIS® 3.1 System-on-a-chip (SoC) enables multi-gigabit per second capable cable modem, gateway, and Set-top Box designs.

Broadcom's BCM3390 DOCSIS® 3.1 modem/gateway SoC delivers IP/video content with a nearly 50 percent increased efficiency on existing spectrum allocations. With multiple gateway interfaces, the BCM3390 enables the distribution of multi-gigabit per second content throughout the home.

Features

- Full compliance with full DOCSIS® 3.1 specification, including:
  - Two 192 MHz OFDM downstream channels
  - Thirty two single-carrier QAM downstream channels
  - Two 96 MHz OFDM-A upstream channels
  - Eight single-carrier QAM upstream channels

- Includes full software support for packet cable voice and e-router applications, including RDK-B software broadband modem solutions

Applications

- Broadband modems
- Home gateways
- Set-top boxes

WiFi, 5G cellular and DOCSIS share many RF technologies

Here are a few high-level RF technologies they share:

1. **Orthogonal Frequency Division Multiplexing (OFDM):** All three technologies use OFDM, a modulation scheme that effectively splits one high-rate data stream into multiple lower-rate streams, which are then transmitted simultaneously over several frequency carriers. This is a method for reducing interference and improving efficiency, especially in multi-path propagation environments.
2. **Multiple-Input Multiple-Output (MIMO):** MIMO technology involves the use of multiple antennas at both the source (transmitter) and the destination (receiver). It's used to enhance performance and increase capacity by exploiting multipath propagation. MIMO is present in Wi-Fi (especially from Wi-Fi 4 onwards), 5G (especially in the Massive MIMO configuration), and DOCSIS 3.0 to some extent (cable operators can set up MIMO in the context of their cable modems and Cable Modem Termination Systems (CMTS)).
3. **Quadrature Amplitude Modulation (QAM):** QAM is a modulation technique that combines both amplitude and phase variations to create different constellation points for encoding data. Wi-Fi, 5G, and DOCSIS 3.0 all use variations of QAM, although the levels can vary (e.g., 64-QAM, 256-QAM, 1024-QAM, etc.).
4. **Beamforming:** Beamforming is a technique used to direct the transmission or reception of radio signals in a specific direction, improving signal quality and reducing interference. Beamforming is used in Wi-Fi, especially from Wi-Fi 5 onwards, and is a significant part of 5G networks. While not common, there is potential for beamforming in the DOCSIS context, particularly with full duplex systems and future cable network iterations.

5. **Forward Error Correction (FEC):** FEC is a technique for controlling errors in data transmission over unreliable or noisy communication channels. Wi-Fi, 5G, and DOCSIS 3.0 all use FEC techniques to increase the reliability of the communication link.
6. **Channel bonding:** Channel bonding is a technique used to combine several channels together to increase the throughput. In the case of DOCSIS 3.0, this means combining multiple downstream and upstream channels. For Wi-Fi, this could mean combining two 20 MHz channels into one 40 MHz channel (or even more in later Wi-Fi versions). For 5G, carrier aggregation (a similar concept) can be used to increase bandwidth.
7. **Frequency bands:** All three technologies utilize RF to transmit and receive signals within specific frequency bands. The specific bands used can vary widely between the technologies and are regulated by different standards bodies and governmental organizations.

Figure 135 - Example of Subsplit Band Plan Used in North America and Other Regions

The actual frequency bands used in DOCSIS systems can depend on the specific configuration of the cable network and can be somewhat flexible. However, traditionally in a DOCSIS 3.1 setup:

1. **Downstream (from the internet to the user):** Downstream frequencies typically range from 54 MHz up to as high as 1218 MHz. The larger part of the cable TV spectrum is allocated to downstream to cater to most users' internet habits, which involve more downloading than uploading (e.g., streaming videos, downloading files, loading web pages).

2. **Upstream (from the user to the internet):** Upstream frequencies traditionally range from 5 MHz up to 42 MHz or 85 MHz. DOCSIS 3.1 introduced the ability to extend this up to 204 MHz, allowing for more upstream capacity, but the actual implementation depends on the cable operator's network configuration.

These frequency allocations are designed to work within the cable TV spectrum, which generally ranges from 5 MHz to 1218 MHz. DOCSIS 3.1's key innovation is to leverage more efficient modulation techniques, like OFDM and LDPC, to deliver more data within this same frequency range, resulting in higher speed and capacity. It should be noted that these ranges can vary based on geographical location and the specific regulations of a country's telecommunications authority.

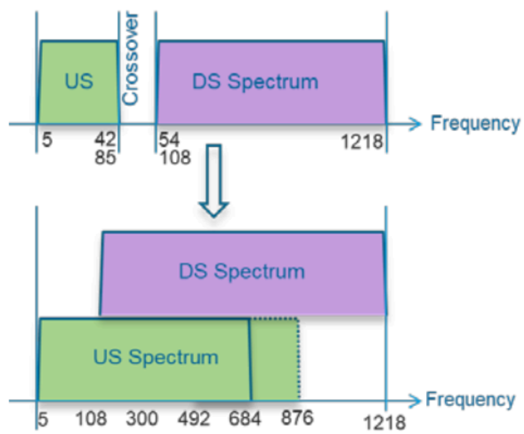


Figure 136 - Frequency Spectrum Usage in FDX DOCSIS Systems (Bottom) Compared to Traditional Subsplit, Midsplit, or High-Split Band Plans (Top)

Firmware/Bootloader

Surfboard modems use a [VxWorks]() bootloader ([headers]()). For other modems, the official broadcom bootloaders are used (BOLT and cmboot); both bootloaders are proprietary. BOLT is used on bcm3384 and later, especially on bcm3390.

Determining if secure boot is enabled

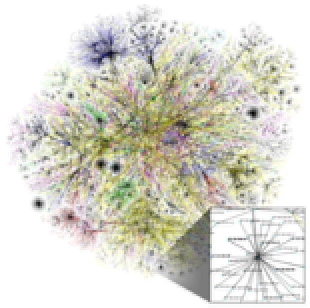
If a device is using the official broadcom bootloader (cmboot), it is possible to determine whether secure boot is enabled by looking for a “Cust key size” message on the serial console.

cmboot: secure boot and/or secure app?

It should be noted that secure boot != secure app, where the former refers to bootrom validation of code stored in flash, and secure app refers to the validation of images passed to cmboot.

While secure boot might not let you replace cmboot with another bootloader, it is still possible to boot up a 2nd-stage bootloader if secure app is not enabled.

Internet access



An Opte Project visualization of routing paths through a portion of the Internet

Governance

Information infrastructure

Services

History

Guides

Internet portal

- v
- t
- e

Internet access is the ability of individuals and organizations to connect to the Internet using computer terminals, computers, and other devices; and to access services such as email and the World Wide Web. Internet access is sold by Internet service providers (ISPs) delivering connectivity at a wide range of data transfer rates via various networking technologies. Many organizations, including a growing number of municipal entities, also provide cost-free wireless access and landlines.

Availability of Internet access was once limited, but has grown rapidly. In 1995, only 0.04 percent of the world's population had access, with well over half of those living in the United States,[1] and consumer use was through dial-up. By the first decade of the 21st century, many consumers in developed nations used faster broadband technology, and by 2014, 41 percent of the world's population had access,[2] broadband was almost ubiquitous worldwide, and global average connection speeds exceeded one megabit per second.[3]

History

Main article: History of the Internet

The Internet developed from the ARPANET, which was funded by the US government to support projects within the government and at universities and research laboratories in the US – but grew over time to include most of the world's large universities and the research arms of many technology companies.[4][5][6] Use by a wider audience only came in 1995 when restrictions on the use of the Internet to carry commercial traffic were lifted.[7]

In the early to mid-1980s, most Internet access was from personal computers and workstations directly connected to local area networks (LANs) or from dial-up connections using modems and analog telephone lines. LANs typically operated at 10 Mbit/s, while modem data-rates grew from 1200 bit/s in the early 1980s, to 56 kbit/s by the late 1990s. Initially, dial-up connections were made from terminals or computers running terminal emulation software to terminal servers on LANs. These dial-up connections did not support end-to-end use of the Internet protocols and only provided terminal to host connections. The introduction of network access servers supporting the Serial Line Internet Protocol (SLIP) and later the point-to-point protocol (PPP) extended the Internet protocols and made the full range of Internet services available to dial-up users; although slower, due to the lower data rates available using dial-up.

An important factor in the rapid rise of Internet access speed has been advances in MOSFET (MOS transistor) technology.[8] The MOSFET, originally invented by Mohamed Atalla and Dawon Kahng in 1959,[9][10][11] is the building block of the Internet telecommunications networks.[12][13] The laser, originally demonstrated by Charles H. Townes and Arthur Leonard Schawlow in 1960, was adopted for MOS light wave systems around 1980, which led to exponential growth of Internet bandwidth. Continuous MOSFET scaling has since led to online bandwidth doubling every 18 months (Edholm's law, which is related to Moore's law), with the bandwidths of telecommunications networks rising from bits per second to terabits per second.[8]

Broadband Internet access, often shortened to just broadband, is simply defined as "Internet access that is always on, and faster than the traditional dial-up access"[14][15] and so covers a wide range of technologies. The core of these broadband Internet technologies are complementary MOS (CMOS) digital circuits,[16][17] the speed capabilities of which were extended with innovative design techniques.[17] Broadband connections are typically made using a computer's built in Ethernet networking capabilities, or by using a NIC expansion card.

Most broadband services provide a continuous "always on" connection; there is no dial-in process required, and it does not interfere with voice use of phone lines.[18] Broadband provides improved access to Internet services such as:

- Faster World Wide Web browsing
- Faster downloading of documents, photographs, videos, and other large files
- Telephony, radio, television, and videoconferencing
- Virtual private networks and remote system administration
- Online gaming, especially massively multiplayer online role-playing games which are interaction-intensive

In the 1990s, the National Information Infrastructure initiative in the U.S. made broadband Internet access a public policy issue.[19] In 2000, most Internet access to homes was provided using dial-up, while many businesses and schools were using broadband connections. In 2000 there were just under 150 million dial-up subscriptions in the 34 OECD countries[20] and fewer than 20 million broadband subscriptions. By 2005, broadband had grown and dial-up had declined so that the number of subscriptions were roughly equal at 130 million each. In 2010, in the OECD countries, over 90% of the Internet access subscriptions used broadband, broadband had grown to more than 300 million subscriptions, and dial-up subscriptions had declined to fewer than 30 million.[21]

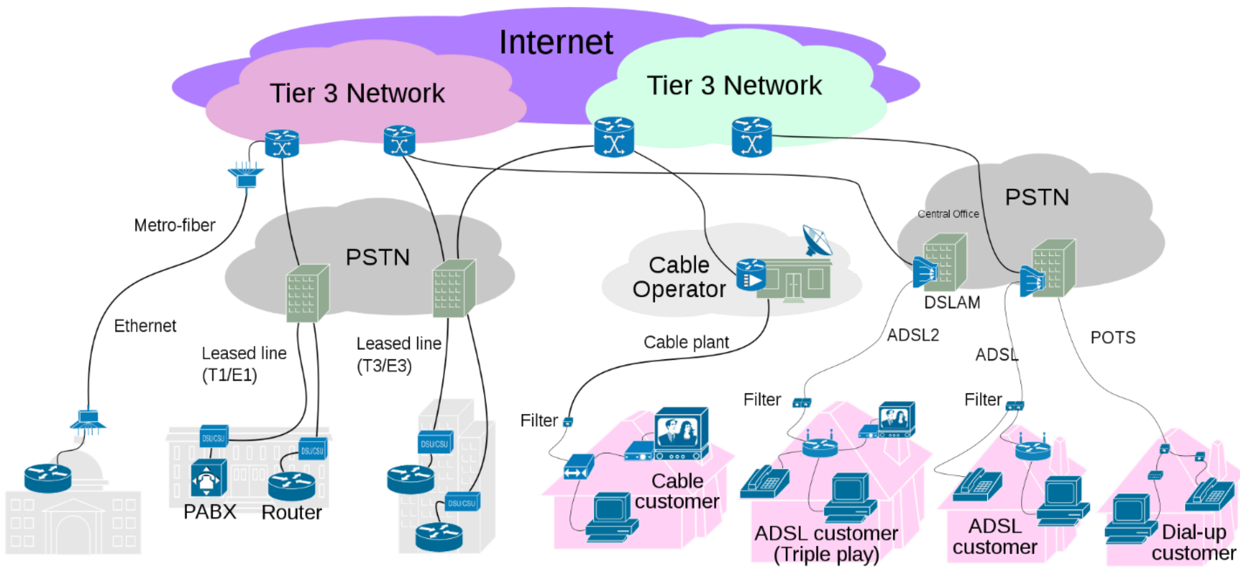
The broadband technologies in widest use are of digital subscriber line (DSL), ADSL and cable Internet access. Newer technologies include VDSL and optical fiber extended closer to the subscriber in both telephone and cable plants. Fiber-optic communication, while only recently being used in premises and to the curb schemes, has played a crucial role in enabling broadband Internet access by making transmission of information at very high data rates over longer distances much more cost-effective than copper wire technology.

In areas not served by ADSL or cable, some community organizations and local governments are installing Wi-Fi networks. Wireless, satellite and microwave Internet are often used in rural, undeveloped, or other hard to serve areas where wired Internet is not readily available.

Newer technologies being deployed for fixed (stationary) and mobile broadband access include WiMAX, LTE, and fixed wireless.

Starting in roughly 2006, mobile broadband access is increasingly available at the consumer level using "3G" and "4G" technologies such as HSPA, EV-DO, HSPA+, and LTE.

Availability



Internet Connectivity Access layer

In addition to access from home, school, and the workplace Internet access may be available from public places such as libraries and Internet cafés, where computers with Internet connections are available. Some libraries provide stations for physically connecting users' laptops to LANs.

Wireless Internet access points are available in public places such as airport halls, in some cases just for brief use while standing. Some access points may also provide coin-operated computers. Various terms are used, such as "public Internet kiosk", "public access terminal", and "Web payphone". Many hotels also have public terminals, usually fee based.

Coffee shops, shopping malls, and other venues increasingly offer wireless access to computer networks, referred to as hotspots, for users who bring their own wireless-enabled devices such as a laptop or PDA. These services may be free to all, free to customers only, or fee-based. A Wi-Fi hotspot need not be limited to a confined location since multiple ones combined can cover a whole campus or park, or even an entire city can be enabled.

Additionally, mobile broadband access allows smartphones and other digital devices to connect to the Internet from any location from which a mobile phone call can be made, subject to the capabilities of that mobile network.

Speed

Main articles: Data signaling rate, Bit rate, Bandwidth (computing), List of interface bit rates, and List of countries by Internet connection speeds
See also: Data-rate units

The bit rates for dial-up modems range from as little as 110 bit/s in the late 1950s, to a maximum of from 33 to 64 kbit/s (V.90 and V.92) in the late 1990s. Dial-up connections generally require the dedicated use of a telephone line. Data compression can boost the effective bit rate for a dial-up modem connection from 220 (V.42bis) to 320 (V.44) kbit/s.[22] However, the effectiveness of data compression is quite variable, depending on the type of data being sent, the condition of the telephone line, and a number of other factors. In reality, the overall data rate rarely exceeds 150 kbit/s.[23]

Broadband technologies supply considerably higher bit rates than dial-up, generally without disrupting regular telephone use. Various minimum data rates and maximum latencies have been used in definitions of broadband, ranging from 64 kbit/s up to 4.0 Mbit/s.[24] In 1988 the CCITT standards body defined "broadband service" as requiring transmission channels capable of supporting bit rates greater than the primary rate which ranged from about 1.5 to 2 Mbit/s.[25] A 2006 Organisation for Economic Co-operation and Development (OECD) report defined broadband as having download data transfer rates equal to or faster than 256 kbit/s.[26] And in 2015 the U.S. Federal Communications Commission (FCC) defined "Basic Broadband" as data transmission speeds of at least 25 Mbit/s downstream (from the Internet to the user's computer) and 3 Mbit/s upstream (from the user's computer to the Internet).[27] The trend is to raise the threshold of the broadband definition as higher data rate services become available.[28]

The higher data rate dial-up modems and many broadband services are "asymmetric"—supporting much higher data rates for download (toward the user) than for upload (toward the Internet).

Data rates, including those given in this article, are usually defined and advertised in terms of the maximum or peak download rate. In practice, these maximum data rates are not always reliably available to the customer.[29] Actual end-to-end data rates can be lower due to a number of factors.[30] In late June 2016, internet connection speeds averaged about 6 Mbit/s globally.[31] Physical link quality can vary with distance and for wireless access with terrain, weather, building construction, antenna placement, and interference from other radio sources.

Network bottlenecks may exist at points anywhere on the path from the end-user to the remote server or service being used and not just on the first or last link providing Internet access to the end-user.

Network congestion

Users may share access over a common network infrastructure. Since most users do not use their full connection capacity all of the time, this aggregation strategy (known as contended service) usually works well, and users can burst to their full data rate at least for brief periods. However, peer-to-peer (P2P) file sharing and high-quality streaming video can require high data-rates for extended periods, which violates these assumptions and can cause a service to become oversubscribed, resulting in congestion and poor performance. The TCP protocol includes flow-control mechanisms that automatically throttle back on the bandwidth being used during periods of network congestion. This is fair in the sense that all users that experience congestion receive less bandwidth, but it can be frustrating for customers and a major problem for ISPs. In some cases the amount of bandwidth actually available may fall below the threshold required to support a particular service such as video conferencing or streaming live video–effectively making the service unavailable.

When traffic is particularly heavy, an ISP can deliberately throttle back the bandwidth available to classes of users or for particular services. This is known as traffic shaping and careful use can ensure a better quality of service for time critical services even on extremely busy networks. However, overuse can lead to concerns about fairness and network neutrality or even charges of censorship, when some types of traffic are severely or completely blocked.

Outages

An Internet blackout or outage can be caused by local signaling interruptions. Disruptions of submarine communications cables may cause blackouts or slowdowns to large areas, such as in the 2008 submarine cable disruption. Less-developed countries are more vulnerable due to a small number of high-capacity links. Land cables are also vulnerable, as in 2011 when a woman digging for scrap metal severed most connectivity for the nation of Armenia.[32] Internet blackouts affecting almost entire countries can be achieved by governments as a form of Internet censorship, as in the blockage of the Internet in

Egypt, whereby approximately 93%[33] of networks were without access in 2011 in an attempt to stop mobilization for anti-government protests.[34]

On April 25, 1997, due to a combination of human error and software bug, an incorrect routing table at MAI Network Service (a Virginia Internet service provider) propagated across backbone routers and caused major disruption to Internet traffic for a few hours.[35]

See also: AS 7007 incident and List of web host service outages

Technologies

When the Internet is accessed using a modem, digital data is converted to analog for transmission over analog networks such as the telephone and cable networks.[18] A computer or other device accessing the Internet would either be connected directly to a modem that communicates with an Internet service provider (ISP) or the modem's Internet connection would be shared via a LAN which provides access in a limited area such as a home, school, computer laboratory, or office building.

Although a connection to a LAN may provide very high data-rates within the LAN, actual Internet access speed is limited by the upstream link to the ISP. LANs may be wired or wireless. Ethernet over twisted pair cabling and Wi-Fi are the two most common technologies used to build LANs today, but ARCNET, Token Ring, LocalTalk, FDDI, and other technologies were used in the past.

Ethernet is the name of the IEEE 802.3 standard for physical LAN communication[36] and Wi-Fi is a trade name for a wireless local area network (WLAN) that uses one of the IEEE 802.11 standards.[37] Ethernet cables are interconnected via switches & routers. Wi-Fi networks are built using one or more wireless antenna called access points.

Many "modems" (cable modems, DSL gateways or Optical Network Terminals (ONTs)) provide the additional functionality to host a LAN so most Internet access today is through a LAN such as that created by a WiFi router connected to a modem or a combo modem router,[citation needed] often a very small LAN with just one or two devices attached. And while LANs are an important form of Internet access, this raises the question of how and at what data rate the LAN itself is connected to the rest of the global Internet. The technologies described below are used to make these connections, or in other words, how customers' modems (Customer-premises equipment) are most often connected to internet service providers (ISPs).

Dial-up technologies

Dial-up access

Main article: Dial-up Internet access

"Dial up modem noises"
0:29
Typical noises of a dial-up modem while establishing connection with a local ISP in order to get access to the Internet.

Problems playing this file? See media help.

Dial-up Internet access uses a modem and a phone call placed over the public switched telephone network (PSTN) to connect to a pool of modems operated by an ISP. The modem converts a computer's digital signal into an analog signal that travels over a phone line's local loop until it reaches a telephone company's switching facilities or central office (CO) where it is switched to another phone line that connects to another modem at the remote end of the connection.[38]

Operating on a single channel, a dial-up connection monopolizes the phone line and is one of the slowest methods of accessing the Internet. Dial-up is often the only form of Internet access available in rural areas as it requires no new infrastructure beyond the already existing telephone network, to connect to the Internet. Typically, dial-up connections do not exceed a speed of 56 kbit/s, as they are primarily made using modems that operate at a maximum data rate of 56 kbit/s downstream (towards the end user) and 34 or 48 kbit/s upstream (toward the global Internet).[18]

Multilink dial-up

Multilink dial-up provides increased bandwidth by channel bonding multiple dial-up connections and accessing them as a single data channel.[39] It requires two or more modems, phone lines, and dial-up accounts, as well as an ISP that supports multilinking – and of course any line and data charges are also doubled. This inverse multiplexing option was briefly popular with some high-end users before ISDN, DSL and other technologies became available. Diamond and other vendors created special modems to support multilinking.[40]

Hardwired broadband access

The term *broadband* includes a broad range of technologies, all of which provide higher data rate access to the Internet. The following technologies use wires or cables in contrast to wireless broadband described later.

Integrated Services Digital Network

Integrated Services Digital Network (ISDN) is a switched telephone service capable of transporting voice and digital data, and is one of the oldest Internet access methods. ISDN has been used for voice, video conferencing, and broadband data applications. ISDN was very popular in Europe, but less common in North America. Its use peaked in the late 1990s before the availability of DSL and cable modem technologies.[41]

Basic rate ISDN, known as ISDN-BRI, has two 64 kbit/s "bearer" or "B" channels. These channels can be used separately for voice or data calls or bonded together to provide a 128 kbit/s service. Multiple ISDN-BRI lines can be bonded together to provide data rates above 128 kbit/s. Primary rate ISDN, known as ISDN-PRI, has 23 bearer channels (64 kbit/s each) for a combined data rate of 1.5 Mbit/s (US standard). An ISDN E1 (European standard) line has 30 bearer channels and a combined data rate of 1.9 Mbit/s.

Leased lines

Leased lines are dedicated lines used primarily by ISPs, business, and other large enterprises to connect LANs and campus networks to the Internet using the existing infrastructure of the public telephone network or other providers. Delivered using wire, optical fiber, and radio, leased lines are used to provide Internet access directly as well as the building blocks from which several other forms of Internet access are created.[42]

T-carrier technology dates to 1957 and provides data rates that range from 56 and 64 kbit/s (DS0) to 1.5 Mbit/s (DS1 or T1), to 45 Mbit/s (DS3 or T3).[43] A T1 line carries 24 voice or data channels (24 DS0s), so customers may use some channels for data and others for voice traffic or use all 24 channels for clear channel data. A DS3 (T3) line carries 28 DS1 (T1) channels. Fractional T1 lines are also available in multiples of a DS0 to provide data rates between 56 and 1500 kbit/s. T-carrier lines require special termination equipment that may be separate from or integrated into a router or switch and which may be purchased or leased from an ISP.[44] In Japan the equivalent standard is J1/J3. In Europe, a slightly different standard, E-carrier, provides 32 user channels (64 kbit/s) on an E1 (2.0 Mbit/s) and 512 user channels or 16 E1s on an E3 (34.4 Mbit/s).

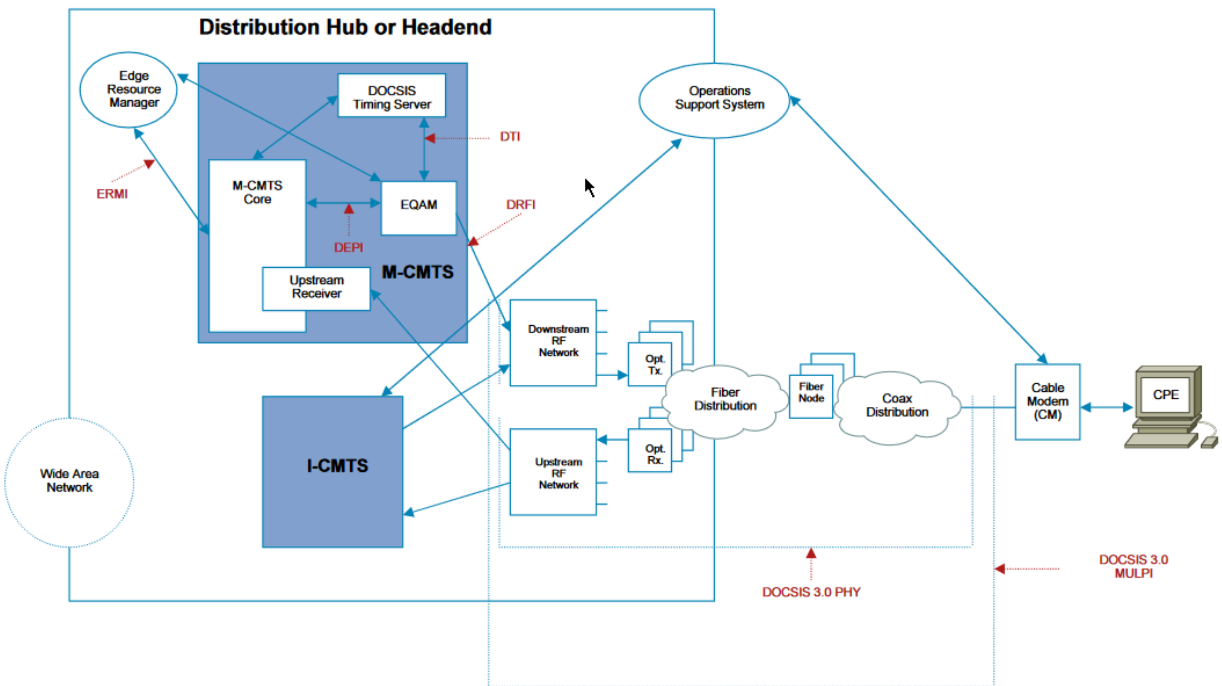
Synchronous Optical Networking (SONET, in the U.S. and Canada) and Synchronous Digital Hierarchy (SDH, in the rest of the world) are the standard multiplexing protocols used to carry high-data-rate digital bit-streams over optical fiber using lasers or highly coherent light from light-emitting diodes (LEDs). At lower transmission rates data can also be transferred via an electrical interface. The basic unit of framing is an OC-3c (optical) or STS-3c (electrical) which carries 155.520 Mbit/s. Thus an OC-3c will carry three OC-1 (51.84 Mbit/s) payloads each of which has enough capacity to include a full DS3. Higher data rates are delivered in OC-3c multiples of four providing OC-12c (622.080 Mbit/s), OC-48c (2.488 Gbit/s), OC-192c (9.953 Gbit/s), and OC-768c (39.813 Gbit/s). The "c" at the end of the OC labels stands for "concatenated" and indicates a single data stream rather than several multiplexed data streams.[42] Optical transport network (OTN) may be used instead of SONET for higher data transmission speeds of up to 400 Gbit/s per OTN channel.

The 1, 10, 40, and 100 Gigabit Ethernet IEEE standards (802.3) allow digital data to be delivered over copper wiring at distances to 100 m and over optical fiber at distances to 40 km.[45]

Cable Internet access

Main article: Cable Internet access

Cable Internet provides access using a cable modem on hybrid fiber coaxial (HFC) wiring originally developed to carry television signals. Either fiber-optic or coaxial copper cable may connect a node to a customer's location at a connection known as a cable drop. Using a cable modem termination system, all nodes for cable subscribers in a neighborhood connect to a cable company's central office, known as the "head end." The cable company then connects to the Internet using a variety of means – usually fiber optic cable or digital satellite and microwave transmissions.[46] Like DSL, broadband cable provides a continuous connection with an ISP.



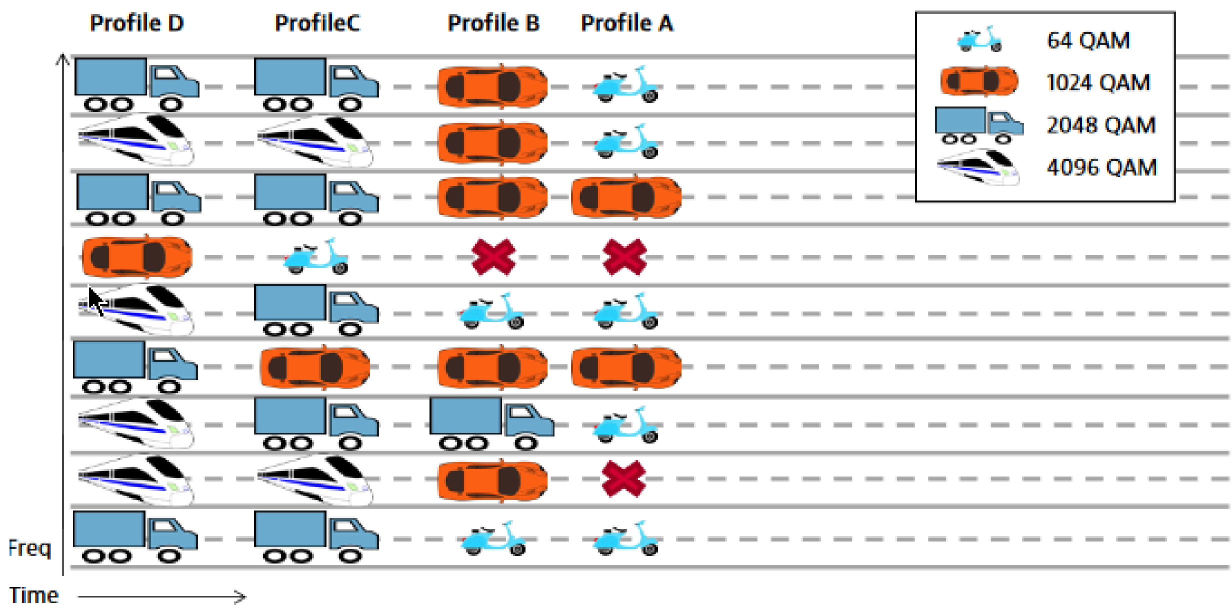


Figure 4. Profiles — a realistic conceptualization. OFDM enables excluding specific subcarriers and lets each profile vary the modulation on each subcarrier. This enables optimizing the overall carrier performance — each profile can have their own exclusions.

Downstream, the direction toward the user, bit rates can be as much as 1000 Mbit/s in some countries, with the use of DOCSIS 3.1. Upstream traffic, originating at the user, ranges from 384 kbit/s to more than 50 Mbit/s. DOCSIS 4.0 promises up to 10 Gbit/s downstream ands 6 Gbit/s upstream, however this technology is yet to have been implemented in real world usage. Broadband cable access tends to service fewer business customers because existing television cable networks tend to service residential buildings; commercial buildings do not always include wiring for coaxial cable networks.[47]

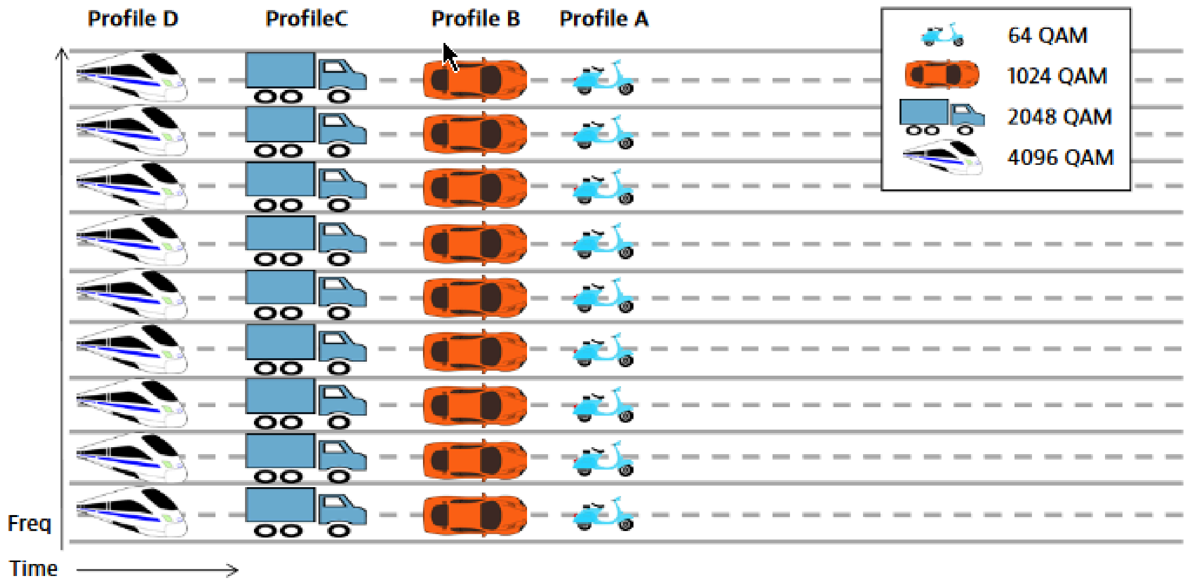
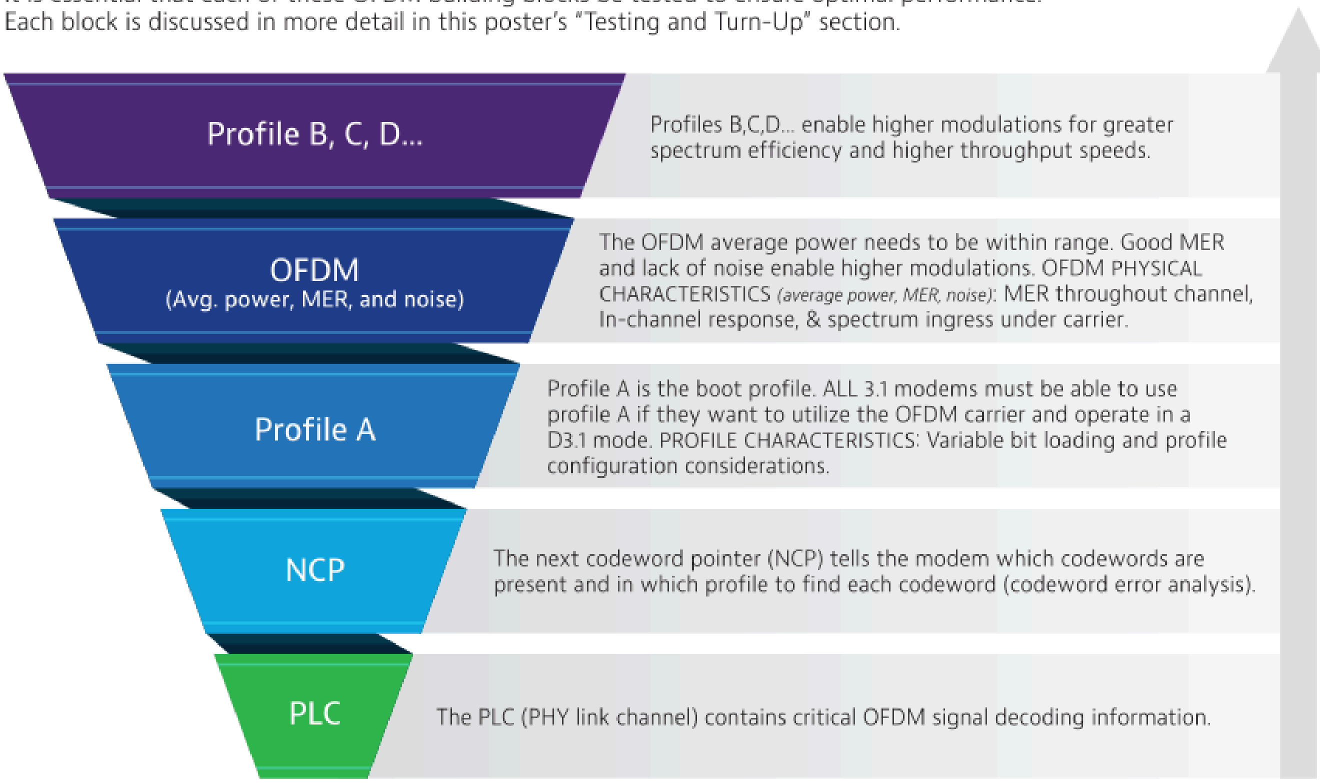


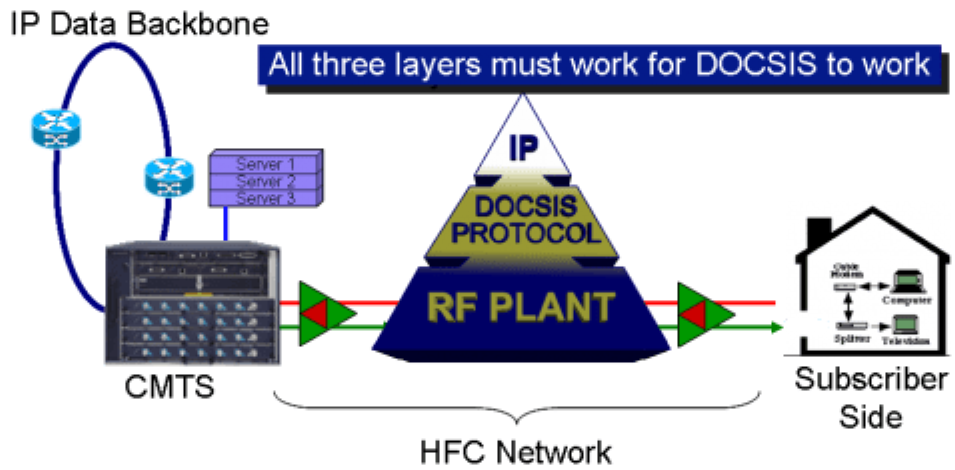
Figure 3. Profiles — a basic conceptualization. For simplicity, assume that the profiles use the same modulation for all subcarriers.

In addition, because broadband cable subscribers share the same local line, communications may be intercepted by neighboring subscribers. Cable networks regularly provide encryption schemes for data traveling to and from customers, but these schemes may be thwarted.[46]

Testing OFDM Building Blocks and Results Analysis

It is essential that each of these OFDM building blocks be tested to ensure optimal performance. Each block is discussed in more detail in this poster's "Testing and Turn-Up" section.





DOCSIS Cable Modem Registration

Through DOCSIS tutorial seminars, I have found the most effective way to bring someone up to speed on DOCSIS communications is by teaching the DOCSIS cable modem registration process. During the registration process, we will cover the RF physical layer, the DOCSIS Media Access Layer (MAC) and the Internet Protocol (IP) layer. Yes, the cable modem exercises the first three layers of the Open Systems Interconnection Reference Model (OSI Reference Model or OSI Model).

First let's consider the picture below to understand conceptually the DOCSIS network as it exists in a standard cable TV (hybrid fiber-coax or HFC) network.
DOCSIS in an HFC Network

DOCSIS Hierarchy

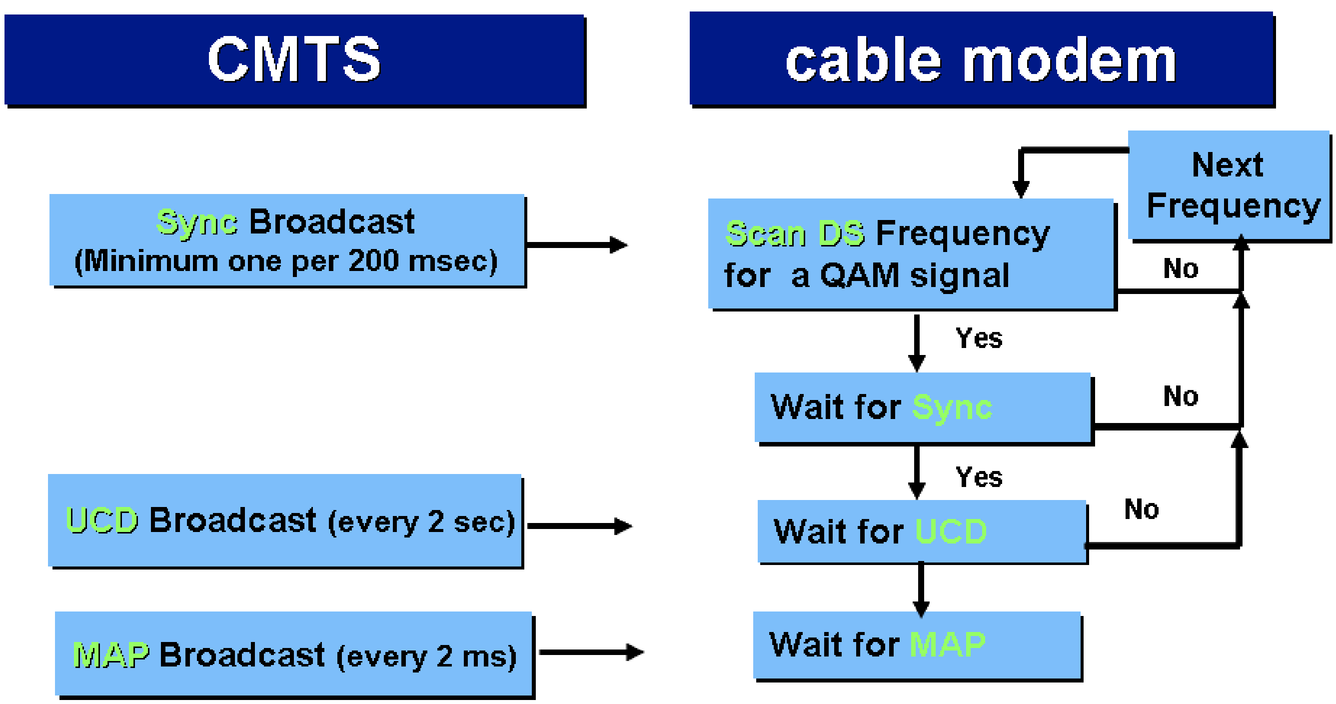
On the left is a Cable Modem Termination System (CMTS) that is connected to an Internet back bone.

To the CMTS is also connected a number of servers which run

- a Dynamic Host Configuration Protocol (DHCP) server,
- a Trivial File Transfer Protocol (TFTP) server, and
- a Time of Day (ToD) server.

The CMTS transmits downstream data via 64- or 256-QAM signals over the RF Plant to the subscriber's home cable modem.

The cable modem transmits data to the CMTS on the upstream over the RF Plant via QPSK, 8-, 16-, 32, or 64-QAM modulation. It is at this point that we must make the assumption that the RF Plant (essentially miles of coaxial cable, fiber optic cable, RF amplifiers, a fiber optic node, Erbium-doped fiber optic amplifiers and countless RF passive devices) is capable of supporting the RF modulations being transmitted by the DOCSIS devices without significant degradation to stop higher layer communications.



Downstream DOCSIS Channel Lock

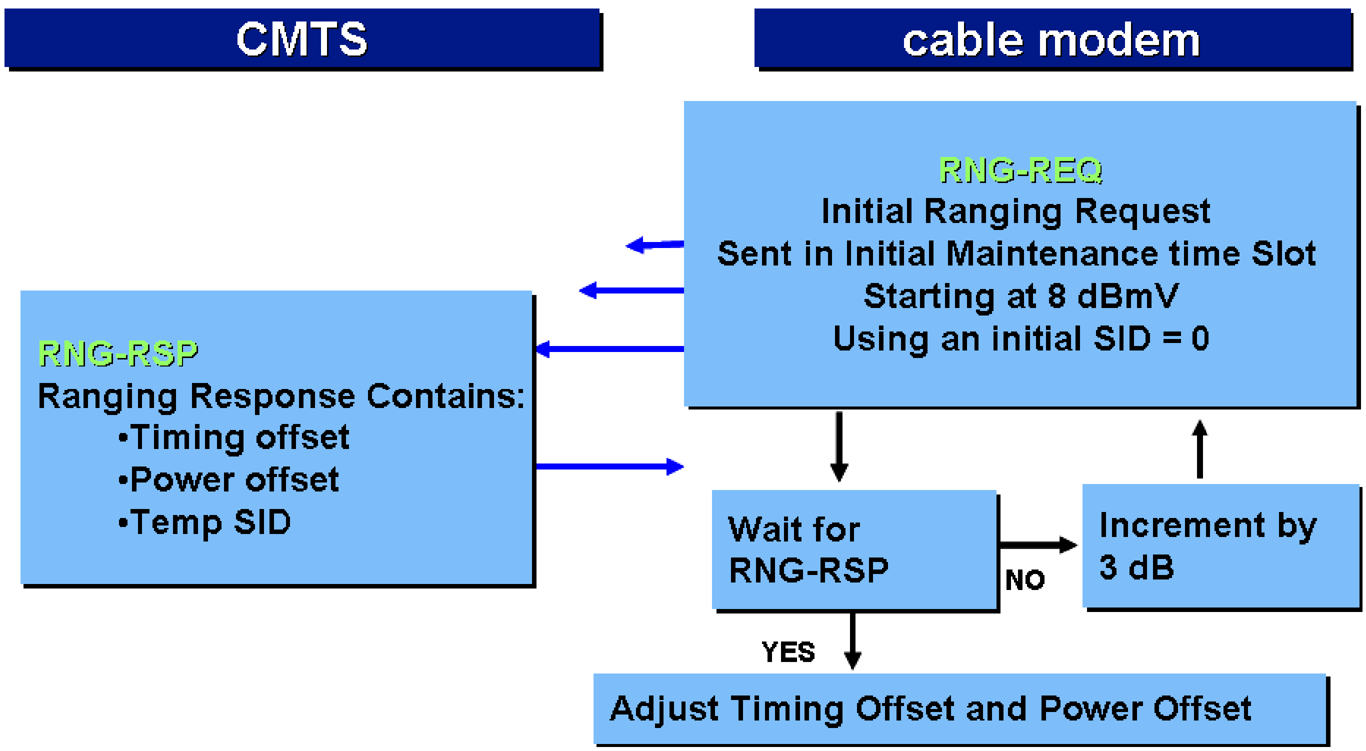
Once a cable modem is powered on and connected to the RF cable of a CATV network, it will begin a “hunt” for a valid downstream DOCSIS channel. First the cable modem looks for and locks to any 64- or 256-QAM digital channel.

Fortunately for the modem, the CMTS is sending out a “Sync” broadcast at least every 200 msec, which is used for system timing. In addition, the CMTS sends out an Upstream Channel Descriptor (UCD) every two seconds, which tells modems the upstream frequency to transmit on, symbol rate, modulation profile, and other parameters necessary to communicate on the network. Finally the CMTS is sending out Media Access Protocol (MAP) messages to allocate “talk time” to each cable modem.

You see, since there are many cable modems and only one upstream frequency, the cable modems must “time-share” the upstream channel, which is called Time Division Multiple Access (TDMA). Now, when the cable modem successfully locks to a QAM channel, it looks for the Sync, UCD and MAP messages from the CMTS. If it finds these it knows it is on an active DOCSIS channel. If they are not present, the cable modem assumes the DOCSIS channel is offline or it is on a video QAM channel and continues its search.

Assuming a successful lock above, the cable modem is now ready to begin ranging with the CMTS. The ranging process begins with Initial Ranging, which is a process in which

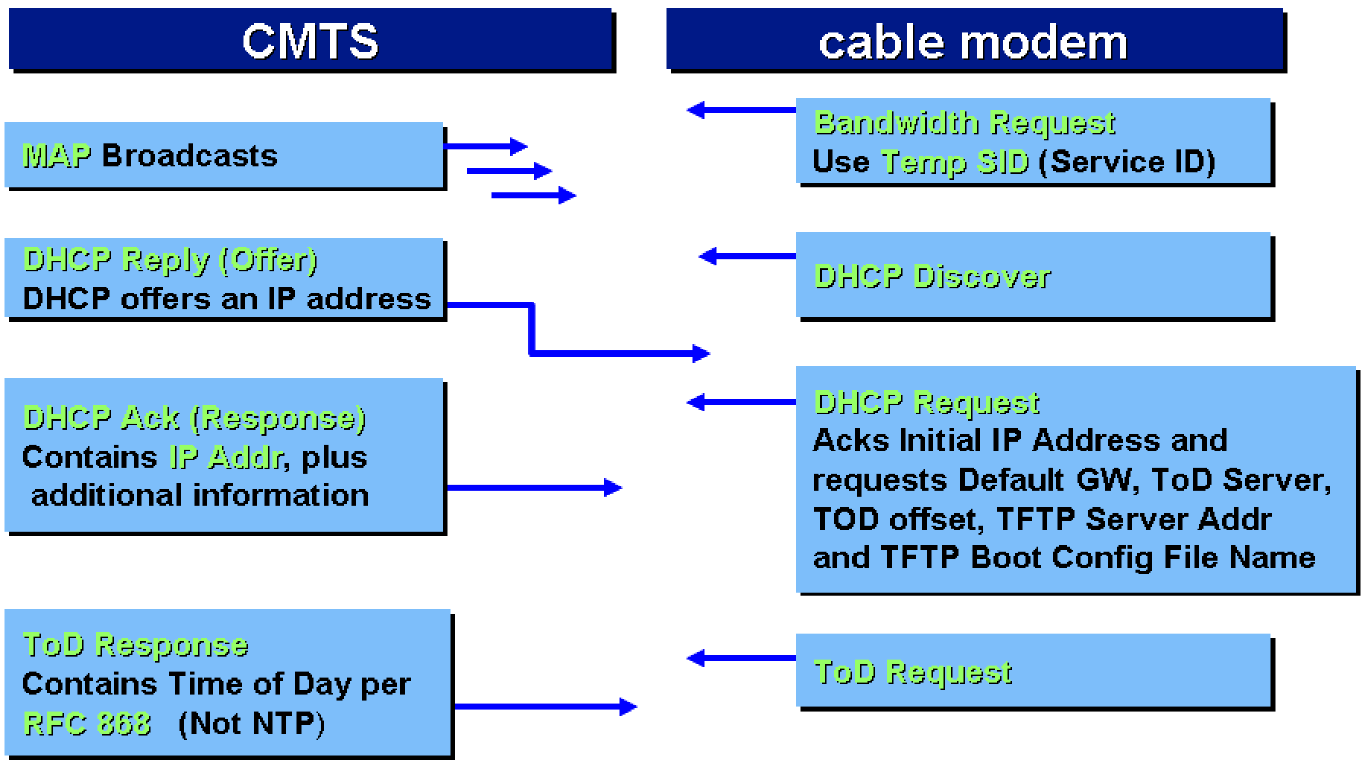
- the cable modem begins by sending a Range-Request at a power of 8 dBmV (very low power).
- If it does not receive a Range-Response from the CMTS the cable modem retransmits the Range-Requests at a 3 dB higher power level and continues the process until a Range-Response is received. See the following diagram:



Ranging with CMTS

All initial ranging occurs during a "contention" window, which means that the CMTS does not have prior knowledge of the cable modems existence. Therefore it is possible that when multiple cable modems are attempting to register during the contention window that they could interfere with each other and cause collisions. DOCSIS has a built-in back-off window for just such an occurrence which will help alleviate collisions in the contention window. This is most prevalent when there is a system outage and many cable modems are trying to come back online at the same time. Once the modem has received its first Range-Response from the CMTS it will moved from Initial Ranging to Station Maintenance. The cable modem will also be instructed by the CMTS to make adjustments to its transmitting frequency, amplitude, timing offset and optionally pre-equalization. Station Maintenance (Ranging) will occur at least once every 30 seconds for each cable modem on the DOCSIS network to continue making these adjustments and so that the CMTS knows the modems are online.

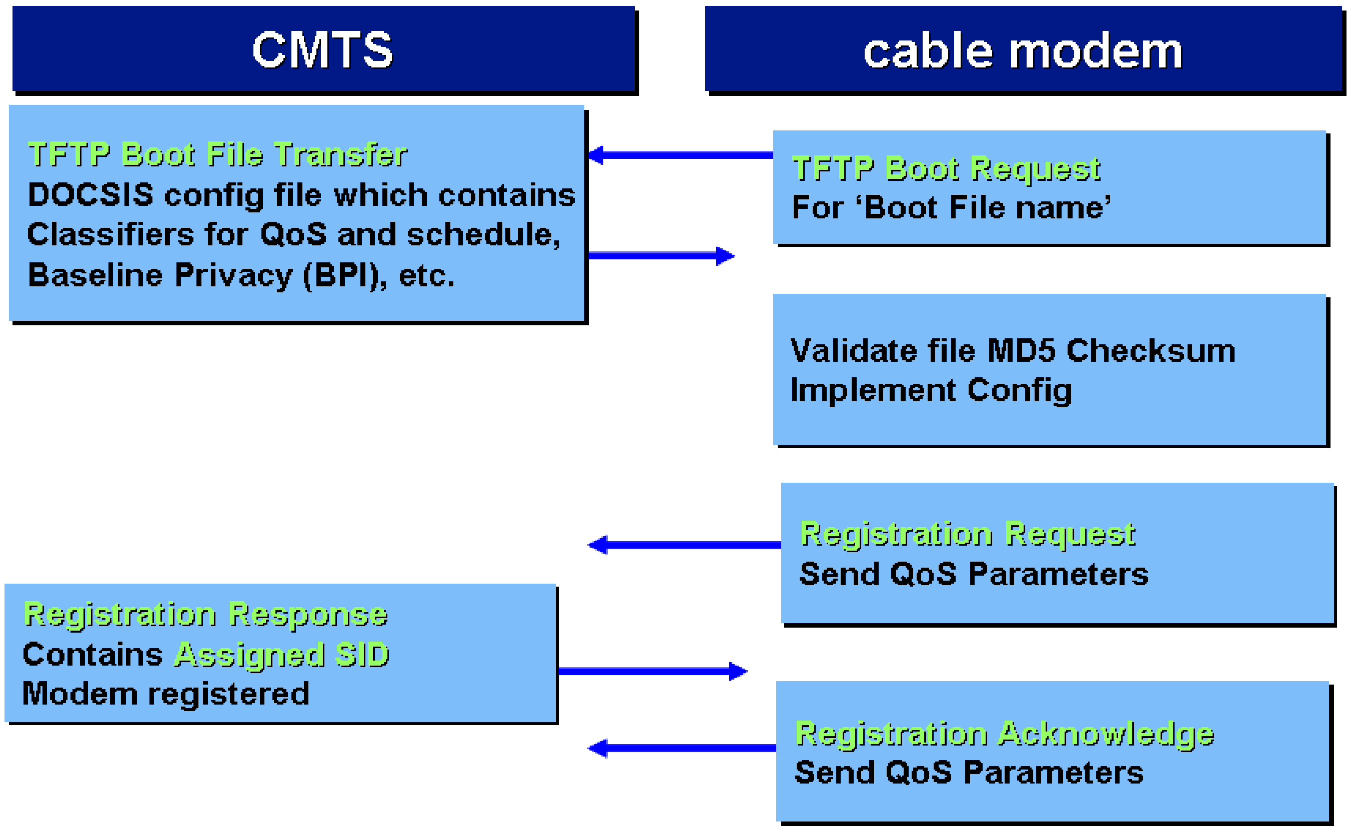
Next the cable modem is ready to move from DOCSIS protocol communications to IP layer communication and perform DHCP to get an IP address and the addresses of other devices in the network. Now that the cable modem is operating within its TDMA parameters, it must first ask for permission to transmit data to the CMTS by sending a bandwidth REQUEST. The CMTS will prioritize the request in its queue and issue a MAP for the specific cable modem. When the cable modem's time slot comes up, it can transmit a DHCP discover to find a DHCP server. The DHCP server on the network will respond and offer an IP address to the cable modem along with a number of other network addresses, gateways and parameters for proper network operation. A DHCP Request and Acknowledgement are required to complete and confirm the transactions.



DHCP and ToD

Next the cable modem will request the Time of Day from the ToD server. This is a simple transaction that was a requirement in DOCSIS 1.0, but has now become an option in later release of the specification. We will see in DOCSIS 3.0 that more emphasis is placed upon the critical nature of over-all network timing accuracy, but this will be addressed in a later post.

Now the cable modem is ready to download a very important file called a configuration file from the TFTP server. The configuration file contains all of the parameters the cable modems needs for network access speeds, quality of service, advanced service features such as voice-over-IP and much more. The following diagram illustrates the flow of procuring the configuration file.



TFTP Download and Registration

Upon validating the MD5 check-sum to ensure the TFTP file was properly downloaded, the cable modem is now ready to perform the most important step – registration. The cable will send a Registration Request to the CMTS along with a list of TLV (Type Length Value) parameters that tell the CMTS how the cable modem has been told it is to operate on the network. The CMTS reviews this information against the parameters it has been programmed with by the system administrator. Provided the cable modem has not be "hacked", data has been corrupted or there is an interoperability issue, the CMTS will send a Registration Response "Okay" message and assign the cable modem a Service IDentifier (SID). The cable modem will respond back with a Registration Acknowledgment notifying the CMTS that it has received confirmation of registration and it is now online and ready for subscribers to transmit Internet data.

So as a basic recap, the process goes throught the following steps:

- Downstream Channel Search and Lock
- DHCP
- ToD
- TFTP
- Registration

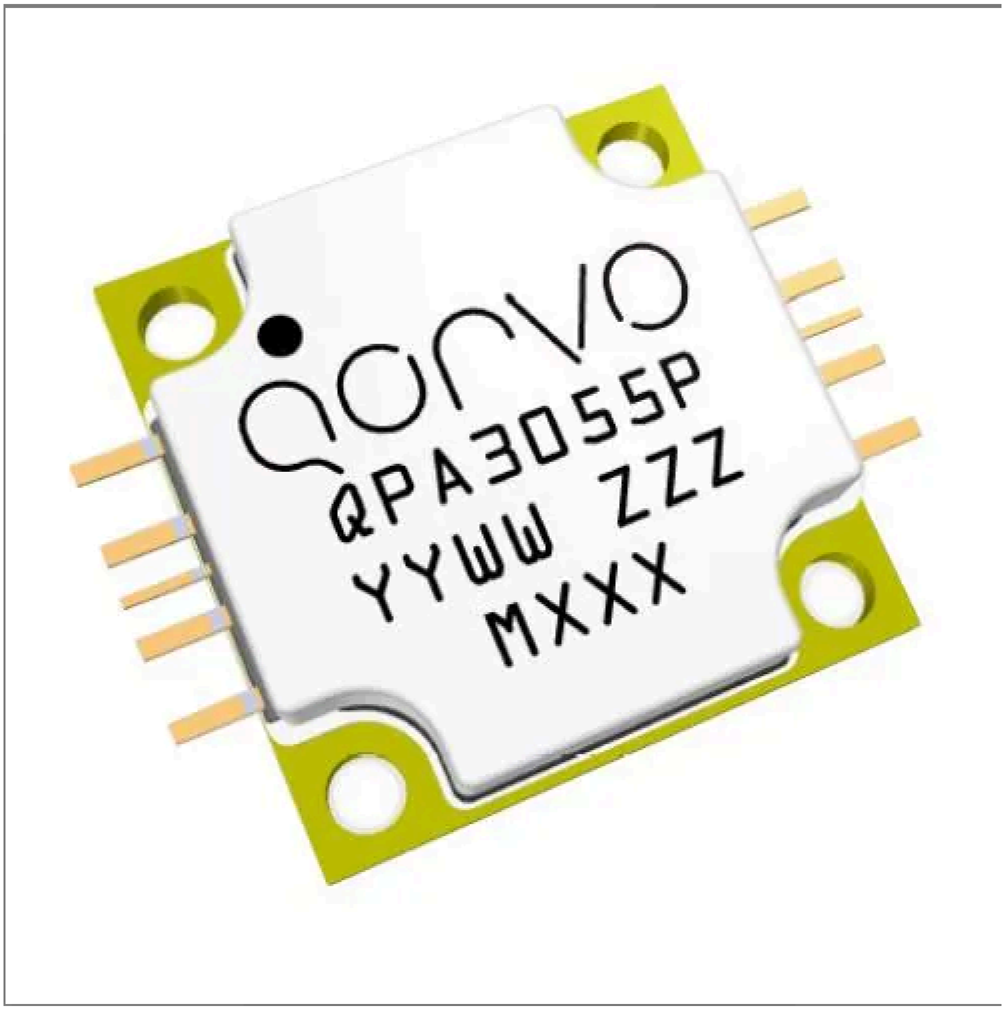
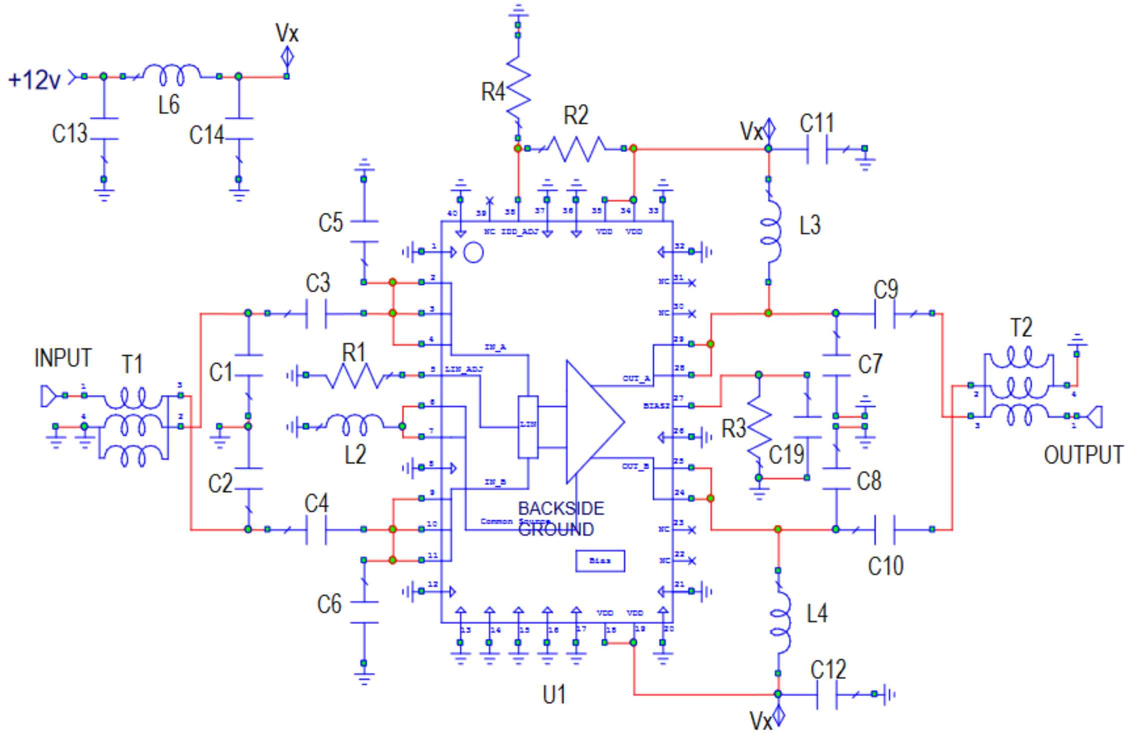


Figure 2 GaN Power Amp $1,029 per amp


ARRIS
RD1322
— REMOTE PHY DEVICE —
CONSOLE
POWER STATUS
DS-RF0
DS0
TP DS0
DS-RF1
DS1
TP DS1
US3
US2
US1
US0
US-RF0
TP RF0
US-RF1
TP RF1
ETH3
ETH2
ETH1
ETH0
DS OVERLAY
US OVERLAY



Tech Savvy Productions

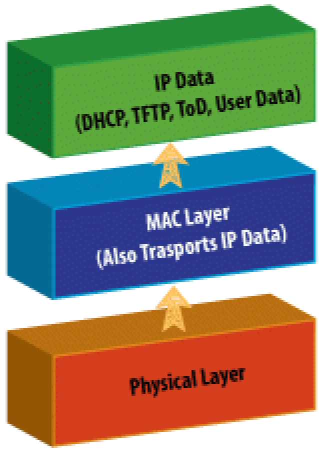
Cable Modem Registration | A Second Look

DOCSIS Cable Modems Registration Process

Even the most interesting man in the world enjoy's the DOCSIS cable modem registration process, so it is worth a second look. It is one of the most popular topics because it covers a wide range of how DOCSIS works, from physical layer to Internet protocol (IP) layer. It is therefore worthy of an encore article with more depth and an update to include DOCSIS 3.0.

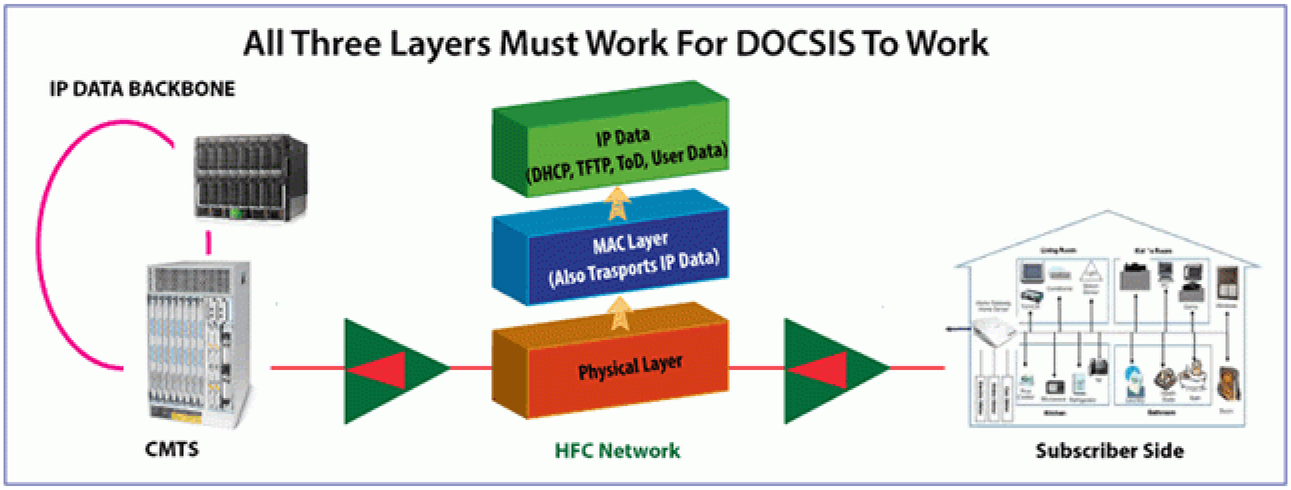
https://volpefirm.com/cable-modem-registration-a-second-look/

During the cable modem registration process it is important to understand that three (3) different levels of communication must take place in order for the registration process to be successful. The first is the RF physical layer which consists of downstream radio frequency signals from the CMTS to the cable modem and upstream radio frequency signals transmitted from the cable modem to the CMTS. These RF signals are transmitting digital data that has been modulated on an analog signal. Second, Media Access Control (MAC) Layer information is contained on the RF signals and is critical communications between the CMTS and cable modem. Finally, IP data is encapsulated in the MAC Layer data, and so it's transported by the RF signals between the cable modem and different severs located beyond the CMTS. In this case the CMTS acts as a relay agent (or router) for the data sent back and forth between the cable modem and IP servers. These multiple services of communications built on top of each other is commonly referred to as the Open Systems Interconnection Reference Model or OSI Model. Conceptually the OSI model for DOCSIS looks like this:



It is important to understand that this is a simplified OSI model and some layers are omitted for the purpose of discussion. What should be apparent from this illustrations is that they physical layer is fundamental to all other layers operating. Today's hybrid-fiber coaxial networks (HFC) are bi-directional (meaning RF signals flow in both directions to and from the home). Signals from the CMTS to the cable modem for DOCSIS 2.0 and 1.x are limited to 88 MHz too 860 MHz while DOCSIS 3.0 cable modems are have an expanded range of 108 MHz to 1002 MHz. This is called the downstream. The DOCSIS upstream starts at 5 MHz and ends at 42 MHz for North America, while Europe supports 65 MHz and DOCSIS 3.0 supports up to 85 MHz. A challenge in all of these scenarios is that the downstream and particularly the upstream have numerous impairments causing MAC Layer and IP Layer data impairments (see my articles on Troubleshooting DOCSIS).

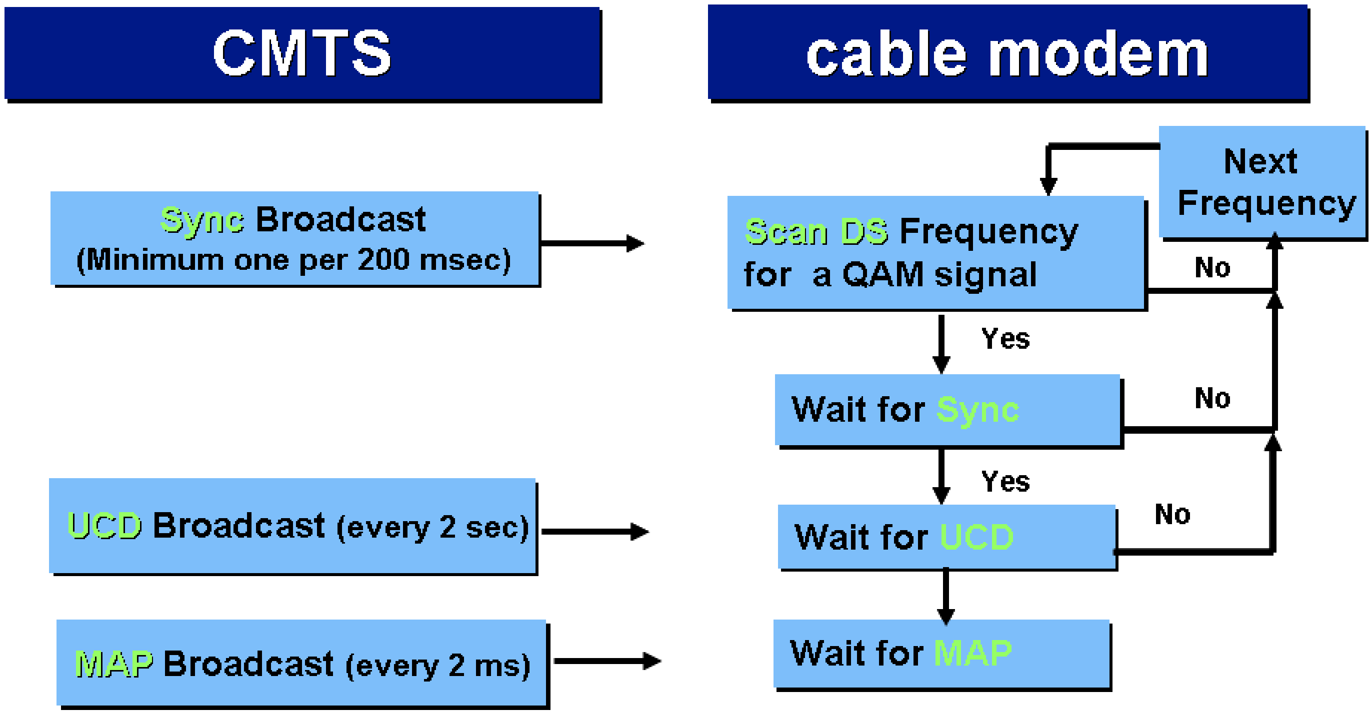
First let's consider the picture below to understand conceptually the DOCSIS network as it exists in a standard cable TV (hybrid fiber-coax or HFC) network.



DOCSIS in a HFC Network

On the left is a Cable Modem Termination System (CMTS) is connected to an Internet back bone in addition to some level of local or remote back office network of servers. The back office servers provide provisioning to cable modems, DOCSIS set-top boxes and embedded Multimedia Terminal Adapters (eMTAs). The most basic elements of the provisioning servers include a Dynamic Host Configuration Protocol (DHCP) server, a Trivial File Transfer Protocol (TFTP) server, and a Time of Day (ToD) server. The CMTS transmits downstream data via 64- or 256-QAM signals over the RF Plant to the subscriber's home cable modem. The cable modem transmits data to the CMTS on the upstream over the RF Plant via QPSK, 8-, 16-, 32-, or 64-QAM modulation. It is at this point that we must make the assumption that the RF Plant (essentially miles of coaxial cable, fiber optic cable, RF amplifiers, a fiber optic node, Erbium-doped fiber optic amplifiers and countless RF passive devices) is capable of supporting the RF modulations being transmitted by the DOCSIS devices without significant degradation to stop higher layer communications.

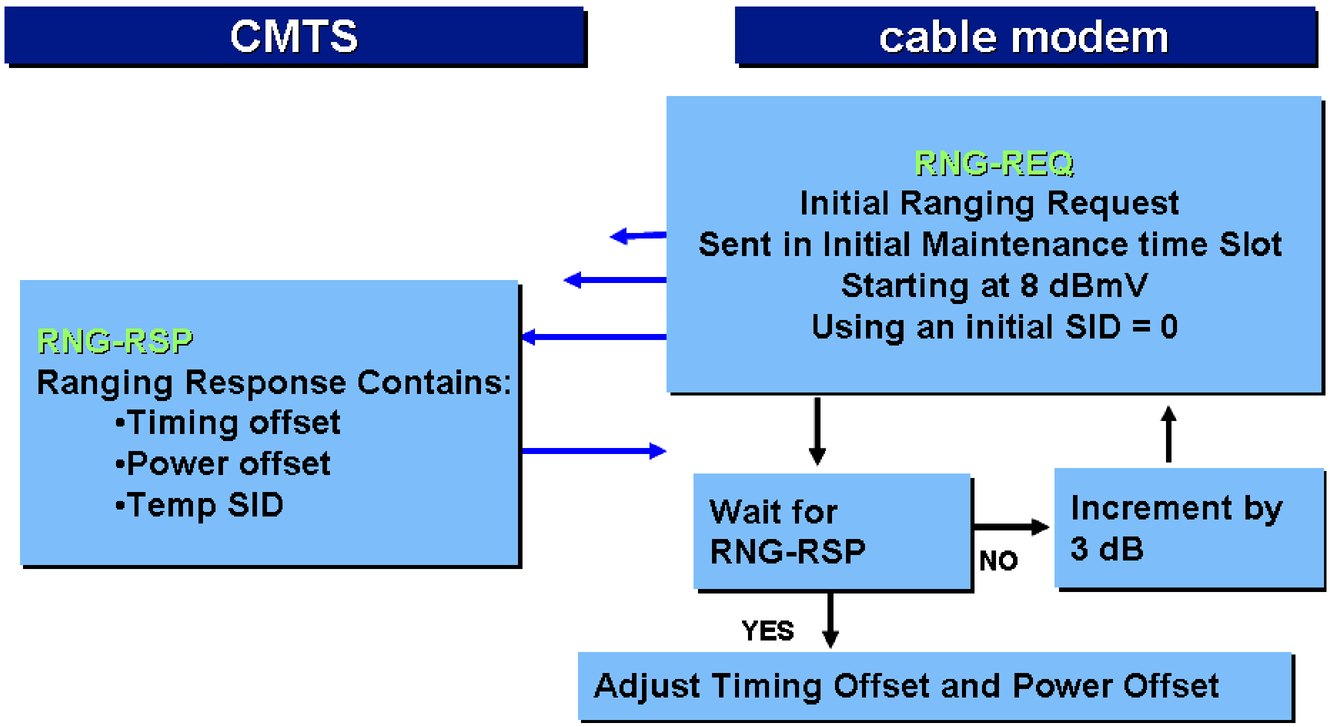
DOCSIS Downstream Scanning and Channel Acquisition



Once a cable modem is powered on and connected to the RF cable of a CATV network, it will begin a "hunt" for a valid downstream DOCSIS channel. First the cable modem looks for and locks to any 64- or 256-QAM digital channel. Fortunately for the modem, the CMTS is sending out a "Sync" broadcast at least every 200 msec, which is used for system timing. In addition, the CMTS sends out an Upstream Channel Descriptor (UCD) every two seconds, which tells modems the upstream frequency to transmit on, symbol rate, modulation profile, and other parameters necessary to communicate on the network. Finally the CMTS is sending out Media Access Protocol (MAP) messages to allocate "talk time" to each cable modem. You see, since there are many cable modems and only one upstream frequency, the cable modems must "time-share" the upstream channel, which is called Time Division Multiple Access (TDMA). Now, when the cable modem successfully locks to a QAM channel, it looks for the Sync, UCD and MAP messages from the CMTS. If it finds these it knows it is on an active DOCSIS channel. If they are not present, the cable modem assumes the QAM channel is a video channel and continues its search.

DOCSIS Cable Modem Ranging / Station Maintenance

Assuming a successful lock above, the cable modem is now ready to begin ranging with the CMTS. The ranging process begins with Initial Ranging, which is a process in which the cable modem begins by sending a Range-Request (RNG-REQ) at its lowest transmit power (8 dBmV for DOCSIS 2.0 and 1.x modems and typically 23 dBmV for DOCSIS 3.0 modems). If it does not receive a Range-Response (RNG-RSP) from the CMTS within 200 msec the cable modem increases its transmit power by 3 dB and retransmits the RNG-REQ. Repeating this process until a RNG-RSP is received. See the following diagram:




VIAVI
OneExpert
Sync
Network
Error
Batt
62%
04:19 PM
ChannelCheck
Tap
Ground Block
CPE
0.0
-20.0
-40.0 dBmV
54.000
MHz
860.000
17.0
-15.5
-48.0 dBmV
CH OFDM
PLC LEVEL
11.3
dBmV
PLC MER
43.9
dB
0.00e+00
0.00e+00
0.00e+00
0.00e+00
4.46e-01
0.00e+00
10.3
11.3
9.9
ICFR
2.0
42.1
1.4
37.6
Echo
-41.5
Save
Sync
Start
OK

All initial ranging occurs during a “contention” window, which means that the CMTS does not have prior knowledge of the cable modems existence, but established a window of opportunity for new cable modems to range called the initial ranging window. Therefore it is possible that when multiple cable modems are attempting to register during the contention window that they could interfere with each other and cause collisions. DOCSIS has a built-in back-off window for just such an occurrence which will help alleviate collisions in the contention window. This is most prevalent when there is a system outage and many cable modems are trying to come back online at the same time. Once the modem has received its first RNG-RSP from the CMTS it will moved from Initial Ranging to Station Maintenance. The cable modem will also be instructed by the CMTS to make adjustments to its transmitting frequency, amplitude, timing offset and optionally pre-equalization. Station Maintenance (Ranging) will occur at least once every 30 seconds (typically every 20 seconds) for each cable modem on the DOCSIS network to continue making these adjustments and so that the CMTS knows the modems are online. It is during the station maintenance window when T3 and T4 timeouts are logged.

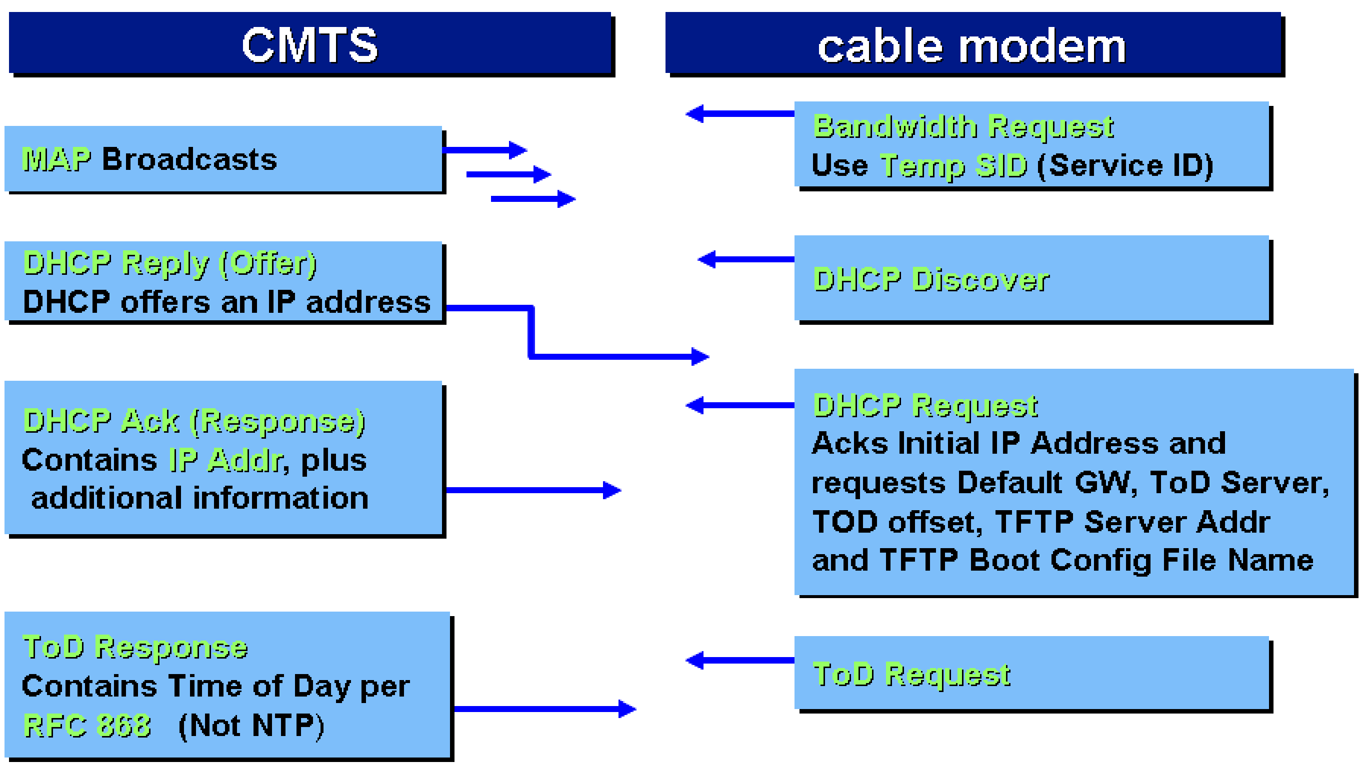
A Brief Aside on T3 and T4 Timeouts

T3 and T4 timeouts occur during station maintenance and do provide insight to the health of a DOCSIS plant as well as diagnostics. The counters themselves are in the DOCSIS cable modems and start and stop at the beginning and end of the station maintenance process. The CMTS sends a MAP message to the cable modem instructing it to send a RNG-REQ to the CMTS, so the CMTS knows the message is coming. Once the cable modem transmits the RNG-REQ it starts an internal counter. If the cable modem does not receive a RNG-RSP in 200 msec it flags a T3 timeout. One can assume if the CMTS did not send the RNG-RSP it most likely did not receive the RNG-REQ due to upstream impairments, therefore T3 timeouts usually indicate upstream impairment.

When the CMTS does not receive the RNG-RSP it will send a new MAP for another RNG-REQ. If again the RNG-RSP is not received another T3 timeout will be generated. Once a certain number of T3 timeouts or time is exceeded (typically about 15 T3 timeouts, but this is vendor-based), the cable modem will be forced to re-register and a T4 timeout error will be logged. A T4 timeout can indicate an upstream that is not passing traffic or even possible downstream problems. But most often a T4 timeout occurs when the MAP message for a RNG-REQ is lost in the downstream, which indicates potential downstream issues.

DOCSIS Cable Modem DHCP

Next the cable modem is ready to move from DOCSIS protocol communications to IP layer communication and perform DHCP to get an IP address and the addresses of other devices in the network. Now that the cable modem is operating within its TDMA parameters, it must first ask for permission to transmit data to the CMTS by sending a bandwidth REQUEST (REQ). The CMTS will prioritize the request in its queue and issue a MAP for the specific cable modem. When the cable modem's time slot comes up, it can transmit a DHCP discover to find a DHCP server. The DHCP server on the network will respond and offer an IP address to the cable modem along with a number of other network addresses, gateways and parameters for proper network operation. A DHCP Request and Acknowledgement are required to complete and confirm the transactions. DOCSIS 3.0 devices have the option of obtaining IPv4 or IPv6 IP addresses.

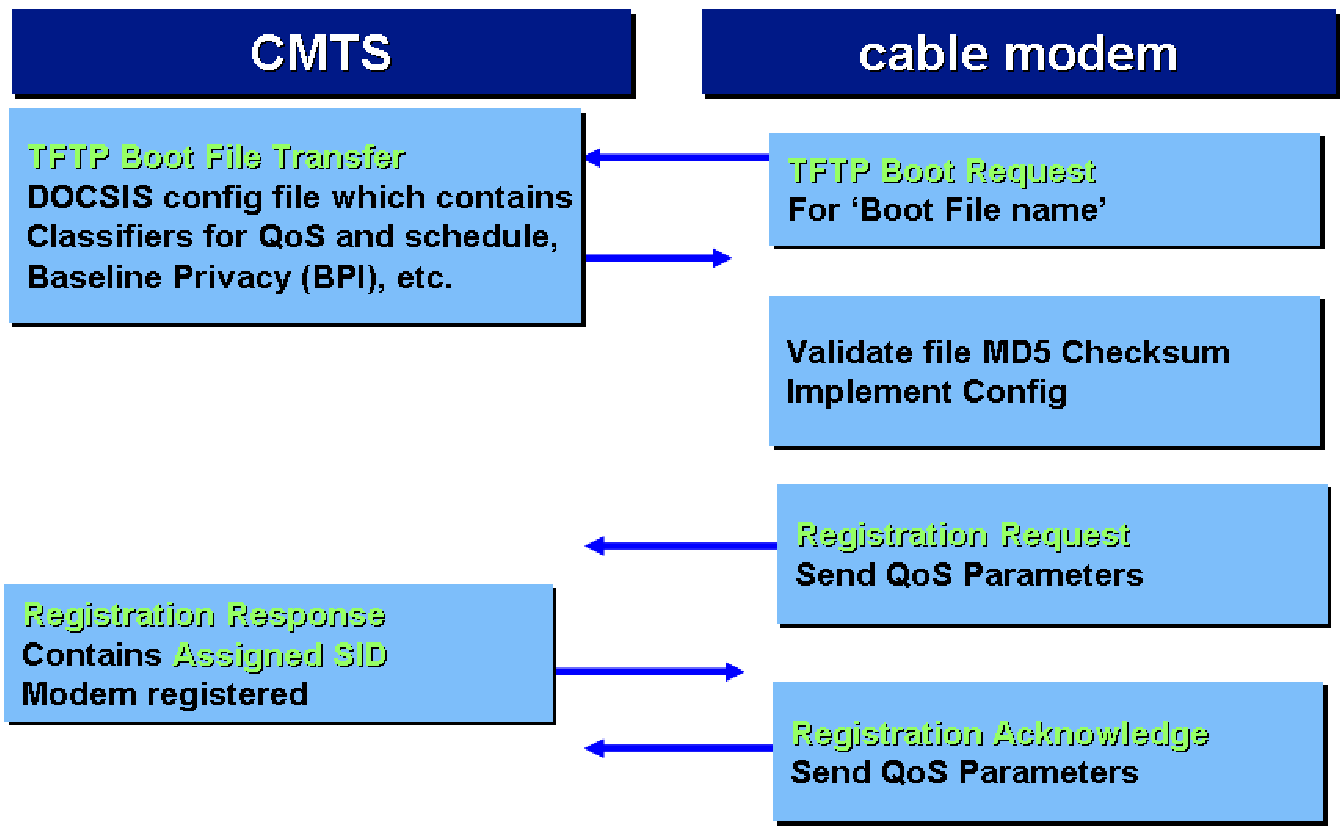


DHCP and ToD

Next the cable modem will request the Time of Day from the ToD server. This is not to be confused with the DOCSIS Timing Interface (DTI) server that is part of DOCSIS 3.0 dramatically improves overall timing accuracy.

DOCSIS Cable Modem Configuration File

Now the cable modem is ready to download a very important file called a configuration file from the TFTP server. The configuration file contains all of the parameters the cable modems needs for network access speeds, quality of service, advanced service features such as voice-over-IP and much more. The following diagram illustrates the flow of procuring the configuration file.



Upon validating the MD5 check-sum to ensure the TFTP file was properly downloaded, the cable modem is now ready to perform the most important step – registration. The cable will send a Registration Request to the CMTS along with a list of TLV (Type Length Value) parameters that tell the CMTS how the cable modem has been told it is to operate on the network. The CMTS reviews this information against the parameters it has been programmed with by the system administrator. Provided the cable modem has not be "hacked", data has been corrupted or there is an interoperability issue, the CMTS will send a Registration Response "Okay" message and assign the cable modem a Service IDentifier (SID). The cable modem will respond back with a Registration Acknowledgment notifying the CMTS that it has received confirmation of registration and it is now online and ready for subscribers to transmit Internet data.

DOCSIS 3.0 Cable Modem Additions

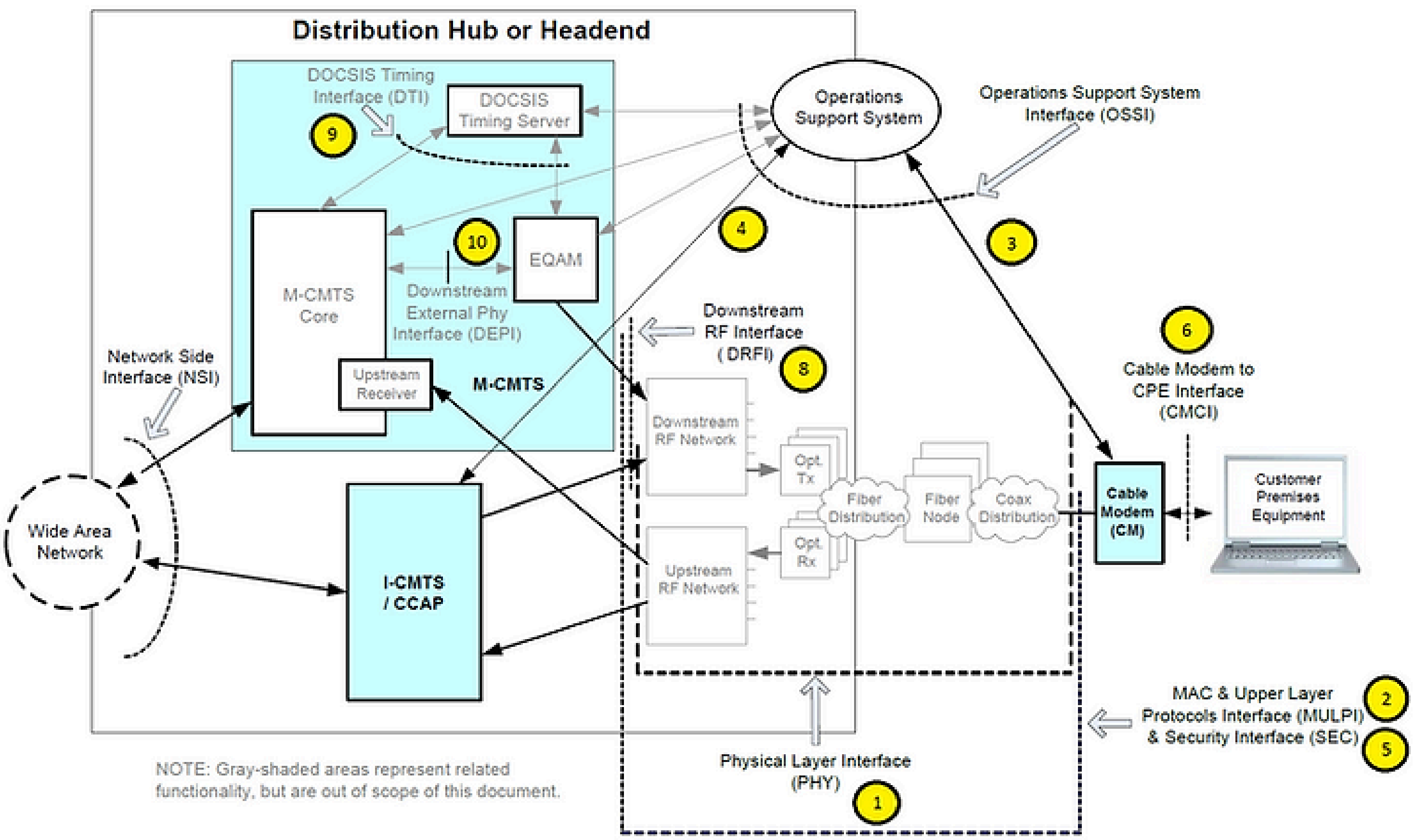
The registration process with a DOCSIS 3.0 cable modem is significantly more complicated than with DOCSIS 1.x or 2.0 cable modems. There are some similarities in that the cable modem must provide its Time, Length, Value (TLV), class of service and other parameters to the CMTS via a REGistration REQuest (REG-REQ) message. The CMTS validates this information and determines if the cable modem is permitted to be on the DOCSIS network. In the case of a DOCSIS 3.0 cable modem, if there are other downstream and/or upstream channels that need to be bonded, this is the time that the bonding must occur.

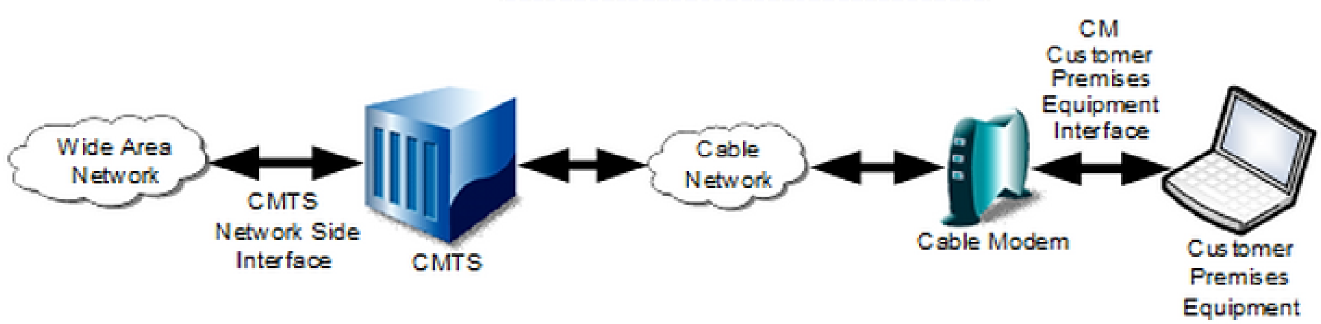
The CMTS checks its Receive Channel Profile (RCP) against the what the cable modem has been told to bond channels in the downstream. If these match up, the CMTS enables Multiple Receive Channel Mode in the cable modem and the cable modem will start downstream bonding. The cable modem must also tell the CMTS that it is able to receive all of the downstreams against a Receive Channel Configuration (RCC) message sent by the CMTS. If anything fails during this process it is likely that the cable modem will end up reverting to a DOCSIS 2.0 state because downstream channel bonding is usually an all-or-nothing proposition. CMTSs are typically not configured to allow for partial downstream bonding, though this can be done with substantial effort.

If the cable modem supports multiple upstream channel transmit and the CMTS is configured for it, the CMTS will enable Multiple Transmit Channel Mode and provide a Transmit Channel Configuration (TCC) message telling the cable modem the center frequency of each upstream channel. Next the cable modem will range with each upstream channel on the TCC. What differs with upstream bonding is if the cable modem us not able to range and register with a particular upstream channel, the cable modem will notify the CMTS but will be permitted to stay online in DOCSIS 3.0 mode and register with as many upstreams as possible. This is called partial service and was discussed in a previous article.

After registration a cable modem could next enter an encryption mode called Baseline Privacy Interface (BPI) protocol.

Cable Physical Layer





1) SP-PHYv3.1 Physical Layer Specification [link][I17]

2) CM-SP-MULPIv3.1 MAC and Upper Layer Protocols Interface Specification [link][I20]

3) CM-SP-CM-OSSIv3.1 Cable Modem Operations Support System Interface Specification [link][I16]

4) CM-SP-CCAP-OSSIv3.1 CCAP Operations Support System Interface Specification [link][I17]

5) CM-SP-SECv3.1 Security Specification [link][I09]

6) CM-SP-CMCIv3.0 Cable Modem CPE Interface Specification [link][I03]

7) CM-SP-eDOCSIS eDOCSIS™ Specification [link][I30]

8) CM-SP-DRFI Downstream Radio Frequency Interface Specification [link][I16]

9) CM-SP-DTI DOCSIS Timing Interface Specification [link][I08]

10) CM-SP-DEPI Downstream External PHY Interface Specification [link][I14]

11) CM-SP-DSG DOCSIS Set-Top Gateway Interface Specification [link][I25]

12) CM-SP-ERMI Edge Resource Manager Interface Specification [link][C01]

13) CM-SP-L2VPN Layer 2 Virtual Private Networks Specification [link][I15]

14) CM-SP-TEI TDM Emulation Interfaces Specification [link][I06]

All specs zip [link]

References

- CableLabs icon from [link]
- DOCSIS® 3.1 Physical Layer Specification CM-SP-PHYv3.1-I17-190917 [link]

What should my Signal Levels be?

Downstream (Rx) Receive Power Level:
This is the amount of signal received by the modem from the transmitter in the cable company head-end.

For all modems DOCSIS 3.0 / 3.1:

-7 dBmV to +7 dBmV "Recommended"
-8 dBmV to -10 dBmV / +8 dBmV to +10 dBmV - "Acceptable"
-11 dBmV to -15 dBmV / +11 dBmV to +15 dBmV - "Maximum"
Lower than -15 dBmV & Higher than +15 dBmV - "Out Of Spec."

SNR (signal to noise ratio) levels:
This is how clear the signal is at either the modem receiver (downstream SNR) or the receiver in the cable company head-end (upstream SNR).

DOCSIS specifications list minimum CNR (carrier to noise ratio) levels not SNR levels. The SNR levels listed here are based on commonly recommended MER levels for digital cable signals. Not all QAM demodulator chipsets accurately calculate SNR levels that approximate actual MER levels, so these levels may vary depending on which chipset and/or firmware is used in the equipment.

***There is no upper SNR limit.**

For all modems DOCSIS 3.0 / 3.1:

256 QAM: 30 dB minimum. 33 dB or higher recommended.
64 QAM: 24 dB minimum. 27 dB or higher recommended.
16 QAM: 18 dB minimum. 21 dB or higher recommended.
QPSK: 12 dB minimum. 15 dB or higher recommended.

Downstream SNR levels are read at the modem on the downstream data channel and can be viewed using the modem diagnostic screens.

Upstream SNR levels are read at the CMTS on the upstream data channel, not the modem or the modem diagnostic screens. The end-user cannot get the upstream SNR directly. Only the provider can read the upstream SNR level, directly from the CMTS. Also, the upstream SNR level provided by most CMTSs is not specific to any single modem, but is an averaged, aggregate level from all modems on that upstream channel on the upstream port.

Upstream (Tx) Transmit Power (a.k.a. Return Signal) level:
This is the amount of signal transmitted by the modem to reach the receiver in the cable company head-end.

***Recommended Upstream signal levels are +35 dBmV to +47 dBmV (DOCSIS 3.1)**
***Recommended Upstream signal levels are +35 dBmV to +49 dBmV (DOCSIS 3.0)**

50 dBmV maximum for OFDMA (DOCSIS 3.1)
52 dBmV maximum for A-TDMA, TDMA & SC-QAM (DOCSIS 3.0)
53 dBmV maximum for S-CDMA DOCSIS 2.0 (All Modulations)
54 dBmV maximum for 32 QAM and 64 QAM. (A-TDMA DOCSIS 2.0)
55 dBmV maximum for 8 QAM and 16 QAM. (DOCSIS 1.0, 1.1)
58 dBmV maximum for QPSK. (DOCSIS 1.0, 1.1)

A cable modem running a higher upstream modulation rate may downgrade itself to a lower modulation rate (i.e. 64 QAM to 16 QAM or 16 QAM to QPSK) if the upstream transmit level is higher than the maximum signal level allowed for the higher modulation rate and the CMTS is configured to allow such a change. This downgrade can cause slow speed, packet loss, and connection loss issues depending on the condition of the upstream channel.

A house or drop amplifier will NOT fix an upstream signal problem because most house amplifiers don't amplify the upstream signals; they only pass the upstream signal through with some loss.

Important notes concerning signal levels:
1. Signal levels not within the specifications listed above can cause slow speeds, connection problems, and connection loss due to packet errors, packet loss, and/or constant packet re-transmission.

2. It's recommended to have the modem's signal levels at least 3dB away from the maximum/minimum levels listed above due to normal temperature related signal variation. If the modem's signal levels are at the maximum or minimum limits, they may be out of spec. if the temperature changes significantly. Signal levels that vary more then 3 dB in a 24-hour period usually indicate a problem that should be looked into.

3. Excess splits, bad connectors, and/or poor quality cabling will certainly effect cable signal levels and will cause problems.

Cable modems often have a diagnostics web page that can help view the cable signal details (signal strength, upstream/downstream power levels, SNR, etc.). This information can be very useful in troubleshooting common connection issues. For Motorola/Arris cable modems, the stats page is at: http://192.168.100.1/. For other models, refer to our broadband hardware database with over 3500 listed devices. You can use the values below as a guideline as to what good "signal levels" are.

Downstream Power (-15dBmV to +15dBmV) - *measure of the signal level received by the cable modem*
Most modems are rated from -15dB to +15dB, however it's best to have it between +8dB and -8dB. Anything less or more than that and you may have quality issues. You can remove splitters on the line if you need to raise and clean up your signal level a bit. You can also use a tap (directional coupler) to get a cleaner signal to the cable modem instead of a splitter.

Upstream Power / Modulation(35dBmV to 55dBmV) - *the strength of signal transmitted by the cable modem*
Generally a lower this number is better. Above 53dB will most likely cause problems, over 57dB and you probably won't be able to connect. Ideally between 40 and 50dB. Lower than 38 may start introducing some packet loss (especially if you have much noise on the line). If you hit 58 the modem will likely drop the connection and resync. Low levels (below 35dBmV) get too close to the noise floors in most areas, causing issues.

Signal/Noise Ratio (SNR , >30dB) - *measure of how clear the signal is*

SNR is best over 30, (the higher the better, might work well with as low as 25 at times). Anything less than 25 will cause dropped connections, packet loss, slow transfers, etc. This is true for both the "Downstream SNR" and the "Upstream SNR", which may be different values. Typically, cable modems show the Downstream SNR, the Upsteram SNR can only be calculated at the remote end of the coax (usually at the node). Just remember that higher SNR means cleaner signal. A value well over 40 may mean you have too much power.

Notes:

Different brand modems may represent the information a bit differently, and may react a little different to exact power levels. For example, Brand/Model A cable modem may have fewer disconnects and timeouts at Downstream Power level closer to the end of the acceptable range (let's say +11dbmV), than Brand/Model B.

High downstream Power (DS) can be reduced closer to zero using a Forward Path Attenuator (FPA).

If there is a 5dB+ tilt on the DOCIS channels (difference in power levels), this could point to water in the line/tap, chewed up insulation, radial crack in the hardline cable, or a failing amplifier near you. That's too much loss in a short spectrum of channels.

https://www.veracityglobal.com/home.aspx

Veracity's HIGHWIRE Ethernet over Coax (EoC) transmission technology revolutionised the way IP video was installed when it was launched back in 2006, and, thanks to its high performance and straightforward, installer-oriented design, remains the universally dominant EoC technology today. This article explains more about EoC technology, its applications and how to use it.

Ethernet over Coax technology

IP cameras offer many benefits compared to analog equipment, including megapixel resolution and increased intelligence and controllability. However, a major hurdle to their adoption for upgrading existing sites is the necessity of new cabling. The cost of laying new Cat 5e cable for network devices can be significant, plus the cable length limitations of Ethernet can be restrictive.

HIGHWIRE provides a means to overcome this hurdle, by re-using the existing analog cabling to create new network connections. This is possible because, ironically, the RG-59 or similar "analog" coaxial cable that may already be present on a site is actually a better transmission medium for digital data than the UTP cable that would otherwise have replaced it. Coaxial cable has a higher bandwidth, with lower noise and signal loss, meaning it can carry more data for greater distances: this is why it costs more than twisted-pair network cable.

To take advantage of this existing infrastructure, Veracity developed their unique HIGHWIRE Ethernet over Coax technology from the ground up to provide a full 100 megabit per second connection in both directions simultaneously, even at maximum range, over a single 75 ohm coaxial cable.

Ethernet over Coax applications

While HIGHWIRE is targeted at IP video surveillance applications, it has been used to provide network connections over a variety of coaxial cable types in different situations, including:

New extended network connections, where it is more cost effective than optical fibre

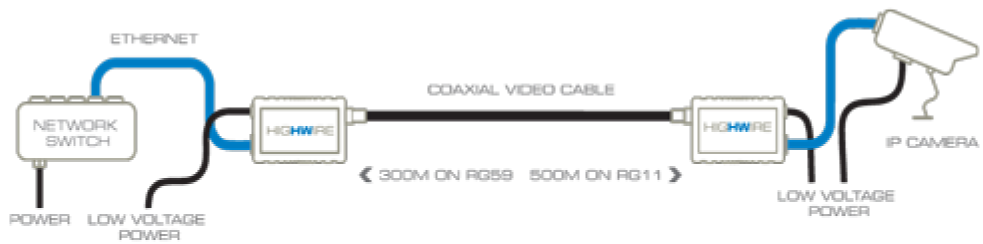
Cable television (CATV) and satellite cabling, including residential and hotel applications

Upgrading of legacy 10BASE2/10-BASE5 (thinnet/thicknet) networks to 100BASE-TX

Pipe and tunnel inspection, deep-sea exploration, rail, radar systems, and other niche applications

How to upgrade analogue coaxial cable to digital

Fortunately, the advanced technology developed to enable HIGHWIRE's unmatched performance also makes HIGHWIRE very straightforward to use, with no specialist knowledge required.

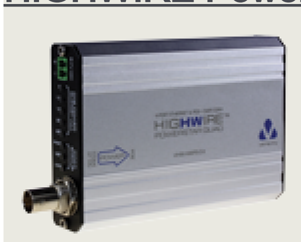


Upgrading an analogue network cable to digital using two standard HIGHWIRE units.

When two HIGHWIRE units are connected together over a coaxial cable, they establish a connetion automatically. No DIP switches (for speed, master/slave configuration, etc) needs to be set. And because HIGHWIRE is a low-power technology, the units can be connected to the low-voltage supplies already installed for the old system.

Network connection is also automatic, and no settings such as IP or MAC address need to be made as the Ethernet-to-coax conversion is completely transparent. This means that, as far as the IP camera and network switch in the diagram above are concerned, they are connected directly by a single cable.

HIGHWIRE Powerstar Quad - Ethernet over Coax for up to four IP cameras

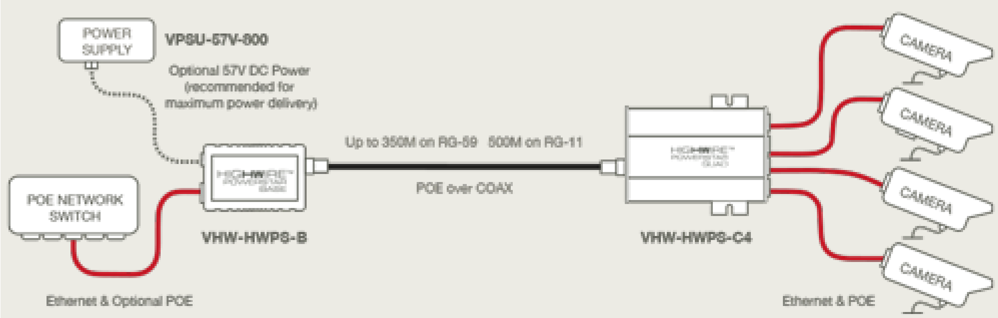


Connect up to four IP cameras with HIGHWIRE Powerstar Quad over an existing coax cable.

Connect up to 4 IP cameras with HIGHWIRE Powerstar Quad over an existing coax cable

HIGHWIRE Powerstar Quad makes the most of your legacy cabling and multiplies its capability by connecting up to four IP cameras or other network devices

...more product details



- Key technical features
- Applications
- Product codes
- Documentation

| Re-uses existing coax cable for 2 IP cameras or devices

| Integrated 2-port POE switch (POE Plus with local power option)

| Eliminates separate power cabling with POE-over-Coax™

| Compatible with all HIGHWIRE Powerstar Base units (1, 4 & 8ch)

| Instantly check connection and power level with SafeView™

| Completely automatic connection, no configuration required

| 100BaseTX performance over 300m of RG59 (500m on RG11)

| Re-uses existing coax cable for up to 4 IP cameras or devices

| Integrated 4-port POE switch (POE Plus with local power option)

| Eliminates separate power cabling with POE-over-Coax™

| Compatible with all HIGHWIRE Powerstar Base units (1, 4 & 8ch)

| Instantly check connection and power level with SafeView™

| Completely automatic connection, no configuration required

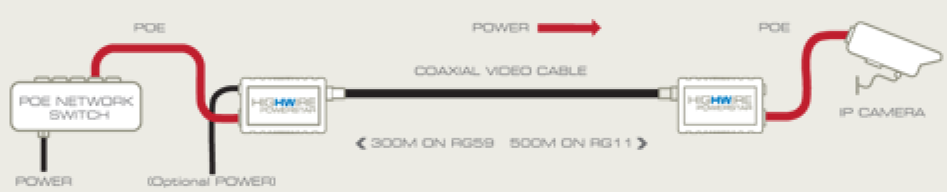
| 100BaseTX performance over 300m of RG59 (500m on RG11)

Fast Ethernet and POE power over coax video cable

HIGHWIRE POWERSTAR lets you install IP cameras easily, quickly, and reliably, without the disruption and expense of installing new cable.

Support for your camera is assured, thanks to HIGHWIRE's unique full-rate Ethernet over Coax technology, which has been tested and trusted by thousands of IP installers worldwide since it launched as an industry first in June 2006.

And now with POE over Coax, you can deliver up to 25 watts of POE power to the camera as well, eliminating the complexity of installing local power supplies.
...more product details



- Key technical features
- Applications
- Product codes
- Documentation

Range

See table in datasheet or manual. Examples, with full 100Base-TX throughput:

- 10 watts of POE at 265m (880ft) of 22AWG CCS RG-59 from a Veracity power supply

- 10 watts of POE at 300m (1000ft) of 20AWG RG-59 from an 802.3af POE switch

- 20 watts of POE+ at 300m (1000ft) of 20AWG RG-59 from an 802.3at POE+ switch

- 25 watts of POE+ at 500m (1600ft) of 14AWG RG-11 from a Veracity power supply

Power

Unit power 1.5 watts max

BASE POE in IEEE 802.3af or 802.3at, class 4 (25.5W max)

CAMERA POE out IEEE 802.3af or 802.3at, any class (25.5W max)

DC power input 44-57 volts, 0.7 amps max, class 2 isolated, screw terminal

Network

100Base-T full-duplex Ethernet with auto-negotiation

Patch or crossover cables auto-detected

Dimensions

84 x 54 x 24mm (3.3 x 2.1 x 0.95in) / 104mm (4.09in) including connector

100g (3.5oz)

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Ethernet over Coax (EoC) Switches & Extenders

Use our award-winning Ethernet over Coax switches and extenders to deliver PoE+ (30W) over coax cabling with up to 6,000ft (1,830m) reach.

- Leverage any new or existing network infrastructure
- Support IP and IoT devices up to 18-times farther
- Modernize without risk, disruption, or complexity

The plug and play EC10 (Coax Leveraged Ethernet Extended Reach) unmanaged switch makes the modernization to IP devices (IoT) simple, secure and cost-effective. When paired with the EC Adapters, this powerful enterprise-grade switch delivers fast Ethernet and PoE+ over Coax cable with up to 3,000ft (915m) reach – **that's 10Xs the reach of standard Ethernet switches.**

With the EC10, customers are taking full advantage of Modern LAN principles, protecting existing infrastructure assets, and eliminating any need to rip/replace the established Coax cabling. The EC10 unmanaged switch optimizes network design with advanced interoperability and easy integration into the overall LAN creating a secure, robust path for IP endpoints.

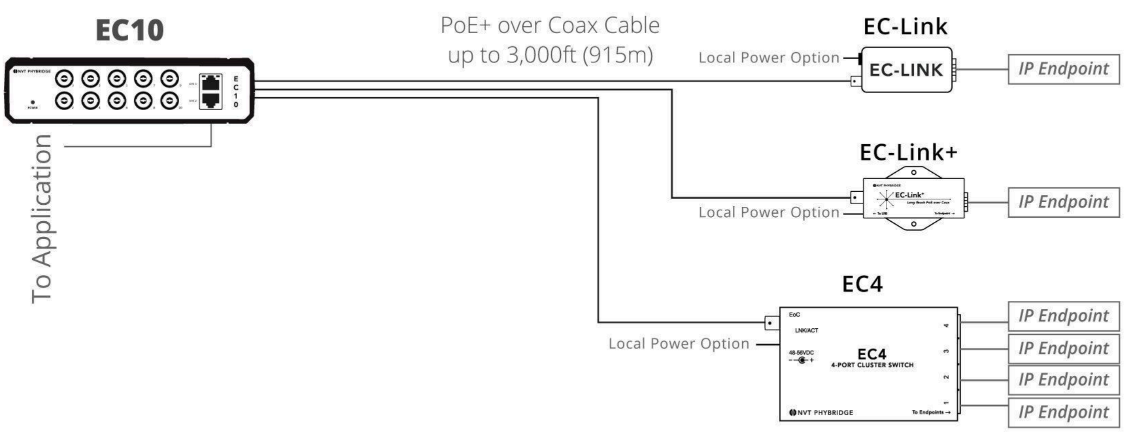
- Accelerate your return on investment by reducing infrastructure costs .
- Simplify your IP modernization, collapsing planning and deployment time.
- Eliminate infrastructure barriers, risks, disruption, and costs.
- Create a robust plug-and-play IP platform that is easy to deploy and manage.
- Be environmentally responsible during your IP upgrades.

Speed, Reach and Power

EC10 delivers 100Mbps symmetrical (full duplex) and PoE+ (30W) over Coax with 3,000ft (915m) reach, providing substantial power to support bandwidth demanding IP endpoints easily and reliably.

Simple Deployment

EC10 comes preconfigured and ready to deploy, making modernization to IP quick and efficient in organizations of every size. Modernizing multiple sites is greatly simplified with a repeatable, predictable and scalable deployment methodology across every location.



Dualcomm Ethernet Over Coax (EoC) Adapters (DECA-100) - Twin Pack
[Brand: Dualcomm]

Lowest price in 30 days

-25% $59.98$59.98

Was: $79.98$79.98

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- Passive adapter for Ethernet transmission over a coaxial cable. Compatible with point-to-point or home-run cabling only.
- Transmission distance up to 600 feet (RG59)/800ft (RG6)
- Great for migrating analog video surveillance systems to IO camera based systems
- Great for 100Mbps home network over existing in-house coax cabling
- Low cost and easy to install with thousands of satisfied users worldwide

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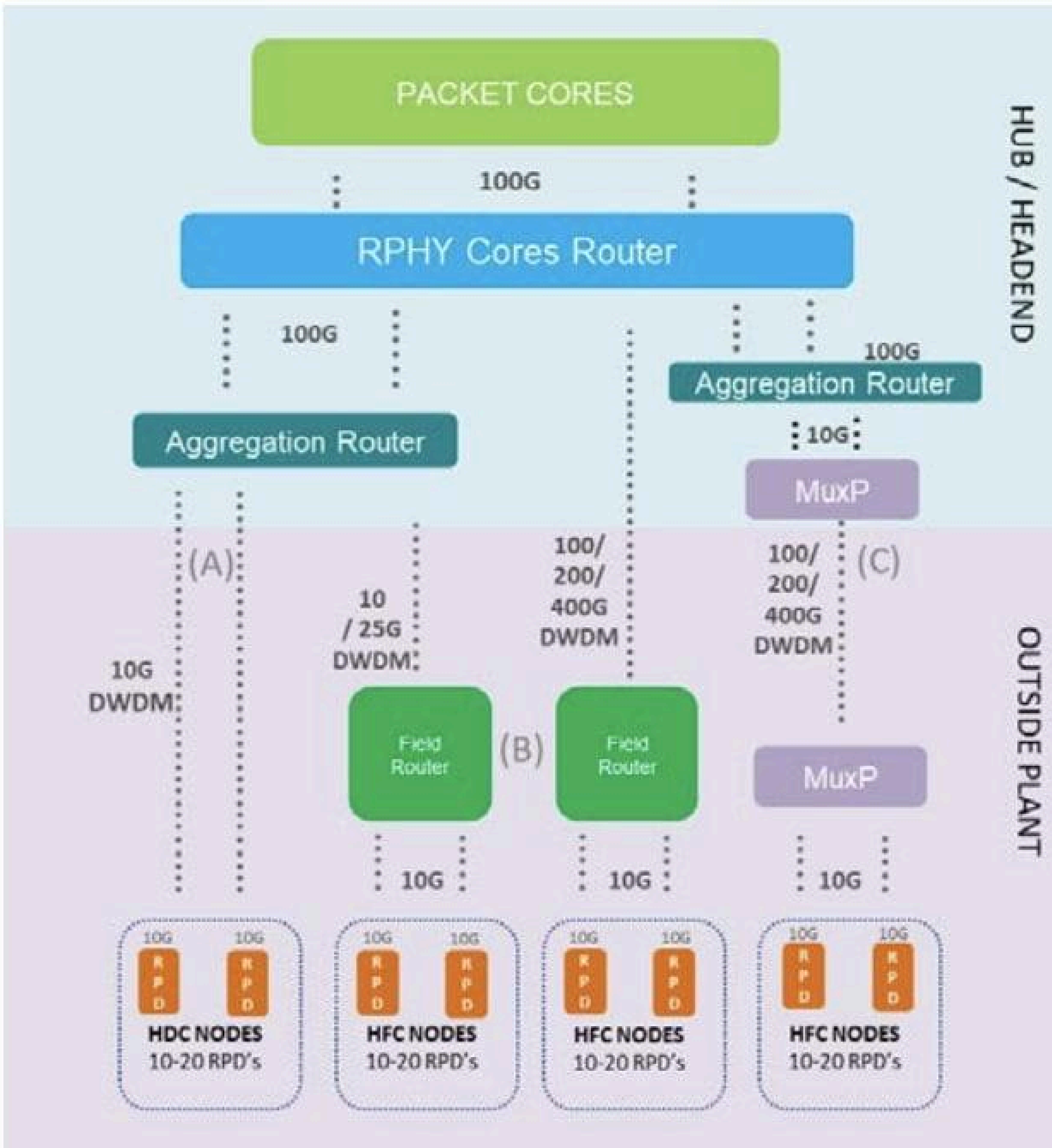
PACKET CORES
100G
RPHY Cores Router
100G
100G
Aggregation Router
Aggregation Router
10G
MuxP
HUB / HEADEND
(A)
10G
DWDM
10
/ 25G
DWDM
100/
200/
400G
DWDM
100/
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400G
DWDM
(C)
Field Router
(B)
Field Router
MuxP
OUTSIDE PLANT
10G
10G
10G
HDC NODES
10-20 RPD's
HFC NODES
10-20 RPD's
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HFC NODES
10-20 RPD's

Ethernet over coax

From Wikipedia, the free encyclopedia

Ethernet over Coax (**EoC**) is a family of technologies that supports the transmission of Ethernet frames over coaxial cable.

Contents

History[edit]

The first Ethernet standard, known as 10BASE5 (ThickNet) in the family of IEEE 802.3, specified baseband operation over 50 ohm coaxial cable, which remained the principal medium into the 1980s, when 10BASE2 (ThinNet) coax replaced it in deployments in the 1980s; both being replaced in the 1990s when thinner, cheaper twisted pair cabling came to dominate the market. The use of coaxial cable for Ethernet has been deprecated by 2011.

Research in Ethernet transmission over coaxial cable continued, as both consumers and telecommunications operators strive to use existing 75 ohm coaxial cable installations (from cable television or CATV), to carry broadband data into and through the home, and into multiple dwelling unit (MDU) installations.

Most EoC technologies are being developed for in home or on premises networking and are expected to be operated within the domain of a single operator.

Standards[edit]

Home networking standards	
Common name	IEEE **standard**
HomePlug HD-PLC	1901
Wi-Fi	802.11a
	802.11b
	802.11g
	802.11n
	802.11ac
Common name	ITU-T **recommendation**
HomePNA 2.0	G.9951–3
HomePNA 3.1/HomeGrid	G.9954
G.hn/HomeGrid	G.9960 (PHY)
G.hn/HomeGrid	G.9961 (DLL/MAC)
G.hn/HomeGrid	G.9962 (Management Plane)
G.hn-mimo	G.9963
G.hn/HomeGrid	G.9964 (PSD Management)

G.hnta	G.9970
G.cx	G.9972

- v
- t
- e

The Institute of Electrical and Electronics Engineers (IEEE) maintains all official Ethernet standards in the 802.x family of protocols.

Active work in Ethernet over Coax is ongoing[when?].[citation needed]

Homeplug[edit]

HomePlug AV as well as its later extension, HomePlug AV2 both operate in a portion of the RF spectrum directly below what is commonly used for terrestrial FM radio broadcasting. HomePlug AV uses BPSK, QPSK, 16 QAM, 64 QAM, 256 QAM, and 1024 QAM modulation strategies between 2 MHz and 30 MHz while the more recent HomePlug AV2 standard extends the upper bound of its spectral use to 86 MHz.

ITU-T G.hn[edit]

The ITU-T G.hn standard provides high-speed (up to 1 Gigabit/s) local area networking over existing home wires, including coaxial cable, power lines and phone lines. It defines an Application Protocol Convergence (APC) layer for encapsulation standard 802.3 Ethernet frames into G.hn MAC Service Data Units (MSDUs).

Other ITU-T standards for home networking over coaxial cable include G.9954, also known as HomePNA 3.1.[1]

MoCA[edit]

Main article: Multimedia over Coax Alliance

CATV compatibility[edit]

This section **does not** cite **any** sources. Please help improve this section by adding citations to reliable sources. Unsourced material may be challenged and removed. *(July 2015)* *(Learn how and when to remove this template message)*

EoC research is focused on the use of existing cable television (CATV) infrastructure for Internet access or broadband data transmission for the purpose of being compatible with the existing CATV (or sometimes satellite television) broadcast signals simultaneously transmitted on the same cable. The EoC technologies must operate outside the frequency domain currently used for CATV or for satellite receiver to set-top box transmissions. Most EoC technologies are designed to operate in frequency bands above 1 GHz, which is the upper bound of television signals and for systems designed to operate in North America using the SCTE 55-1 and SCTE 55-2 CATV transmission systems, as well as in most of Europe and portions of Asia. In many localities CATV systems operate only up to 550 MHz or 750 MHz, wherein some EoC technologies focus on using spectrum between 550 MHz or 750 MHz and 1 GHz. Though less costly, they could potentially conflict with future spectrum expansion up to 1 GHz. Some markets focus on using this 750 MHz to 1 GHz spectrum for EoC, specifically avoiding EoC bands above 1 GHz due to potential ingress noise from over-the-air transmissions and cellular systems.

See also[edit]

- DOCSIS - Data Over Cable Service Interface Specification

Digital subscriber line (DSL, ADSL, SDSL, and VDSL)

Digital subscriber line (DSL) service provides a connection to the Internet through the telephone network. Unlike dial-up, DSL can operate using a single phone line without preventing normal use of the telephone line for voice phone calls. DSL uses the high frequencies, while the low (audible) frequencies of the line are left free for regular telephone communication.[18] These frequency bands are subsequently separated by filters installed at the customer's premises.

DSL originally stood for "digital subscriber loop". In telecommunications marketing, the term digital subscriber line is widely understood to mean asymmetric digital subscriber line (ADSL), the most commonly installed variety of DSL. The data throughput of consumer DSL services typically ranges from 256 kbit/s to 20 Mbit/s in the direction to the customer (downstream), depending on DSL technology, line conditions, and service-level implementation. In ADSL, the data throughput in the upstream direction, (i.e., in the direction to the service provider) is lower than that in the downstream direction (i.e. to the customer), hence the designation of asymmetric.[48] With a symmetric digital subscriber line (SDSL), the downstream and upstream data rates are equal.[49]

Very-high-bit-rate digital subscriber line (VDSL or VHDSL, ITU G.993.1)[50] is a digital subscriber line (DSL) standard approved in 2001 that provides data rates up to 52 Mbit/s downstream and 16 Mbit/s upstream over copper wires[51] and up to 85 Mbit/s down- and upstream on coaxial cable.[52] VDSL is capable of supporting applications such as high-definition television, as well as telephone services (voice over IP) and general Internet access, over a single physical connection.

VDSL2 (ITU-T G.993.2) is a second-generation version and an enhancement of VDSL.[53] Approved in February 2006, it is able to provide data rates exceeding 100 Mbit/s simultaneously in both the upstream and downstream directions. However, the maximum data rate is achieved at a range of about 300 meters and performance degrades as distance and loop attenuation increases.

DSL Rings

DSL Rings (DSLR) or Bonded DSL Rings is a ring topology that uses DSL technology over existing copper telephone wires to provide data rates of up to 400 Mbit/s.[54]

Fiber to the home

Fiber-to-the-home (FTTH) is one member of the Fiber-to-the-x (FTTx) family that includes Fiber-to-the-building or basement (FTTB), Fiber-to-the-premises (FTTP), Fiber-to-the-desk (FTTD), Fiber-to-the-curb (FTTC), and Fiber-to-the-node (FTTN).[55] These methods all bring data closer to the end user on optical fibers. The differences between the methods have mostly to do with just how close to the end user the delivery on fiber comes. All of these delivery methods are similar in function and architecture to hybrid fiber-coaxial (HFC) systems used to provide cable Internet access. Fiber internet connections to customers are either AON (Active optical network) or more commonly PON (Passive optical network). Examples of fiber optic internet access standards are G.984 (GPON, G-PON) and

10G-PON (XG-PON). ISPs may instead use Metro Ethernet for corporate and institutional customers.

The use of optical fiber offers much higher data rates over relatively longer distances. Most high-capacity Internet and cable television backbones already use fiber optic technology, with data switched to other technologies (DSL, cable, LTE) for final delivery to customers.[56]

In 2010, Australia began rolling out its National Broadband Network across the country using fiber-optic cables to 93 percent of Australian homes, schools, and businesses.[57] The project was abandoned by the subsequent LNP government, in favor of a hybrid FTTN design, which turned out to be more expensive and introduced delays. Similar efforts are underway in Italy, Canada, India, and many other countries (see Fiber to the premises by country).[58][59][60][61]

Power-line Internet

Power-line Internet, also known as Broadband over power lines (BPL), carries Internet data on a conductor that is also used for electric power transmission.[62] Because of the extensive power line infrastructure already in place, this technology can provide people in rural and low population areas access to the Internet with little cost in terms of new transmission equipment, cables, or wires. Data rates are asymmetric and generally range from 256 kbit/s to 2.7 Mbit/s.[63]

Because these systems use parts of the radio spectrum allocated to other over-the-air communication services, interference between the services is a limiting factor in the introduction of power-line Internet systems. The IEEE P1901 standard specifies that all power-line protocols must detect existing usage and avoid interfering with it.[63]

Power-line Internet has developed faster in Europe than in the U.S. due to a historical difference in power system design philosophies. Data signals cannot pass through the step-down transformers used and so a repeater must be installed on each transformer.[63] In the U.S. a transformer serves a small cluster of from one to a few houses. In Europe, it is more common for a somewhat larger transformer to service larger clusters of from 10 to 100 houses. Thus a typical U.S. city requires an order of magnitude more repeaters than a comparable European city.[64]

ATM and Frame Relay

Asynchronous Transfer Mode (ATM) and Frame Relay are wide-area networking standards that can be used to provide Internet access directly[43] or as building blocks of other access technologies. For example, many DSL implementations use an ATM layer over the low-level bitstream layer to enable a number of different technologies over the same link. Customer LANs are typically connected to an ATM switch or a Frame Relay node using leased lines at a wide range of data rates.[65][66]

While still widely used, with the advent of Ethernet over optical fiber, MPLS, VPNs and broadband services such as cable modem and DSL, ATM and Frame Relay no longer play the prominent role they once did.

Wireless broadband access

Wireless broadband is used to provide both fixed and mobile Internet access with the following technologies.

Satellite broadband

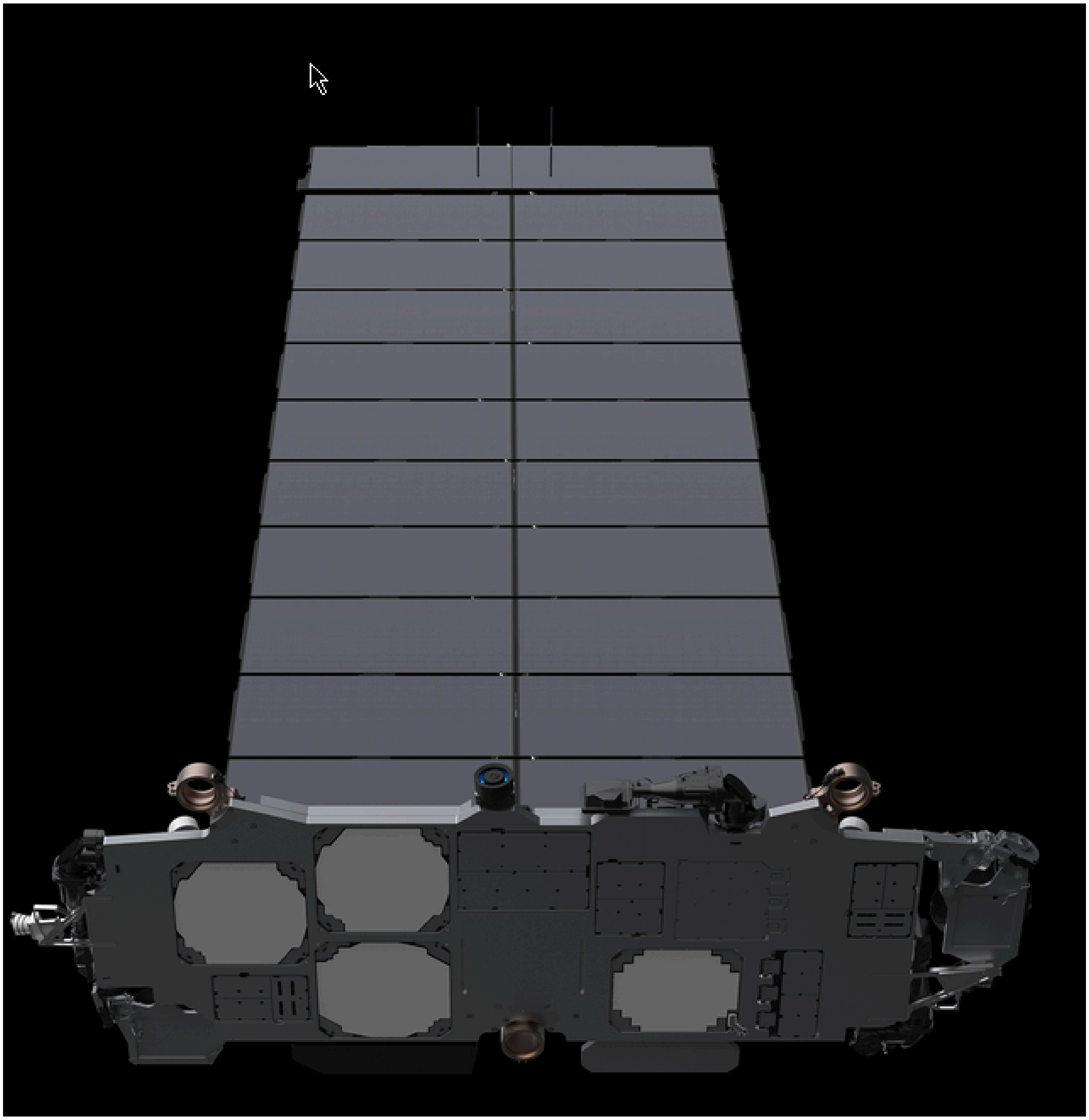
Satellite Internet access via VSAT in Ghana

Satellite Internet access provides fixed, portable, and mobile Internet access.[67] Data rates range from 2 kbit/s to 1 Gbit/s downstream and from 2 kbit/s to 10 Mbit/s upstream. In the northern hemisphere, satellite antenna dishes require a clear line of sight to the southern sky, due to the equatorial position of all geostationary satellites. In the southern hemisphere, this situation is reversed, and dishes are pointed north.[68][69] Service can be adversely affected by moisture, rain, and snow (known as rain fade).[68][69][70] The system requires a carefully aimed directional antenna.[69]

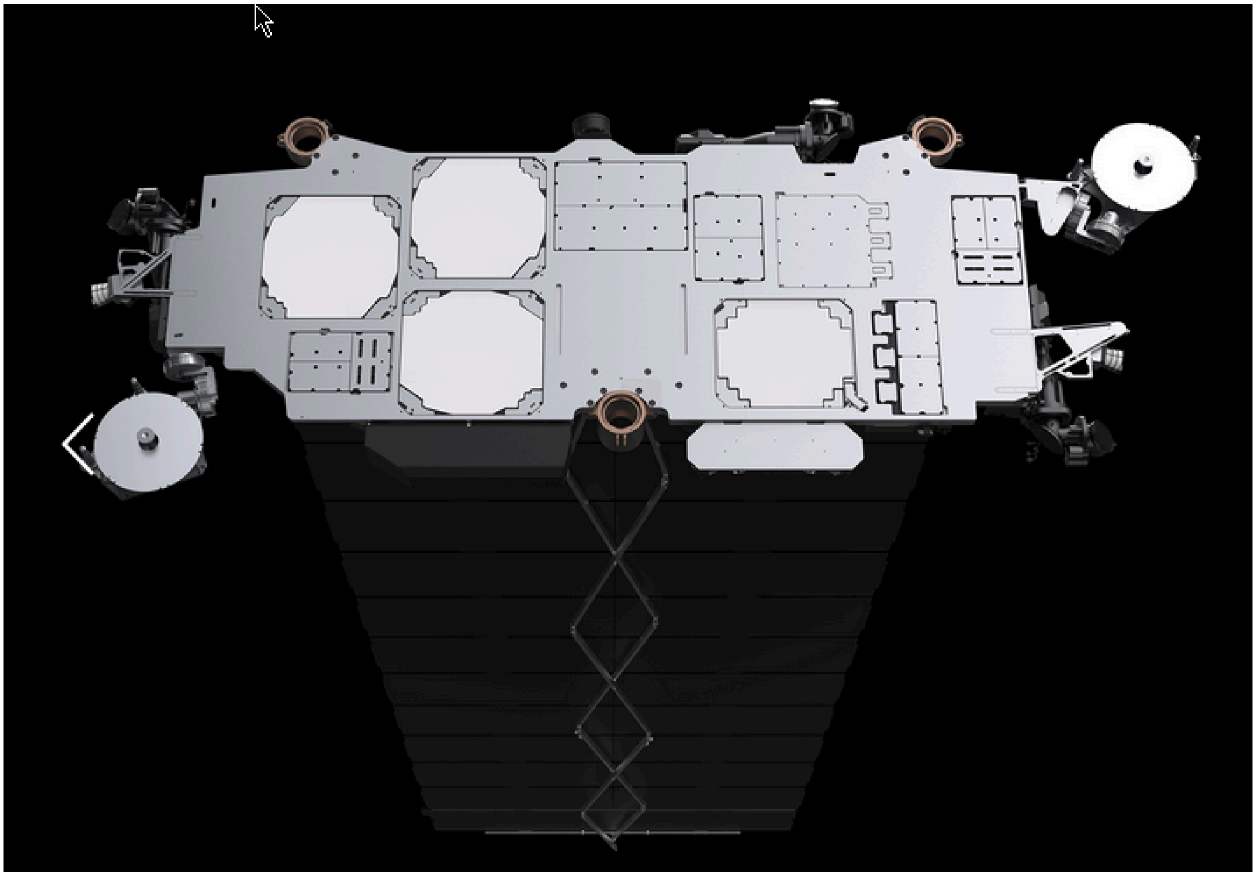
Satellites in geostationary Earth orbit (GEO) operate in a fixed position 35,786 km (22,236 mi) above the Earth's equator. At the speed of light (about 300,000 km/s or 186,000 miles per second), it takes a quarter of a second for a radio signal to travel from the Earth to the satellite and back. When other switching and routing delays are added and the delays are doubled to allow for a full round-trip transmission, the total delay can be 0.75 to 1.25 seconds. This latency is large when compared to other forms of Internet access with typical latencies that range from 0.015 to 0.2 seconds. Long latencies negatively affect some applications that require real-time response, particularly online games, voice over IP, and remote control devices.[71][72] TCP tuning and TCP acceleration techniques can mitigate some of these problems. GEO satellites do not cover the Earth's polar regions.[68] HughesNet, Exede, AT&T and Dish Network have GEO systems.[73][74][75][76]

Satellites in low Earth orbit (LEO, below 2,000 km or 1,243 miles) and medium Earth orbit (MEO, between 2,000 and 35,786 km or 1,243 and 22,236 miles) operate at lower altitudes, and are not fixed in their position above the Earth. Because of their lower altitude, more satellites and launch vehicles are needed for worldwide coverage. This makes the initial required investment very large which initially caused OneWeb and Iridium to declare bankruptcy. However, their lower altitudes allow lower latencies and higher speeds which make real-time interactive Internet applications more feasible. LEO systems include Globalstar, Starlink, OneWeb and Iridium. The O3b constellation is a medium Earth-orbit system with a latency of 125 ms. COMMStellation™ is a LEO system, scheduled for launch in 2015,[needs update] that is expected to have a latency of just 7 ms.

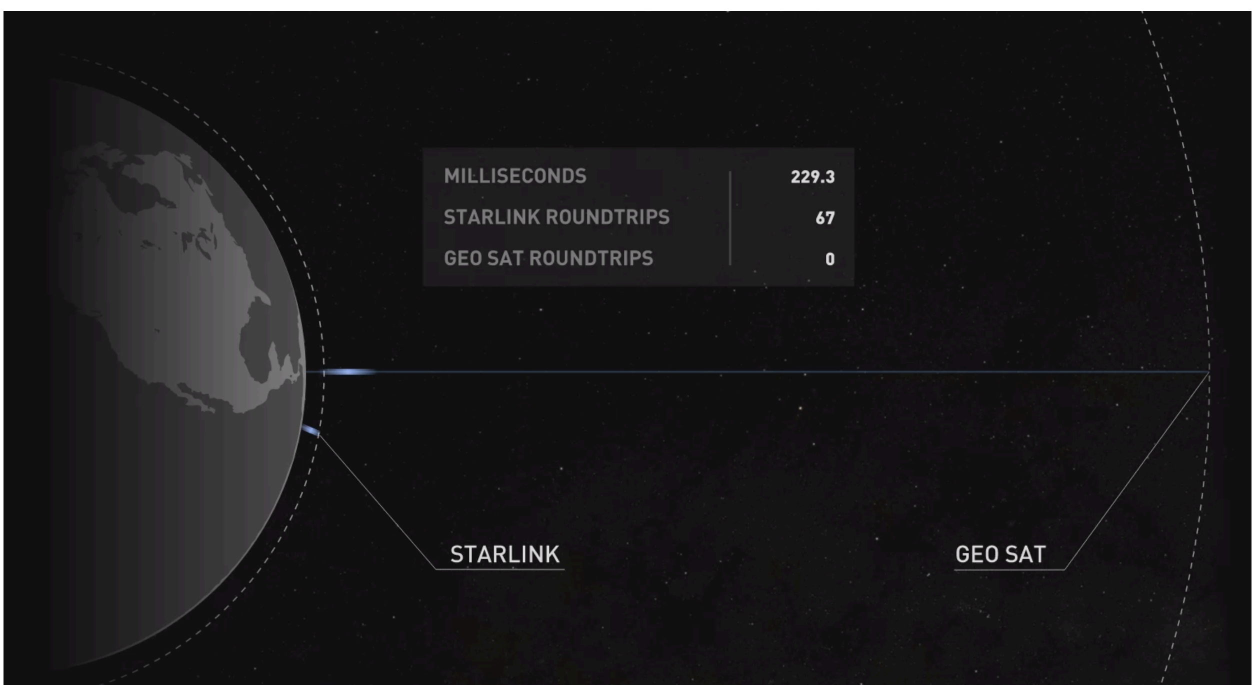
StarLink coverage of Florida



Starlink solar array



Starlink antennas



Tech Savvy Productions

Mobile broadband

Service mark for GSMA

Mobile broadband is the marketing term for wireless Internet access delivered through mobile phone towers (cellular networks) to computers, mobile phones (called "cell phones" in North America and South Africa, and "hand phones" in Asia), and other digital devices using portable modems. Some mobile services allow more than one device to be connected to the Internet using a single cellular connection using a process called tethering. The modem may be built into laptop computers, tablets, mobile phones, and other devices, added to some devices using PC cards, USB modems, and USB sticks or dongles, or separate wireless modems can be used.[77]

New mobile phone technology and infrastructure is introduced periodically and generally involves a change in the fundamental nature of the service, non-backwards-compatible transmission technology, higher peak data rates, new frequency bands, wider channel frequency bandwidth in Hertz becomes available. These transitions are referred to as generations. The first mobile data services became available during the second generation (2G).

Second generation (2G) from 1991:

Speeds in kbit/s	down and up
GSM CSD	9.6 kbit/s
CDPD	up to 19.2 kbit/s
GSM GPRS (2.5G)	56 to 115 kbit/s
GSM EDGE (2.75G)	up to 237 kbit/s

Third generation (3G) from 2001:

Speeds in Mbit/s	down	up
UMTS W-CDMA	0.4 Mbit/s	
UMTS HSPA	14.4	5.8
UMTS TDD	16 Mbit/s	
CDMA2000 1xRTT	0.3	0.15
CDMA2000 EV-DO	2.5–4.9	0.15–1.8
GSM EDGE-Evolution	1.6	0.5

Fourth generation (4G) from 2006:

	Speeds in Mbit/s down	up
· HSPA+	21–672	5.8–168
· Mobile WiMAX (802.16)	37–365	17–376
· LTE	100–300	50–75
· LTE-Advanced:		
· moving at higher speeds	100 Mbit/s	
· not moving or moving at lower speeds	up to 1000 Mbit/s	
· *MBWA (802.20)*	80 Mbit/s	

The download (to the user) and upload (to the Internet) data rates given above are peak or maximum rates and end users will typically experience lower data rates.

WiMAX was originally developed to deliver fixed wireless service with wireless mobility added in 2005. CDPD, CDMA2000 EV-DO, and MBWA are no longer being actively developed.

In 2011, 90% of the world's population lived in areas with 2G coverage, while 45% lived in areas with 2G and 3G coverage.[78]

5G was designed to be faster and have lower latency than its predecessor, 4G. It can be used for mobile broadband in smartphones or separate modems that emit WiFi or can be connected through USB to a computer, or for fixed wireless.

Fixed wireless

Fixed wireless internet connections that do not use a satellite nor are designed to support moving equipment such as smartphones due to the use of, for example, customer premises equipment such as antennas that can't be moved over a significant geographical area without losing the signal from the ISP, unlike smartphones. Microwave wireless broadband or 5G may be used for fixed wireless.

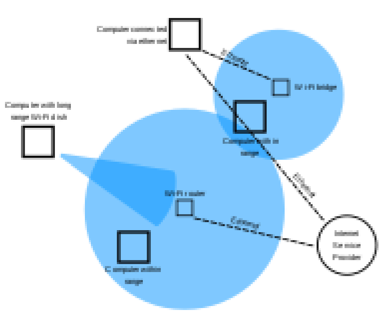
WiMAX

Worldwide Interoperability for Microwave Access (WiMAX) is a set of interoperable implementations of the IEEE 802.16 family of wireless-network standards certified by the WiMAX Forum. It enables "the delivery of last mile wireless broadband access as an alternative to cable and DSL".[79] The original IEEE 802.16 standard, now called "Fixed WiMAX", was published in 2001 and provided 30 to 40 megabit-per-second data rates.[80] Mobility support was added in 2005. A 2011 update provides data rates up to 1 Gbit/s for fixed stations. WiMax offers a metropolitan area network with a signal radius of about 50 km (30 miles), far surpassing the 30-metre (100-foot) wireless range of a conventional Wi-Fi LAN. WiMAX signals also penetrate building walls much more effectively than Wi-Fi. WiMAX is most often used as a fixed wireless standard.

Wireless ISP

Wi-Fi logo

Wireless Internet service providers (WISPs) operate independently of mobile phone operators. WISPs typically employ low-cost IEEE 802.11 Wi-Fi radio systems to link up remote locations over great distances (Long-range Wi-Fi), but may use other higher-power radio communications systems as well, such as microwave and WiMAX.



Wi-Fi range diagram

Traditional 802.11a/b/g/n/ac is an unlicensed omnidirectional service designed to span between 100 and 150 m (300 to 500 ft). By focusing the radio signal using a directional antenna (where allowed by regulations), 802.11 can operate reliably over a distance of many km(miles), although the technology's line-of-sight requirements hamper connectivity in areas with hilly or heavily foliated terrain. In addition, compared to hard-wired connectivity, there are security risks (unless robust security protocols are enabled); data rates are usually slower (2 to 50 times slower); and the network can be less stable, due to interference from other wireless devices and networks, weather and line-of-sight problems.[81]

With the increasing popularity of unrelated consumer devices operating on the same 2.4 GHz band, many providers have migrated to the 5GHz ISM band. If the service provider holds the necessary spectrum license, it could also reconfigure various brands of off the shelf Wi-Fi hardware to operate on its own band instead of the crowded unlicensed ones. Using higher frequencies carries various advantages:

- usually regulatory bodies allow for more power and using (better-) directional antennae,
- there exists much more bandwidth to share, allowing both better throughput and improved coexistence,
- there are fewer consumer devices that operate over 5 GHz than over 2.4 GHz, hence fewer interferers are present,
- the shorter wavelengths don't propagate as well through walls and other structures, so much less interference leaks outside of the homes of consumers.

Proprietary technologies like Motorola Canopy & Expedience can be used by a WISP to offer wireless access to rural and other markets that are hard to reach using Wi-Fi or WiMAX. There are a number of companies that provide this service.[82]

Local Multipoint Distribution Service

Local Multipoint Distribution Service (LMDS) is a broadband wireless access technology that uses microwave signals operating between 26 GHz and 29 GHz.[83] Originally designed for digital television transmission (DTV), it is conceived as a fixed wireless, point-to-multipoint technology for utilization in the last mile. Data rates range from 64 kbit/s to 155 Mbit/s.[84] Distance is typically limited to about 1.5 miles (2.4 km), but links of up to 5 miles (8 km) from the base station are possible in some circumstances.[85]

LMDS has been surpassed in both technological and commercial potential by the LTE and WiMAX standards.

Hybrid Access Networks

See also: Hybrid Access Networks

In some regions, notably in rural areas, the length of the copper lines makes it difficult for network operators to provide high-bandwidth services. One alternative is to combine a fixed-access network, typically XDSL, with a wireless network, typically LTE. The Broadband Forum has standardized an architecture for such Hybrid Access Networks.

The Best Internet Options for Rural Areas: Satellite vs DSL

Written by

- [Tyler Cooper]

Last Updated: May 5, 2023 | Published: Aug 28, 2020

Satellite internet is widely available in the U.S.

Rural areas and small towns across America often have fewer internet options than urban areas.[1] The situation is slowly improving, but for now, rural residents pay higher monthly fees for slower service. Rural residents typically have the following internet options available to them: DSL, satellite, and fixed wireless.

DSL is usually the best option as it gets faster speeds but it might not be available in all areas. Satellite has 100 percent coverage in the U.S. but is the slowest option. Lastly, fixed wireless is usually the fastest option in rural areas but it has limited coverage.

Our guide primarily covers key differences between satellite internet and DSL since these connection types are the most common in rural areas. As we help you decide which one is best for your household and budget, we're one step closer to bridging the digital divide.

Satellite Internet vs DSL

Satellite internet and DSL services are generally available in overlapping areas, but the two technologies work quite differently from one another. Satellite internet relies on a physical dish mounted to your roof to receive signals from space while DSL delivers internet using your landline. Satellite dish technology has been improving in recent years and is quickly catching up to DSL connection speeds. In some areas, the difference is negligible. DSL utilizes your phone line, but it doesn't interrupt phone calls like dial-up. Typically, DSL speeds are faster than satellite, but they vary. Both satellite and DSL have their own strengths and weaknesses, which we delve deeper below.

Satellite Internet Pros and Cons

Although it usually isn't the case, sometimes satellite internet is faster than DSL. Faster speeds will largely depend on your location.

Pros

- Available almost anywhere you can see the sky
- Depending upon location, may offer faster speeds than DSL

Cons

- Subject to speed and latency issues, data caps, and service interruptions in inclement weather
- Higher minimum contract terms (usually around two years)
- Need to have physical dish installed
- Higher equipment costs
- ETFs (Early Termination Fees) are more common

DSL Internet Pros and Cons

While rural internet providers are few and far between, a good DSL service provider can be a lifesaver.

Pros

- Minimal equipment installation needed
- Usually doesn't come with lengthy minimum term agreements
- No need for heavy equipment installation

Cons

- Can be extremely slow if you are far from the local office or access point

DSL vs Satellite — Which Is A Better Rural Internet Option?

Both DSL and satellite have the potential to be better for you, depending on your situation. In most cases, DSL is a better overall service for rural areas, but in areas where speeds top out at just 1–5 Mbps, satellite internet might actually be faster. A satellite connection is also the only rural internet option that is available virtually everywhere. Of course, one of the main drawbacks of satellite is that internet plans tend to come with restrictive data caps. This limits you to more basic internet functions and prohibits bandwidth-heavy activities such as regularly streaming Netflix.

Satellite data caps usually range anywhere from 40-150 GB for most providers. Once you meet the limit, you may lose internet connection altogether in extreme cases. However, most users are still able to access the internet at extremely limited, or throttled, speeds. DSL, on the other hand, sometimes offers data caps at around 1 TB. You can eat through hundreds of gigabytes very quickly by streaming HD videos, so keep that in mind when making your decision.

To break it down, here are the main points when comparing rural DSL service vs satellite:

- Satellite dish internet speeds are usually slower than DSL unless you happen to be far from the access point.
- Satellite internet plans limit you with data caps and long contract terms.
- Satellite offers more readily available internet while DSL may be unavailable where you live.

DSL and Satellite Rural Internet Providers

If you're looking for the best rural internet providers, our innovative search tool can show you exactly which providers cover your rural area. The following are some common rural ISPs:

- Verizon Wireless LTE (installed)
- AT&T Internet
- CenturyLink
- HughesNet
- Rise Broadband
- Viasat
- Windstream

Not only does our search tool show you every internet service provider that offers satellite internet, DSL, or fixed wireless in your area but also their speeds and prices.

Is "Unlimited" Satellite Internet Really Unlimited?

Recently, several major providers have begun offering customers "unlimited" satellite internet internet packages. These may sound like an attractive option at first glance, but we've noticed that many of these plans tend to come with data guidelines or "soft caps" in place of hard caps.

What this means for you is that once these soft caps are exceeded, the provider will then throttle your connection, slowing the speeds considerably (even if you're only halfway through the month). For most satellite providers, data throttling is a common and legal practice. This can make even the most basic online tasks feel painfully slow, so it's important to know your data caps before signing up for one of these plans.

One common misconception is that satellite TV and satellite internet are the same when in fact, these services are provided by separate companies. As of 2018, none of the big satellite internet providers have their own TV service. That said, they will often bundle services with satellite TV services such as DISH and DIRECTV.

Why Are There So Few Rural Internet Options?

In recent years, urban areas have seen a rise in affordable, high-speed internet options from a variety of providers and services. Why then, have more of these not come to the countryside? Unsurprisingly, the high cost of expansion is a significant reason that high-performance options such as cable and fiber haven't spread out into rural areas just yet. In areas of high population density, these companies can justify paying for costly new lines to be run, but in areas where you may not see another house for miles, the math simply doesn't add up.

In spite of this, progress is being made that may be able to bring high-speed internet access to even the most remote regions of the country. Improvements to satellite technology, for instance, may soon allow for much higher speeds, as well as drastically increased data limits, eliminating two of the main drawbacks of the service as it stands. The FCC has also invested in building more infrastructure in rural areas to bridge the digital divide.

Companies like SpaceX have launched low-orbit satellites through its own satellite internet service called Starlink to compete with DSL. On the government side, as we mentioned earlier, the FCC puts millions into rural broadband development every year. [2]

Another potential solution relies on a different type of connection entirely. Across the country, smaller, independent providers are beginning to offer consumers an alternative to both satellite and DSL. These companies are commonly referred to as WISPs, or wireless internet service providers, and they offer what is called a "fixed wireless" service that can support surprisingly fast download speeds.

Is SpaceX Starlink Good for Rural Internet?

SpaceX's Starlink service is a rapidly growing advanced satellite internet service that offers faster speeds and lower latency (lag time) than traditional providers. This is because SpaceX has satellites in a lower orbit in space than regular satellite providers, meaning the signal doesn't need to travel as far to reach you.

It is available in many rural areas around the U.S., and its service footprint is expanding quickly. If it is available near you, it's well worth considering; the speeds can make it an obvious choice for those looking for performance.

Because the service uses a network of satellites in low Earth orbit, it does not require the infrastructure of ground-based towers or cables, making it more practical to deploy in remote areas. Additionally, Starlink's low-latency and high-bandwidth capabilities make it well-suited for activities such as online gaming and video streaming.

Fixed Wireless Internet vs Satellite Internet and DSL

Fixed wireless differs from satellite and DSL in several ways. The main difference lies in how the signal reaches your home. Instead of relying on a satellite or physical wiring, fixed wireless technology works by way of a direct, point-to-point connection with an access point. This usually means faster speeds than both satellite and DSL, so if it's available in your area, it's probably the better option.

Unfortunately, one of the main practical limitations of fixed wireless is that it isn't a very widespread service. This is due to many factors, but one issue is that you need to have a line-of-sight connection to the access point, which could be up to several miles away from your home. In areas with uneven terrain, this can be tricky, if not impossible. Of course, it's always worth checking to see if this type of service is available in your area. Our comprehensive internet provider search tool is broken down by service type, and can help you determine the best option available.

Rural Internet Options: Slim Pickings

DSL might be the best rural internet option when faster options like cable and fiber aren't usually available. If you can't get DSL, satellite internet may be the only choice. Fixed wireless is a third rural option which has improved in recent years. As it stands, rural internet options are still limited.

Progress is being made on new technologies that may be able to provide better service in the near future, like 5G home internet, but for now, fixed wireless and DSL are likely to be best for most users. That said, satellite service is still the only technology that'll work just about anywhere.

Frequently Asked Questions

Is satellite internet better for rural areas?

Satellite internet can be a good option for providing internet access in rural areas where traditional wired or cellular internet service is limited or unavailable. However, satellite internet service can be limited by factors such as weather conditions and high latency, which can affect the quality of the service and make it less suitable for certain activities such as online gaming or real-time video conferencing.

Is satellite internet good enough for streaming?

Satellite internet can be suitable for streaming, but it may not provide the same level of performance as wired or cellular internet service. The latency, or delay, in satellite internet service can be higher than other types of internet service, which can affect the quality of streaming video.

Is satellite internet a good value?

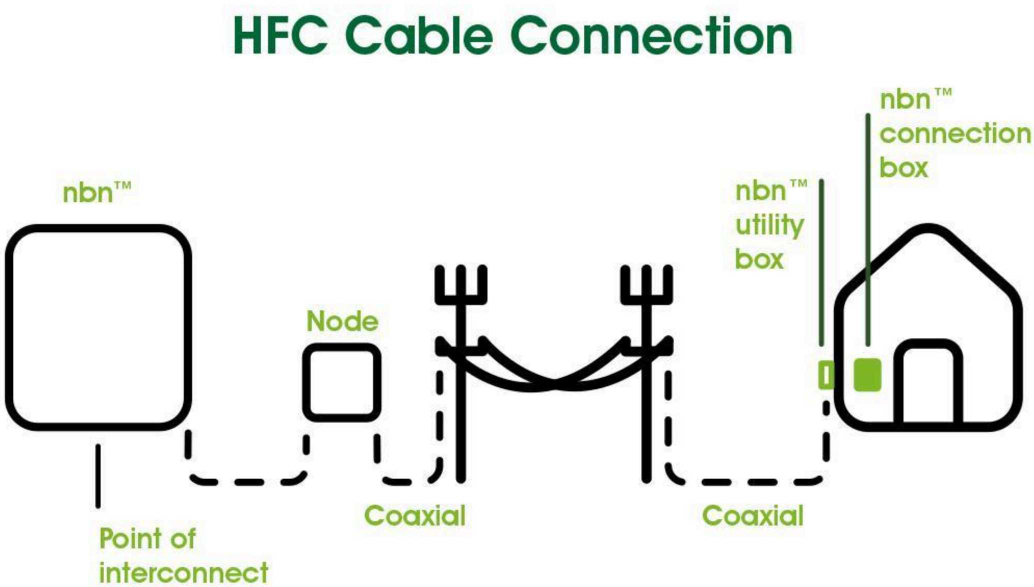
Satellite internet is often the best choice for consumers in areas where wired internet options don't currently operate. That said, be sure to check all the options in your area before making a choice, as there may be a wired solution that works better for you.

Is SpaceX Starlink available everywhere?

SpaceX's Starlink satellite internet is not yet available in all areas of the US. Be sure to check availability in your area for more details.

References and Footnotes

1. https://www.fcc.gov/reports-research/reports/broadband-progress-reports/2016-broadband-progress-report ↩
2. https://docs.fcc.gov/public/attachments/DOC-348732A1.pdf ↩



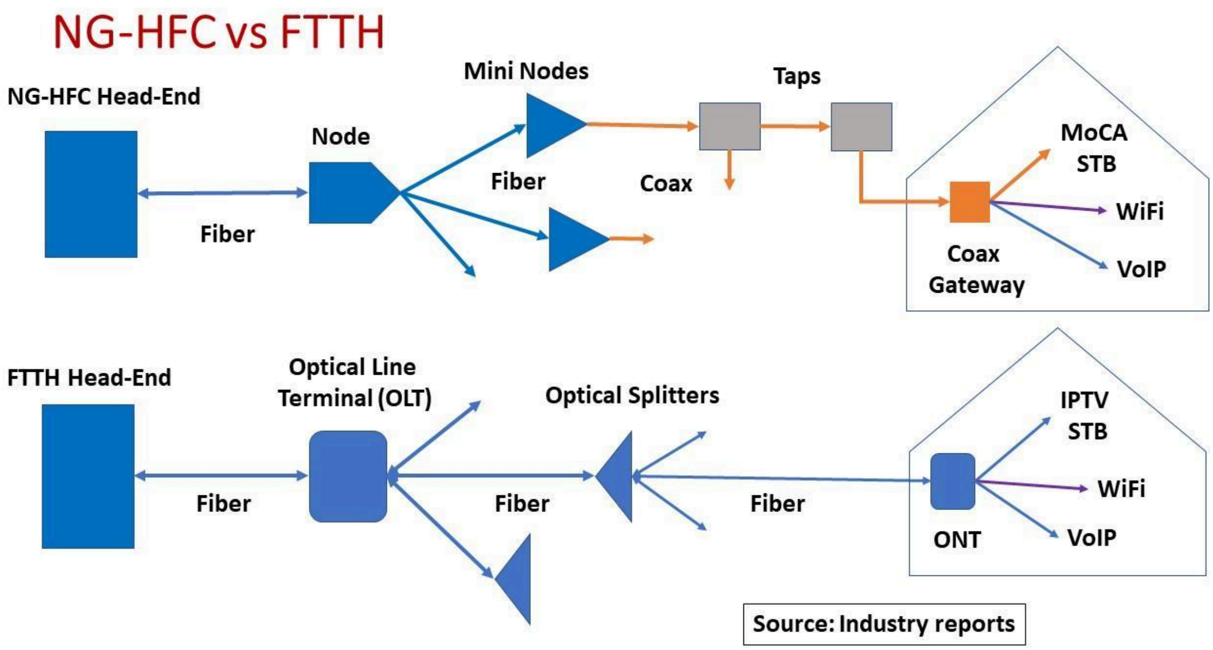
Cable Nodes Becoming a Choke Point

Cable companies have been talking about a network architecture called node-plus-zero for several years, and finally some have begun deploying it, with Comcast and Cox leading the way. Node+0 is finally being deployed now because only recently did it become technologically and economically feasible, thanks to the introduction of a new generation of power amplifiers based on gallium nitride (GaN). (See Comcast Goes N+0 in Gigabit Markets and Cox Reveals Next Steps for D3.1, CCAP.)

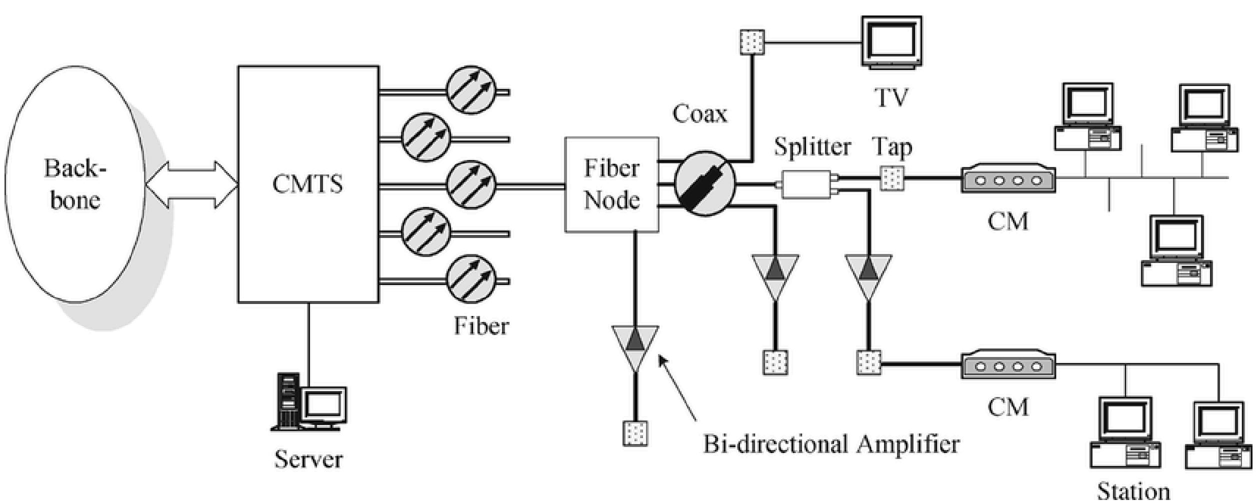
Cable operators are also considering increasing the amount of spectrum in their networks, expanding from 1GHz to 1.2GHz. Plus, they're evaluating an architectural change **referred to as remote PHY**. Although all three are distinct technologies, they all place new demands on cable nodes, and for now there's no way to accede to all those demands simultaneously.

- Qorvo Inc. is one of the very small handful of suppliers of **new GaN power doubler amps** that help make all three upgrades possible.
- Macom has a gallium arsenide (GaAs) amp that also supports 1.2GHz of spectrum.
- Shenzhen Sanland Technology appears to have a similar part.
- A barely known startup called One Tree Microdevices claims to have a device that might serve the purpose in its portfolio.

Cable operators, in their hybrid fiber coaxial (HFC) networks, run fiber from their central headends to nodes placed in every neighborhood, and then run coaxial cable from nodes to customers' premises.



The coaxial run starts with amps in the nodes, supplemented by as many as four or five more amplifiers spaced along the line to maintain signal strength on the way to customers. A network with four or five amps per line would be denoted as node+4 or node+5, respectively. Node+0, then, is an architecture in which all amplifiers are removed from the line, leaving only those in the nodes -- commonly four per node.



Because the terminology isn't obscure enough already, [Comcast Corp.](#) (Nasdaq: CMCSA, CMCSK) and some other companies also refer to node+0 as "fiber deep."

Not only are some companies ditching the cascade of amps on their coax lines, they're moving their nodes closer to their customers, extending the fiber portion of the HFC network "deeper." That naturally makes the coaxial runs shorter.

Migrating to node+0 eliminates the cost of periodically replacing all those amps, and also the expense of maintaining them all, including the cost of powering them. A cable operator might end up adding 20% more nodes, but eliminating 80% of the active devices in its network compensates enough that an operator might be able to cut its overall power bill by as much as 50%.

Amps tend to have 15- to 18-year lives, and the last major wave of amp upgrades occurred between 12 and 15 years ago. At the time, node+0 was not an option because the approach requires amps in the nodes to compensate for removal of the subsequent daisy chain of amps on the line. Not only did they have to be more powerful, they would have had to do it without blowing the power budget for the nodes. Amps that could do all that simply did not exist back then.

During the last wave of amp upgrades, MSOs had another factor to consider, though. The spectrum available in a cable network is dependent on the frequency range that amplifiers installed in the network can support. The latest amps at the time wouldn't support node+0, but they would support higher frequencies up to 1GHz.

So the choice operators had was that they could buy amps that would get them to 870MHz or amps that went to 1GHz. If they bought the 870MHz amps, it would be a problem if they needed to go to 1GHz shortly after, because then they'd be buying and installing yet another round of amps, a waste of money and effort. The alternative was to buy amps that supported 1GHz from the get-go. If the operator needed the additional 130MHz, it was there. If not, the company had to replace its amps anyway. There was no single correct answer; different MSOs had different needs.

Today, cable companies are in a similar situation. Installed amps are starting to age out, and MSOs are going to have to do something about it. This time around, though, the latest amps -- the new GaN models -- can not only support yet another expansion of the frequency range, up to 1.2GHz, but are also capable of compensating for the removal of the daisy chain of amps on the line, enabling node+0.

It is absolutely no coincidence at all that the latest iteration of cable's DOCSIS standard, DOCSIS 3.1, was engineered to support a spectrum expansion to 1.2GHz. (It also anticipates a subsequent step probably to 1.7GHz, and allows for additional expansions beyond that, should they ever become useful.)

GaN amps represent a legitimate technological leap, but they aren't magic. If operators want to do node+0 and add spectrum, that's difficult. If operators want to do those two things and also prepare for remote PHY, they're asking too much of what's available now.

Why? Node+0 requires more powerful amps for the nodes to drive signals the full distance from node to customer premises, and they have to do it without drawing significantly more current. The only way to increase the power while minimizing the current draw is to switch to GaN-based amps, and even then, the switch to GaN amps is not a perfectly ideal solution. GaN cannot reduce the power required; but it will draw less *additional* power than all alternatives.

Previous amps operate at 11W or so. The new GaN amps draw about 18W, so with four per node that's 28 extra watts. So far that's been acceptable for those operators eager to do node+0.

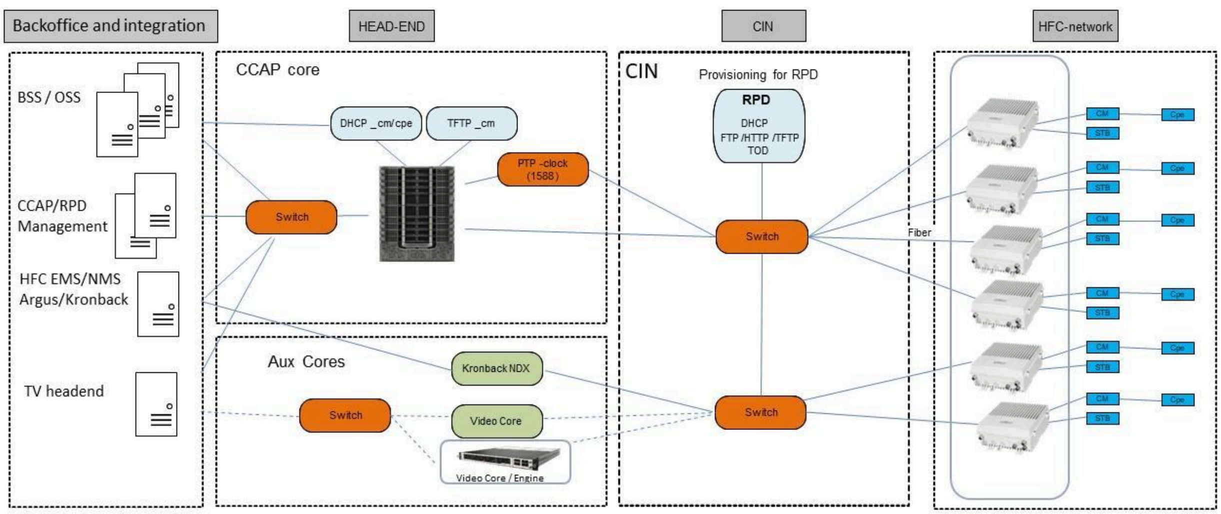
There's a complication for cable operators that want to do node+0 and simultaneously increase spectrum to 1.2GHz, however.

A node+0 system at 1GHz typically operates at 58 dBm out, but attenuation increases at higher frequencies, so if an MSO wants to do node+0 *and* go to 1.2GHz, it needs more power.

Comcast is upgrading its amps now and it wants the option to go to 1.2GHz, so it's asking for 64 dBm out, tickling technological limits all up and down the supply chain.

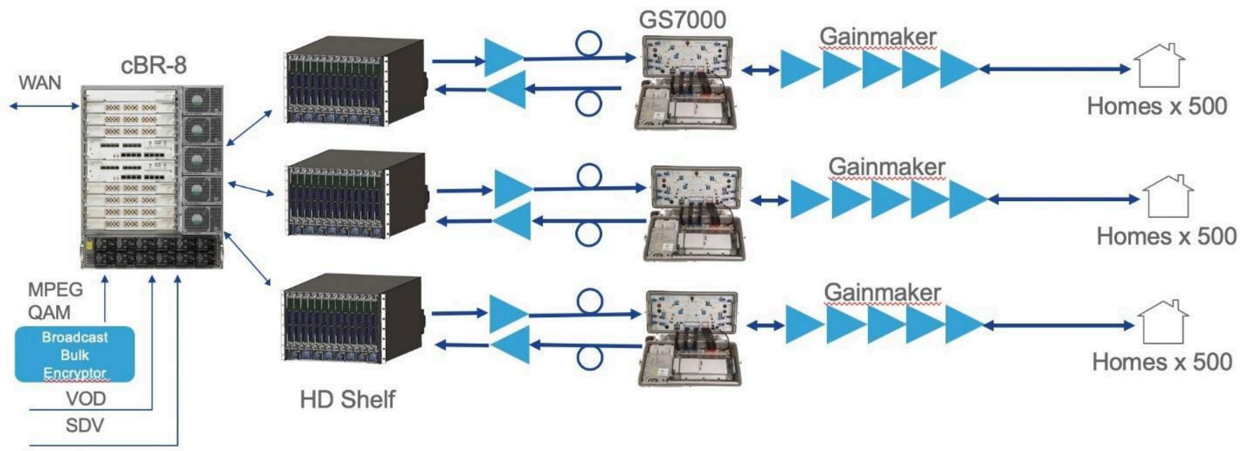
What about adding remote PHY? Remote PHY doesn't put any stress on the amps, but what it does, however, as it moves resources from the headend to the node, is add another increase in power required by the node.

Traditionally, the physical layer is housed in a central location, like the cable modem termination system (CMTS) or converged cable access platform (CCAP). However, in a Remote PHY setup, the physical layer is moved away from the central location and out towards the edges of the network, often to the same location as the optical nodes. This architecture is designed to improve the efficiency and capacity of the network.



"You have fixed power consumption the node can carry. You're asking for more performance, but you're asking to cut the power down? Well, it's just not going to happen," observed Kellie Chong, director of CATV and Broadband Access products at Qorvo.

Tech Savvy Productions



What does appear possible is amp manufacturers reducing GaN device power consumption just enough to keep the overall power budget for the node unchanged when remote PHY is factored in.

Qorvo said it is looking at a technique called digital predistortion (DPD), which is commonly used in the wireless industry but is less well known in the cable industry. DPD algorithms predict the non-linear behavior of amplifiers, Chong explained.

"If you can correct for that, then you might be able to save power from the amplifiers so you can have remote PHY and node+0," she said.

The cable industry can expect that in maybe in a year, a year and a half she said.

There are also rumors of some unspecified digital alternative still being worked on in laboratories that might bear fruit in a year or two.

Every MSO has different needs, and all of these considerations will factor into their decisions on when to embark on all of these upgrades.

It turns out that many MSOs who have networks capable of 1GHz still aren't using the extra 130MHz they bought themselves when they upgraded from 870MHz. Toss in the complications associated with also going node+0 or opting for remote PHY, and many operators are apt to wait a year or two for the next generation of improved amps before they embark on their upgrades.

And it's unlikely that those MSOs already doing node+0 will also do remote PHY any time before that.

— Brian Santo, Senior Editor, Components, T&M, Light Reading