Foundation Topics

Cable Access Technologies

Cable access is among the fastest growing technologies for home access to multiple services via a common connection. One connection to the cable company carries the television signal and Internet traffic. Most cable carriers are now getting into the voice market as well by providing voice services with unlimited long distance and other traditional services over the cable connection. The addition of teleworker functionality is a natural extension of this already multiservice connection technology.

Today, cable access is typically sold in bundles. These bundles offer a mix of services including television, Internet access, and voice. Most companies also offer a "build your own" bundle for services, to allow a customer to mix and match the solution to meet their needs.

Cable Internet access typically is available at speeds ranging from 2-Mbps to 6-Mbps downstream bandwidth (that is, from the Internet to the home) from the average carrier. The cost of this connection is typically bundled with the monthly cable television recurring charge at a discounted rate, as most companies seem to avoid offering Internet access without other services in the bundle, most importantly, television. The concern with downstream speeds versus upstream speeds is relevant simply because the bulk of the traffic load on the connection will be generated by small outbound (from the subscriber) requests returning large amounts of inbound (to the subscriber) data. For example, when a web browser is pointed to http://www.cisco.com, little in the way of traffic is generated by the request. However, a significant amount of information is generated by the reply and subsequent loading of images and information requested. For this reason, service providers have taken an asynchronous view of bandwidth allocation, preferring to focus on the speed of the connection toward the subscriber.

Cable Technology Terminology

In any discussion of relatively new or different technologies, a definition of terminology associated with that technology is necessary. This allows a more rapid familiarization with the technology. With cable access, the new terms are quite numerous compared with other networking technologies. The following are terms that will be referenced throughout this chapter:

- **Broadband**—Data transmission using a multiplexing methodology to provide more efficient use of available bandwidth. In cable, the term *broadband* refers to the frequency-division multiplexing (FDM) of multiple signals in a wide radio frequency (RF) bandwidth over a hybrid fiber-coaxial (HFC) network and the capability to handle large amounts of information. FDM is a means by which information from multiple channels or frequencies can be allocated bandwidth on a single wire.

- **Community Antenna Television (CATV)**—A broad term referring to cable television in general.
- **Coaxial cable**—The primary medium used in the construction of cable television systems. Coaxial cable (or coax) is used in the transmission of RF signals and has specific physical characteristics regarding signal attenuation. These characteristics include cable diameter, dielectric construction, ambient temperature, and operating frequency.
- **Tap**—A device used to divide the input signal RF power to support multiple outlets. Typically, cable operators deploy taps with two, four, or eight ports.
- **Amplifier**—A device that magnifies an input signal, thus producing a significantly larger output signal.
- **Hybrid fiber-coaxial (HFC)**—A mixed optical-coaxial network in which fiber optic cable is installed in place of some or all of the traditional trunk portion of the cable network.
- **Downstream**—An RF signal transmission traveling in the direction of the subscriber from the headend. Downstream is also called a *forward path* (viewed from the perspective of the cable provider).
- **Upstream**—An RF signal transmission traveling in the direction of the headend from the subscriber. Upstream is also called a *return* or *reverse path* (again, from the provider perspective).

As most of the general population has lived with cable television for a number of years, the coaxial cable associated with it is quite readily recognized. Obviously, there are many types of coaxial cable available in the marketplace at any given time. Each has differing characteristics and is utilized in a variety of manners and technologies. For example, Ethernet 10BASE2 and 10BASE5 networks used a coaxial cable but each had differing physical and electrical characteristics. Table 3-2 shows the physical differences in some coaxial cable types.

Table 3-2 *Coaxial Cable Types and Characteristics*

Specification	Cable Type	American Wire Gauge (AWG)
10BASE2 Ethernet	RG-58	20
10BASE5 Ethernet	RG-11	12
CATV cable	RG-6 or RG-59	18

Hopefully, the table establishes something of a point of reference for coaxial cable uses. CATV cable is somewhat thick and rigid in comparison to 10BASE2 or Thinnet cable. The 10BASE2 cable is quite flexible and, as the name “Thinnet” implies, quite small in diameter. In general, the thinner the cable, the shorter the functional distance. The use of an HFC network remedies much of the issue caused by cable distance limitations by introducing fiber optic cabling where needed.

Cable System Standards

Like any networking technology, cable systems have associated standards meant to loosely govern the manner in which the technologies evolve and the manner in which they are implemented by various hardware and software vendors. These standards include

- **National Television Standards Committee (NTSC)**—Created in 1941, and named after its authoring committee, NTSC defines technical standards for analog television systems (utilizing a 6-MHz modulated signal) used in North America.
- **Phase Alternating Line (PAL)**—A color coding system used in broadcast television throughout Europe, Asia, Africa, Australia, Brazil, and Argentina using a 6-, 7-, or 8-MHz modulated signal. Color differences signal an alternate phase at the horizontal line rate.
- **Système Electronic Couleur avec Memoire (SECAM)**—An analog color television system used in France and some other Eastern European countries using an 8-MHz modulated signal.

Modulation is the addition of information to an electronic or optical signal carrier. It can be applied to direct current (DC) by turning it on or off, to alternating current (AC), or to optical signals. Signal modulation is a process of varying a *waveform* to convey a message. The waveform can be changed in amplitude, frequency, phase, or some combination of any or all three to convey these messages.

Cable System Components

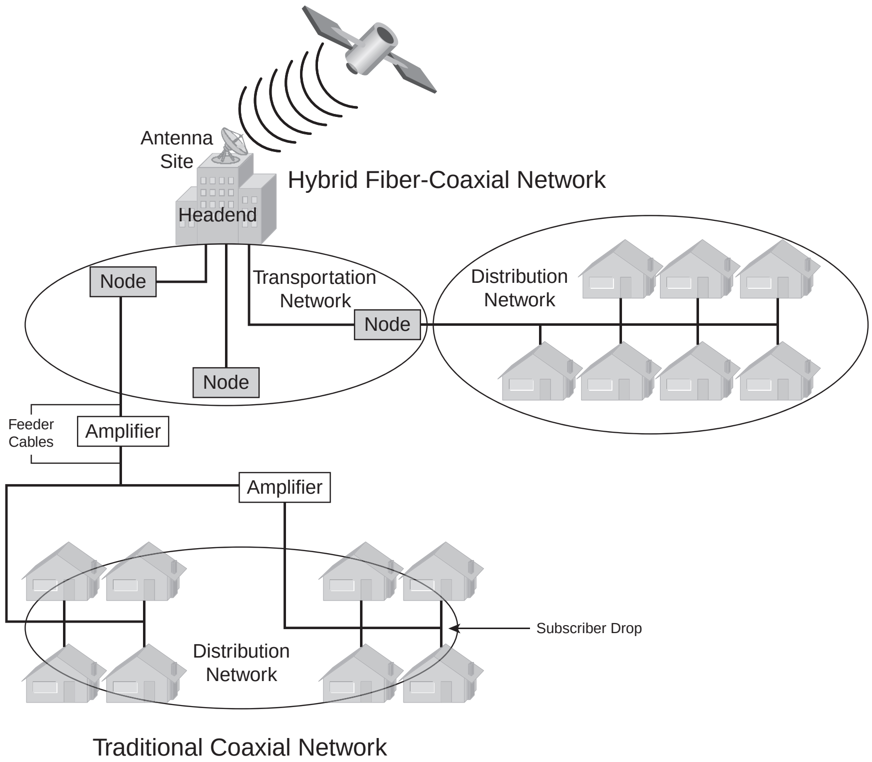
The description of the components associated with cable systems essentially equates to defining additional terminology. Typical components include:

- **Antenna site**—A location containing a cable provider’s main receiving and satellite dish facilities. This site is chosen based on potential for optimal reception of transmissions over the air, via satellite, and via point-to-point communication.
- **Headend**—A master facility where signals are received, processed, formatted, and distributed over to the cable network. This includes both the transportation and distribution networks. This facility is typically heavily secured and sometimes “lights-out,” meaning that it is not regularly staffed.
- **Transportation network**—The means and media by which remote antenna sites are connected to the headend facility. Alternately, this could be a headend facility connection to the distribution network. The transmission media may be microwave, coaxial supertrunk, or fiber optic.

- **Distribution network**—In typical cable system architectures, consists of trunk and feeder cables. The trunk is the backbone cable (usually 0.75-inch diameter) over which the primary connectivity is maintained. In many networks, the distribution network tends to be a hybrid fiber-coaxial network.
- **Node—**Performs optical-to-RF conversion of CATV signal as needed. Feeder cables (typically 0.5-inch diameter) originate from nodes that branch off into individual communities to provide services to anywhere between 100 and 2000 customers each.
- **Subscriber drop**—Connects the subscriber to the cable service network via a connection between the feeder portion of a distribution network and the subscriber terminal device (for example, TV set, VCR, high-definition TV set-top box, or cable modem). The subscriber drop components consist of the physical coaxial cabling, grounding and attachment hardware, passive devices, and a set-top box.

These components tend to be relatively easy to understand in concept. In practice, these are implemented in differing manners depending on the cable provider. Regardless of the chosen architecture, the concepts remain the same. Figure 3-1 illustrates typical cable provider architecture.

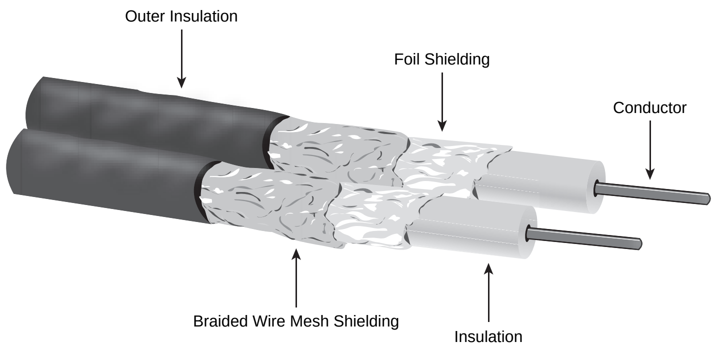
Figure 3-1 *Cable System Provider Architecture*



Cable Features

Cable systems use coaxial cable at the subscriber premises. The cable itself consists of a copper core surrounded by insulation and grounded shielding of braided wire. Figure 3-2 illustrates the basic anatomy of the coaxial cable.

Figure 3-2 *Coaxial Cable Anatomy*



Traditional television signal transmitted over the air lacked in quality and was subject to significant adverse effects from outside interference. It also required an external antenna in many rural and suburban locations. In locations in or near a major city, "rabbit ears" were sufficient to receive the transmissions. To overcome the need for external antennas, a coaxial cable was put in place and connected directly into the television. Today, all televisions include a "cable-ready" connection.

The construction of the cable is meant to minimize the effects of external electrical and RF interference. The ground shielding and the signal wire share a common axis to provide better protection against outside interference. The name "coaxial" is derived from this concept. This allows a high-quality signal to be transmitted and protected until it arrives at the subscriber premises. Initially, CATV networks were unidirectional and consisted of various amplifiers in cascade compensating for the signal loss of the coaxial cable in series. Taps coupled video signal from the main trunks to subscriber homes via drop cables. This is illustrated in Figure 3-1 as the Traditional Coaxial Network. Today's cable architecture is more in line with the right side of Figure 3-1 with the advent of the HFC network. The previously unidirectional nature of cable networks was a hindrance. The demand for bidirectional signals for both TV and the newer data services drove the evolutionary cycle of the cable network to include fiber for longer reach without the need for amplifiers.

The CATV system transmits RF signals from the headend via the trunk to a neighborhood node and down into the distribution network to subscriber drops.

Cable System Benefits

The essential idea behind cable is to bring cost-effective television and services to a dense subscriber base while maintaining high-quality content. Traditionally, this content was limited simply to television channels ranging from “life-line” (local weather/news/information channels) to premium-channel content.

In recent years, additional services have been added to the mix, including voice, data, and digital television options. Over the next few years, all of the services offered by cable providers will leverage the IP network as a platform for integrated services. IP-based services will carry all data, voice, and video content to the subscriber premises. Set-top boxes currently using RF signal will be IP attached and capable of delivering content to any number of access devices, including IP phones, mobile phones, and more.

The more advanced capabilities offered by high-speed network access brought about a practice of placing equipment, including telephone switches and cable modem termination systems (CMTS), in a common facility so that services could be leveraged in a variety of manners. The resulting broadband Internet access offering presents corporations with cost-effective connectivity for teleworkers who connect back to a central site either through a IPsec VPN or remote-access VPN. Additionally, interactive television content and Public Switched Telephone Network (PSTN) voice access for voice and fax calls allow cable providers to offer VoIP services.

Radio Frequency Signals

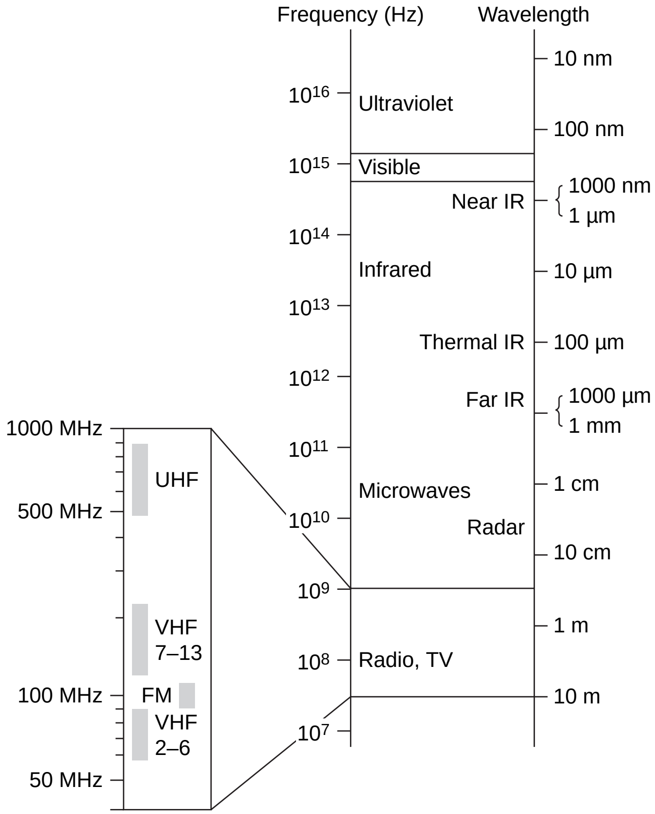
The term *radio frequency* defines a relatively small portion of the known electromagnetic spectrum. Figure 3-3 shows a small portion of the electromagnetic spectrum.

The whole of the electromagnetic spectrum is significantly more wide-ranging in terms of frequencies than what is shown in the figure. Smaller still is the portion of the spectrum specifically associated with RF (5 MHz to 1 GHz).

Generally, *frequency* is defined as the rate at which a repeated event occurs over time. In terms of electromagnetism, that event is known as a *cycle*. One cycle per second is known as 1 hertz (Hz). RF is measured in number of cycles or “waves” per second. Other characteristics of interest include wavelength and amplitude. The wavelength is the distance between peaks or valleys in the wave cycle (that is, the length of one complete cycle) where the amplitude is the peak height or depth of the wave during the cycle. *Frequency* has an inverse relationship to wavelength. As frequency increases, the wavelength tends to decrease. Where *f* is frequency, *c* is the speed of light ($3 * 10^8$ meters per second), and Λ is wavelength:

$$f = c/\Lambda$$

Figure 3-3 *Partial Electromagnetic Spectrum*



This calculation assumes a waveform moving through a vacuum. As the wave travels through different media types, the frequency is constant but the wavelength and speed change. The effect of various media types on a waveform is measured by a refractive index and would need to be factored into the discussion for a true representation. However, because the physics of waveform dynamics is outside the scope of the exam, further discussion will be put aside.

When tuning a radio or television, the tuner is finding individual frequencies in their respective ranges. When a frequency used by a radio station is tuned in, the transmission from that station is transformed into voltage that applies current of varying strength to a strong magnet in the speaker. The speaker's magnet becomes stronger with the application of that current. Metallic rings in the diaphragm of the speaker are attracted to the magnet, creating motion and vibration that our ears end up interpreting as sound.

In cable systems, a similar concept is applied. Rather than being transmitted over the air, the signals are sent across the cable provider's HFC to the subscriber. Televisions (high-definition or otherwise), set-top boxes, cable modems, and other equipment tune to various frequencies that allow them to interpret the signals to provide content.

In terms of over-the-air television broadcasts, there are traditionally very high frequency (VHF) and ultra-high frequency (UHF) channels. VHF utilizes the 30- to 300-MHz range and UHF the 300- to 3000-MHz range. The individual television channels utilize broadcast frequencies in their respective ranges.

The cable television industry defines the television spectrum only in the downstream path. The upstream path is not subject to a frequency plan. The frequencies can be monitored and upstream signals placed into “clean” areas free from interference and noise from other signals. Typically the range of 5 to 15 MHz tends to be noisy and difficult or impossible to utilize.

The cable network is able to transmit upstream and downstream simultaneously. For downstream signals, those directed toward subscribers, the frequency range includes 50 to 860 MHz. Alternately, upstream signals, those directed away from subscribers, utilize the range of 5 to 42 MHz.

The downstream range has been subdivided into smaller channels as defined by a standardized frequency plan. This plan places a “guard band” between the ranges for upstream and downstream transmissions. This is required due to the cutoff characteristics of high-pass and low-pass filters. Such filters are needed to ensure that there is no signal leakage into other frequency spectrums.

Digital Signals over RF Channels

Cable specifications are defined by a document known as Data-over-Cable Service Interface Specifications (DOCSIS). DOCSIS is an international standard developed by CableLabs, a nonprofit organization and development consortium dedicated to cable-related technologies. Founded in 1988, CableLabs is essentially charged with the testing and certification of cable technology access equipment such as cable modems and CMTS. The organization makes decisions on standardization and grants for DOCSIS certification and qualification.

The core of DOCSIS defines the manner in which individual components communicate in the cable network. The specification for data-over-cable defines high-speed data transfer over an existing CATV system. Cable operators use DOCSIS to implement Internet access over their existing HFC infrastructure.

Cable transmissions are highly similar to wireless transmissions, with the obvious exception of the presence or absence of copper. DOCSIS defines the frequency plan to be used as well (6 MHz for DOCSIS, 7 MHz and 8 MHz for Euro-DOCSIS). As discussed, cable transmission uses the RF bands. The RF band is composed of the frequencies above audio and below infrared.

Within DOCSIS are the OSI Layer 1 and Layer 2 requirements for connectivity between cable devices:

- **Physical layer (Layer 1)**—Definition of data signals to be used by cable operators. DOCSIS specifies bandwidths for each channel. These channel widths are 200 kHz, 400 kHz, 800 kHz, 1.6 MHz, 3.2 MHz, and 6.4 MHz. Additionally, DOCSIS defines the manner in which these signals are modulated.
- **MAC layer (Layer 2)**—Definition of a deterministic access method depending on DOCSIS version: time division multiple access (TDMA) for version 1.0, 1.1, and 2.0 or synchronous code division multiple access (S-CDMA) in version 2.0. The MAC layer protocol controls access to the return path. The DOCSIS MAC protocol uses a request/grant system for transmissions. This means that there is little or no use of contention for bandwidth as in Ethernet networks (and no collisions).

Like many other standards and specifications relating to technology, DOCSIS is evolving. DOCSIS version 1.0 was released in March 1997, followed by version 1.1 in April 1999. Version 2.0 came about in January 2002 as a result of increased demand for symmetric, real-time services and applications such as IP telephony. This release enhanced the technology by augmenting upstream speeds and putting QoS capabilities in place.

DOCSIS 3.0 was released in August 2006. Expected enhancements may include IPv6 support and channel bonding. Channel bonding allows the use of multiple downstream and upstream channels together, at the same time, by the same subscriber to increase overall bandwidth. In fact, through the use of the Wideband architecture pioneered by Cisco, current expectations would allow the offering of 100+ Mbps services to the subscriber. In fact, DOCSIS 3.0 expects capabilities reaching 160 Mbps downstream with 120 Mbps upstream.

With new products on the horizon from Cisco's Linksys and Scientific Atlanta business units, speeds and services will most likely continue to evolve well beyond current imagination.

More information regarding DOCSIS can be found at CableLabs' website: http://www.cablemodem.com/specifications/.

Data over Cable

Television, alone, simply doesn't meet the market demand anymore. Bruce Springsteen's song, "57 Channels (And Nothin' On)" says it well. While in need of an update to a number of channels placed well into triple-digits, it may well ring true for the foreseeable future. The Internet has changed the definition of what is considered entertainment.

Cable provider infrastructure has evolved somewhat from pure coaxial networks to HFC. The driving force behind this evolution to HFC is easily understandable. Simply put, the signal from the antenna degrades as it travels across the copper medium. This can be corrected to some degree by amplifiers in the path, roughly every 2000 feet. This ensures that the signal is delivered to the subscriber with adequate power to provide all of the channels within the spectrum for analog television, digital television, and cable modem services (the range of 50 to 860 MHz).

In a 20-mile plant, roughly 52 amplifiers would be required to maintain the necessary signal strength to serve all subscribers along the line. Unfortunately, as the signal degrades, it picks up noise or distortion, and that noise or distortion is amplified along with the signal. Eventually, what's left is an unusable mass of wasted voltage. The result is a disruption in service and unhappy customers.

To mitigate the risk of customer satisfaction issues, the network must implement infrastructure necessary to avoid the signal degradation and loss. Luckily, a suitable technological solution is available in the form of fiber optics.

Hybrid Fiber-Coaxial Networks

Fiber dramatically cuts the number of amplifiers needed in the distribution and transport networks. The degree to which fiber is installed varies from provider to provider. Some providers have opted to go entirely fiber into the subscriber premises. Fiber transports the signal using either laser or light emitting diode (LED) technologies depending on the type being deployed.

Fiber has a number of benefits over traditional cable. Fiber is thin and lightweight, able to cover longer distances with virtually no loss of signal or noise, and is immune to outside sources of electromagnetic interference. Because the number of amplifiers is reduced, there is some monetary benefit associated with support and equipment costs. There is some discussion as to which is easier to handle, cable or fiber. Essentially, that discussion comes down to preference. Cable tends to be rigid and sturdy whereas fiber is thin and somewhat pliable, requiring some advanced skills and care to properly terminate.

Fiber trunks have been used to replace trunk cables in the architecture. These carry downstream traffic from the headend to the neighborhood node where the signal is converted from light to electrical and forwarded on to the subscriber via copper coaxial cable at signal strength greater than 50 decibels (dBm). A *decibel* is a unit of measure for expressing ratios between two quantities. The prefix "deci-" follows the International System of Units (SI) unit designation, meaning 1/10, and is always lowercase. To further confuse the issue, the decibel merely follows the SI naming convention; it is not an SI unit. The "bel" portion of the word is derived from Alexander Graham Bell's name; therefore, it is capitalized. When discussing absolute power levels, such as the signal strength on a cable network when the signal reaches the subscriber, the power is given in relation to milliwatts. This is expressed as dBm.

The movement of the cable system infrastructure to the HFC network architecture is essentially the catalyst that allowed for more advanced services to be offered. Initially, this was limited to data over cable but has evolved significantly and will continue to do so. DOCSIS 3.0 and Cisco's Wideband channel bonding technology will push the services and applications offerings forward at an unimaginable pace. This, coupled with the integrated services and applications afforded to the teleworker by Service-Oriented Network Architecture (SONA), will reinvent the way in which we work, live, play, and learn. In the same manner that SONA provides the framework for enterprise evolution to an Intelligent Information Network (IIN), the service provider market has an IP-Next Generation Network (IP-NGN) architecture providing a path to a similar destination. Once both the enterprise and the service providers begin to reach the true IIN state, the goal of "one experience regardless of locale or access device" will evolve to encompass both networks. One user, any service, anywhere will be a realistic expectation.

Data Transmission

DOCSIS has a number of components that comprise its architecture. These include

- **Cable modem termination system (CMTS)**—The CMTS usually resides in the headend. The CMTS modulates the signal to the cable modem (CM) and demodulates the CM response.
- **Cable modem (CM)**—The CM is a CPE device that terminates as well as performs modulation and demodulation of signals to and from the CMTS. Typical transmission speeds for CMs range from 1.5 to 6 Mbps.
- **"Back office" services**—Services such as TFTP (for configuration file upload/download), DHCP (dynamic IP addressing), ToD (Time of Day for log timestamping), and others that provide vital tools for the maintenance of a CM installation.

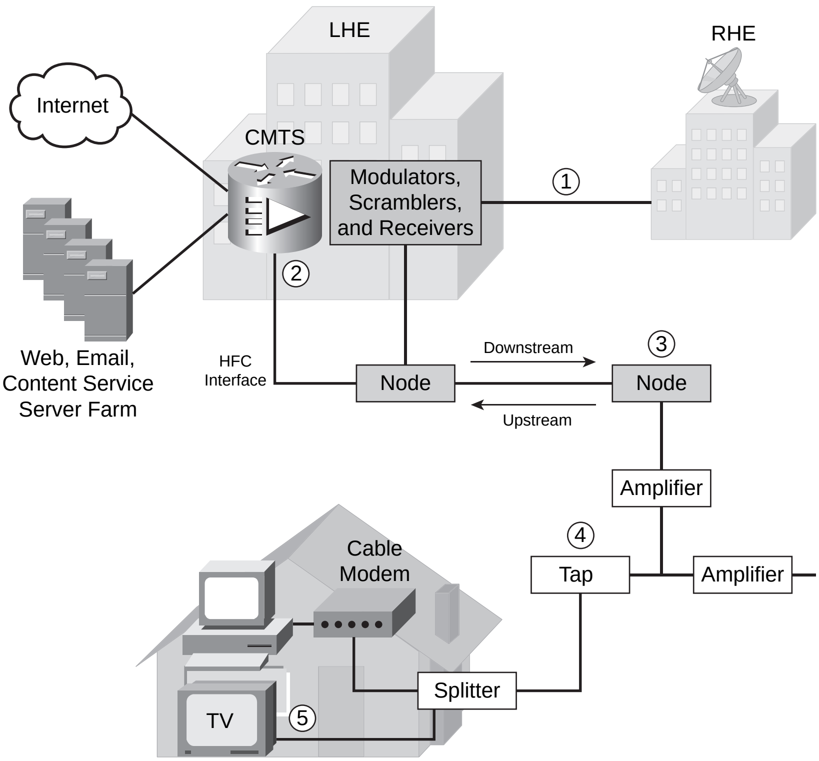
Critical information for the configuration of CM hosts is carried in the DOCSIS configuration file. This is a file that contains information pertinent to all CM hosts attaching to the provider network.

The headend CMTS communicates with the CMs located in subscriber homes. The headend provides the systems necessary to provide Internet access for associated CMs. A typical network segment serves anywhere from 500 to 2000 active data connections sharing the upstream and downstream bandwidth. The cable network can support up to 40 Mbps downstream and 30 Mbps upstream under the DOCSIS 2.0 specification. DOCSIS 3.0 will increase capacity to 160 Mbps downstream and 120 Mbps upstream. However, the current service offerings vary based on cable provider architecture and provisioning practices—the typical range is 256 kbps to 6 Mbps for access speeds.

As the network grows through the provisioning of additional subscribers and services, the network infrastructure can be augmented with relative ease. This is accomplished by adding an additional television channel allocated to high-speed data, thus doubling available subscriber bandwidth. Alternatively, a reduced number of subscribers per network segment would have a similar effect of increased bandwidth per subscriber. This is done either by increasing the number of headends or by laying additional fiber infrastructure connections close to the subscriber base to be served.

Figure 3-4 serves the purpose of bringing together a more complete vision of the technologies discussed in this chapter.

Figure 3-4 *Cable Technology Architecture*



With much of the technology and terminology defined, Figure 3-4 provides a conceptual illustration of the operations of cable networks.

Step 1 In the downstream path, the local headend (LHE) receives television signals through the satellite dishes, antennas, analog and digital video servers, local programming, and other headends.

Step 2 The LHE distributes these television signals throughout a distribution network to subscribers. The signals are combined onto a coaxial cable, and then passed to a fiber transmitter in the headend.

Step 3 The headend fiber transmitter performs the signal conversion from RF to light. The signal is then passed across the network to a fiber node located relatively near the subscribers it serves, where a conversion from light back to RF is performed.

Step 4 The RF is passed via coaxial cable to the subscriber home where it passes through taps and splitters to reach destination devices.

Step 5 The RF splitter divides the combined RF signal into its individual service pieces, in this case data and video. The data portion goes to the cable modem while the video goes to the cable set-top box. The cable modem demodulates the signal back into digital data prior to passing it on to the destination end station (user workstation PC) over the LAN connection, be it wired Ethernet or wireless 802.11a/b/g.

For outbound or upstream data transmissions, the user's computer transmits the data via the available connection (Ethernet, wireless, and so on) to the cable modem. The cable modem modulates the digital data from the computer to RF signal and transmits the data at predefined RF and power levels. The CMTS receives the data RF channels and demodulates the data signal back into digital data for routing across the network and Internet.

Cable Technology Issues

The primary drawback for cable networks is the fact that the data services are using a shared infrastructure. That is, all of the subscribers on a cable carrier's network are essentially competing for scarce resources (in this case bandwidth). These issues are readily resolved by the cable carrier by limiting subscribers or by expanding available data channels. DOCSIS 3.0 has addressed this issue significantly as well with the concept of channel bonding. However, it is unclear how much time will pass before full adoption and deployment of the 3.0 capabilities.

The most compelling drawback to using shared bandwidth architectures is that privacy issues can potentially arise if the network is not properly secured. This can be addressed by encryption and other features specified in the DOCSIS standards.

As with any technology, oversubscription of a CMTS is a potential issue. This is a factor well out of control of the subscriber. Fortunately, the technological advances within DOCSIS are providing innovation with minimal incremental hardware costs. They are finding new ways to utilize the same resources more effectively.

Many of the support issues that arise surrounding cable installations end up having to do with the manner in which the cabling was installed in the subscriber home. The home must be grounded and bonded correctly for both safety and the elimination of ground loops. Ground loops can result in the introduction of significant noise on the wire. Coils, ferrite beads, and filters might be able to reduce noise on the wire. If the cable was tightly coiled before installation, the cable might experience some degradation of signal due to breaches in the cable sheath.

Provisioning Cable Modems

Cable modem provisioning can seem a bit daunting when compared with other technologies. There are several steps involved in the process. The headend CMTS must have operational provisioning servers such as DHCP and TFTP in order for IP addressing and configuration files to be provided. The steps defined by DOCSIS are as follows:

Step 1 **Downstream setup**—At power-on, the cable modem scans and locks the downstream path for the allocated RF data channel in order for physical and data link layers to be established.

Step 2 **Upstream setup**—The cable modem listens to the management messages arriving via the downstream path. These include information regarding how and when to communicate in the upstream path. These are used to establish the upstream physical and data link layers.

Step 3 **Layer 1 and 2 establishment**—Connection established from CM to CMTS to build physical and data link layers.

Step 4 **IP address allocation**—After Layer 1 and 2 are established, Layer 3 can be allocated as well. This is done by the DHCP server.

Step 5 **Getting DOCSIS configuration**—The CM requests the DOCSIS configuration file from the TFTP server. This is an ASCII file created by DOCSIS editors. A DOCSIS configuration file is a “binary file” and has the parameters for cable modems to come online in accordance to what the ISP is provisioning, such as maximum downstream and upstream rates, maximum upstream burst rate, class of service or baseline privacy, management information bases (MIBs), and many other parameters. This file can be loaded on the CM via TFTP or the CM can be manually configured.

Step 6 **Register QoS with CMTS**—The CM negotiates traffic types and QoS settings with the CMTS.

Step 7 **IP network initialization**—Once Layers 1, 2, and 3 are established and the configuration file is pulled from the TFTP server, the CM provides routing services for hosts on the subscriber side of the CM. It also performs some Network Address Translation (NAT) functions so that multiple hosts might be represented by a single public IP address.

As part of the initialization phase, the CM makes contact with a DHCP server on the provider's network. The DHCP server provides the following information to the CM:

- IP address
- Subnet mask
- Default gateway
- TFTP server
- DHCP relay agent
- The complete name of the DOCSIS configuration file
- Address of ToD server
- Syslog server address

Once this information is obtained, the CM can issue a request to the ToD server to set its clock to the correct time. This facilitates syslog timestamps. At this point, also, it can issue a TFTP request to the TFTP server for its DOCSIS configuration file.

To facilitate standardization of router software on client CMs, the Cisco IOS images desired for use with the CMs can be stored on the TFTP server. The Cisco IOS version and filename can be specified in the DOCSIS configuration file to be downloaded at each power-on of the router. This takes several minutes, but does provide some degree of control on the part of the service provider.

Additionally, the router configuration(s) can be stored on the TFTP server to be downloaded at each power-on as well.

These are additional steps, as the Cisco IOS image and configuration can be stored on the router as traditionally done in most routing environments. This makes the power-on sequence a much shorter process in the event of a router reload.

Critical information for the configuration of CM hosts is carried in the DOCSIS configuration file. This is a file that contains information pertinent to all CM hosts attaching to the provider network. All DOCSIS-compliant configuration files include the following information elements:

- Radio frequency information
  - — Downstream frequency
  - — Upstream channel ID
  - — Network access configuration
- Class of service information
  - — Class of service ID
  - — Maximum downstream rate

- — Maximum upstream rate
- — Upstream channel priority
- — Minimum upstream rate
- — Maximum upstream channel burst
- — Class of service privacy enable

- Vendor-specific options
  - — Vendor ID
  - — Vendor-specific options
- SNMP management
  - — SNMP write-access control and SNMP MIB objects
- Baseline privacy interface configuration
  - — Authorize wait timeout
  - — Reauthorize wait timeout
  - — Authorization grace timeout
  - — Operational wait timeout
  - — Rekey wait timeout
  - — TEK grace time
  - — Authorize reject wait timeout
- Customer premises equipment
  - — Maximum number of CPEs
  - — CPE Ethernet MAC address
- Software upgrade
  - — TFTP software server IP address
  - — Software image filename
- Miscellaneous
  - — Concatenation support
  - — Use RFC 2104 HMAC-MD5
  - — CMTS authentication

After the CM has downloaded its configuration file, it can begin to communicate further on the network. Many options in the DOCSIS configuration file are unused for the bulk of CM provisioning.

Foundation Summary

Cable architecture will continue to evolve and grow to add more applications and services. Subscriber demand will drive the speed of that evolution. The needs of the teleworker will be no small part of that drive.

The term *cable* refers to the coaxial cable predominantly used in the cable provider's network. The cable system architecture provides a broadcast or shared media access method to subscribers. Table 3-3 lists the components in a cable system.

Table 3-3 *Cable System Components*

Component	Description
Antenna site	Location with primary receiving antennas and satellite dishes
Headend	Facility where signals are received, processed, formatted, and combined Transmits cable signal via distribution network to subscriber drops
Transportation network	Links an antenna site to a headend
Distribution network	Trunk and feeder cable infrastructure
Subscriber drop	Devices and components used to connect the subscriber home to the distribution network (for example, taps, splitters, and cable modem)

As with any technology, cable systems have numerous associated standards, as listed in Table 3-4.

Table 3-4 *Cable System Standards*

Standard	Description
NTSC	Technical standards for analog TV systems used in North America Uses a 6-MHz modulated signal
PAL	Color encoding system used in broadcast television systems in most of the world Uses 6-, 7-, or 8-MHz modulated signal
SECAM	Analog color TV system used in France and some other European countries Uses an 8-MHz modulated signal

DOCSIS provides the specification for data over cable. It is the data service interface standard for data carried over RF interfaces. DOCSIS also dictates the process by which CMs are provisioned. The DOCSIS CMTS uses differing channels to communicate upstream and downstream with the CM in the subscriber home. The RF range for the downstream flow will be specified while the upstream range will by allocated based on available bandwidth frequencies.

The HFC network allows providers to increase services offered while decreasing infrastructure cost. Fiber optic cable overcomes issues of coaxial cable relating to noise, electromagnetic interference, and relatively short distance limitations.

Q&A

The questions and scenarios in this book are designed to be challenging and to make sure that you know the answer. Rather than allowing you to derive the answers from clues hidden inside the questions themselves, the questions challenge your understanding and recall of the subject.

Hopefully, mastering these questions will help you limit the number of exam questions on which you narrow your choices to two options, and then guess.

You can find the answers to these questions in Appendix A. For more practice with exam-like question formats, use the exam engine on the CD-ROM.

1. Describe a situation in which a cable provider would benefit from the use of fiber over coaxial cable.
2. List at least three of the cable system components detailed in this chapter and their purpose.
3. Data over cable has enabled a number of advanced services and applications. List at least three, then consider two to three additional services that may be beneficial as a future offering.
4. Describe how the cable access technology fits in to the SONA framework.
5. Describe the provisioning process for a cable modem.
6. DOCSIS 3.0 promises some very interesting service offerings. Which technology innovation allows these promises to become reality?
7. With the release of DOCSIS 3.0, what are the advertised maximum upstream and downstream transmission speeds?
8. A DOCSIS configuration file contains a standard listing of information. List at least five of the items included in the file.

Exam Topic List

This chapter covers the following topics that you need to master for the CCNP ISCW exam:

- **DSL Features**—Describes the features of DSL
- **DSL Limitations**—Describes the limitations of DSL technology
- **DSL Variants**—Describes the various implementations of DSL, including symmetric and asymmetric DSL types
- **ADSL Basics**—Describes the basics of ADSL technology
- **ADSL Modulation**—Describes ADSL modulation technologies
- **Data Transmission over ADSL**—Describes data transmission over ADSL
- **PPP over Ethernet**—Describes the architecture and deployment models of PPPoE
- **PPP over ATM**—Describes the architecture and deployment models of PPPoA