Goals of On-Demand Services

On-demand services share many of the same goals as interactive services (see Chapter 8).

Successful on-demand services add value in some way for the programmer, cable operator, and customer. Added value can come from a number of sources:

- Customer-generated revenue—If an on-demand service is useful or compelling, the customer will be prepared to pay for it. Specifically, video-on-demand has demonstrated significantly higher buy rates than impulse pay-per-view in a number of trials.
- Advertiser-generated revenue—If an on-demand service can increase the effectiveness of existing commercials or allow the customer to access a company's product and service information, the advertiser will be prepared to pay the cable operator for that service.
- Enhanced customer perception and retention—Increased competition from DBS, MMDS, and others make it even more important to cable operators that their customers are happy with their cable service. Availability of on-demand services enhances the customer's perception of the overall cable service.

To be successful, on-demand services must provide a satisfying experience for the customer in the following areas:

- They must be friendly and intuitive to use. The service needs to be easily accessible from the remote control with little or no customer training.
- They must present an attractive, graphically rich interface. The customer is accustomed to the high production values of most television programming and will not tolerate an uninteresting or static user interface.
- They must be reliable and highly available. If an interactive service becomes popular with customers, they will be frustrated if it is unreliable or unavailable.

The business case for on-demand services is simple: An on-demand service is economical if the revenue generated by it can pay for the capital cost of the additional hardware in a reasonable period of time (for example, four years). Until recently, there were two fundamental barriers to on-demand services:

- The cable system could not provide sufficient bandwidth to support revenue generating movies-on-demand service; that is, too few customers would be able to access the service simultaneously to make it successful.
- The cost of the digital set-top was prohibitive and made the movies-on-demand business case uneconomic.

The first problem has been solved by hybrid fiber coax upgrades, which provide a massive increase in the bandwidth available to each customer. The second problem has been solved because the digital set-top has been cost-reduced and is now justified economically for broadcast digital services. This chapter describes how the video-on-demand architecture is tailored to provide the best economic solution to these problems.

On-Demand Services

There are many services that are enabled by on-demand technology. The following list of services provides some examples:

- Movies-on-demand
- Music-on-demand
- Post-broadcast on-demand
- Special interest programming
- Distance learning
- Library access
- Video mail

Movies-on-Demand

Usually called video-on-demand, the idea of providing access to a movie library is very appealing. The movies-on-demand (MOD) service has been extensively tested in trials, and customer response has been enthusiastic.

This service emulates the current video rental business, so it is easiest to justify from an economic point of view. The cable industry today has later *windows* (that is, the period of time at which particular movies are available) than the video rental market. However, if a movies-on-demand service can be successfully deployed, the cable industry will be well-positioned to negotiate better windows for MOD titles.

Music-on-Demand

The music-on-demand service provides access to a music library. Broadcast music services (for example, Music Choice and DMX) are effectively niche services, and it is unclear whether on-demand access to a music library will change the status of music services.

This service emulates the CD player, but allows the customer to access any musical selection. For the same reasons that there are no CD rental stores, it is unlikely that there is much business potential in a music-on-demand service. However, music-on-demand can be used to promote CD sales in the same way as the Internet.

Post-Broadcast On-Demand

Post-broadcast on-demand uses video-on-demand technology to allow access to a library of titles that have been broadcast. It allows the customer to view shows they have missed and caters to the segment of the market that is prepared to pay for this convenience.

This service emulates using a VCR to record broadcast programming for viewing at a later time. It provides convenience, because the customer does not have to remember to record the program, and flexibility, because many titles can be offered. Some early tests also showed that the success of this service is very programming type–dependent; for example, post-broadcast on-demand might work well for soap operas or hit sitcoms, but it might not be as successful for children's programming. The real question is whether this kind of service is commercially viable—will customers pay for this type of service?

Special Interest Programming

Video-on-demand can allow random access to special interest programs and provides an alternative to creating new special interest channels. New special interest channels are being created at an amazing rate; digital compression allows many more channels on a cable system, but at some point there is a limit to the number of channels. In addition, many special interest channels are hard-pressed to provide sufficient programming to fill their schedule. With the addition of each new channel, the potential audience is further subdivided, making advertiser sponsorship more difficult. Therefore on-demand delivery of special interest programming provides a solution to dedicated channel assignments and limited viewership.

Distance Learning

The capability of providing multimedia delivery of video, graphics, and text makes on-demand technology ideal for distance learning applications. Distance learning is an ideal candidate for on-demand services. In many ways, it is similar to special interest programming—appealing only to a niche audience and not justifying a dedicated channel. (Currently, distance learning channels aggregate a number of courses to justify a channel allocation, but this model can be very inconvenient for customers if the broadcast time of the course does not fit into their schedule.)

Library Access

The idea of a large online, multimedia library is not new, but the technology to retrieve titles in real-time makes this concept compelling. On-demand library access emulates the service currently provided (albeit poorly) by the WWW. This service allows retrieval of short clips of multimedia information and would primarily support research activity.

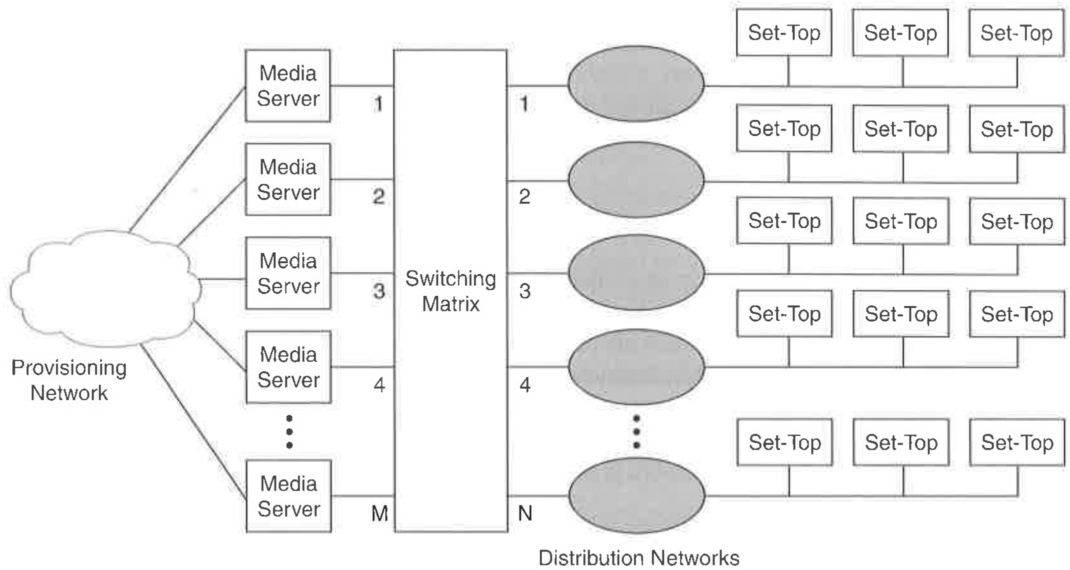
Video Mail

The store-and-forward approach to communications is often more convenient. This approach can be extended to a video mail service that allows one customer to send a video and audio message to another. Video mail is a communications service and is not really part of video-on-demand, but VOD technology could be used to provide the record and playback capabilities required for a multimedia e-mail service.

On-Demand Reference Architecture

Figure 10-1 is a reference diagram for an on-demand system.

Figure 10-1 *On-Demand Reference Architecture*



At this level of detail, the system is composed of the following major components:

- Provisioning network—This allows new content or multimedia *assets* to be loaded onto the media servers.
- Distribution networks—In a cable system, the distribution networks are formed by the hybrid fiber coax (HFC) plant. Each distribution network supplies a group of set-tops.
- Media servers—The media servers provide the streaming content for distribution to the set-tops.
- Switching matrix—The switching matrix provides a path from each media server to each distribution network.
- Set-tops—The set-top provides termination of the streaming content and adapts it to the television set.

Each of these components is described in more detail in the following sections.

Provisioning Network

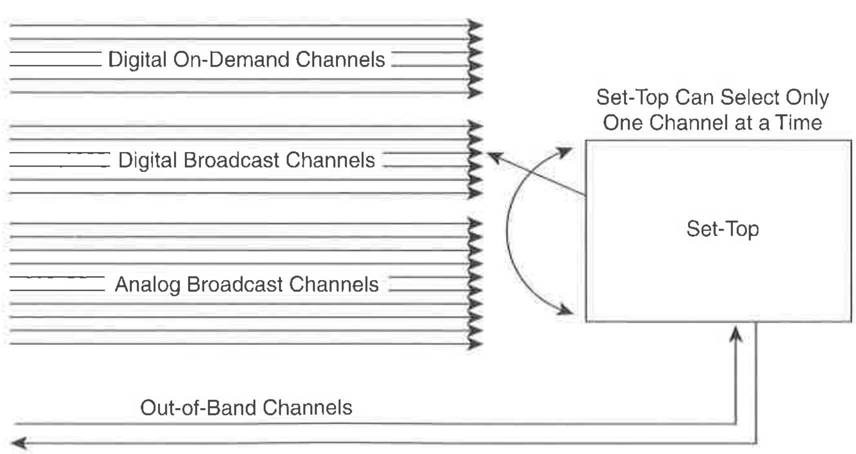
The provisioning network provides secure delivery of content from the content provider to the video server location. Satellite or terrestrial links could provide this network. The important point to note is that the content provisioning can be modeled as a series of file transfers and, accordingly, the requirements for the content provisioning network are considerably relaxed compared to the distribution network. In fact, multimedia assets do not need real-time delivery, and the QoS of the provisioning network does not have to be guaranteed. Therefore, available bit rate services (on a satellite channel, for example) can be used to deliver multimedia assets.

Distribution Network

Figure 10-1 shows that in an on-demand cable system, there are actually *multiple, parallel* distribution networks. Each distribution network serves a group of set-tops so that sufficient capacity is allocated to meet the peak on-demand traffic generated by those set-tops (see Chapter 2, "Analog Cable Technologies"). Media servers are connected via a switching matrix to the distribution networks. Finally, each media server is connected to a provisioning network for content provisioning. Note that in Figure 10-1, for simplicity, the control and signaling network is not shown.

Figure 10-2 shows the channel allocation to each set-top. The analog and digital broadcast channels are the same for all set-tops (and all customers), but the on-demand channels are narrowcast to a *set-top group*.

Figure 10-2 *Set-Top Channel Allocation*



The size of the set-top group can be calculated as follows:

- The aggregate capacity of the on-demand channels is equal to the number of channels multiplied by the capacity of each channel. The more channels the better, because this provides better statistical multiplexing. For example, if 10 channels are allocated (requiring 60 MHz of cable spectrum) and 256-QAM modulation is used, the aggregate bandwidth is 10×38.8 Mbps, or 388 Mbps.
- The traffic generated by each set-top is determined by the on-demand session rate. For standard definition compressed digital television, 3.8 Mbps is a realistic number (and makes the math easier).
- The next factor is the peak utilization of on-demand services. This is the percentage of all customers who simultaneously request on-demand services at the busiest time. On-demand services are usually engineered for a peak-utilization rate of 10% because this number seems to be validated by on-demand trials (see Chapter 11).
- The number of set-tops per distribution network is given by the following formula:

  aggregate capacity × peak utilization ÷ on-demand session rate

  Using the numbers in the example, each distribution network can serve 1,000 set-tops. In a cable system serving 100,000 set-tops, 100 distribution networks would be required.

The distribution network provides many areas for innovation in the cost-effective delivery of on-demand services. There are a number of technology choices to be made by the network architect:

- Physical protocol—In a fiber-based network, the physical layer protocol can use a digital (for example, SONET) or analog physical layer, or a combination of both. In an HFC network, the digital payload must be modulated to traverse the analog part of the network.
- Transport protocol—There are a number of alternative transport protocols to choose from for on-demand services. The leading alternatives are MPEG-2 transport, ATM, and IP.

Physical Protocols

In an HFC cable system, the distribution network is composed of a series of cascaded fiber links and coaxial links (see Chapter 2). The physical layer protocol over the fiber link can be digital (for example SONET) or analog, but the physical layer over the coaxial links is always analog. A modulator performs the conversion from digital to analog and may be placed anywhere in the signal path between the switching matrix and the first analog link.

In practical terms, modulators are sensitive pieces of equipment that require a temperature-controlled environment; the possible locations are the headend or the distribution hub.

Modulation at Headend

Placing the modulators at the headend centralizes all the digital components of the system and uses analog fiber to transport the modulated carriers all the way to the set-tops. Centralizing the modulators might require considerable space—for example, a 100,000 set-top system would require 1,000 modulators at 10% peak utilization. However, located at the headend, the modulators can easily be reconfigured to best match the traffic pattern changes of the system as it grows.

The use of analog fiber transport is familiar to most cable operators because it is already used for analog and digital broadcast channels; the only change is that instead of one channel line-up, a separate bank of on-demand channels is required for each set-top group. However, multiple fibers or wavelength division multiplexing can be used to carry each bank of on-demand channels to the set-top group.

Modulation at Distribution Hub

Modulation at the hub allows on-demand traffic to be integrated over a single transport with other digital signals, such as cable modem, telephony, out-of-band signaling, and network management traffic. In the distribution hub, the modulators are closer to the set-top (in terms of fiber miles), and there is less analog degradation of the modulated signal. Although digital transport provides more flexibility and can be extended over greater distances than analog transport, there is a cost premium to be paid for digital transport.

Transport Protocols

There are a number of alternative transport protocols for on-demand services. The leading alternatives are MPEG-2 transport, ATM, and IP:

- MPEG-2 transport—MPEG-2 transport is optimized for compressed, streaming media.
- Asynchronous transfer mode (ATM)—ATM transport is a compromise protocol designed to handle video, data, and telephony traffic.
- Internet Protocol (IP)—IP was designed for data traffic but is being extended to add features for streaming media.

These transport protocols are discussed in more detail in Chapter 4, "Digital Technologies." There is no *correct* choice for all circumstances, but the following guidelines will help you select the best choice for your application:

- If a single traffic type dominates, select the best transport for that traffic type. For example, the best choice for a video-on-demand application is MPEG-2 transport.
- The choice of transport type is closely related to the need for distributed switching and routing. MPEG-2 transport switches are not available commercially, and ATM or IP might be a better choice for flexibility if the additional cost can be justified.

- What transport protocol is used by set-tops that are already deployed? Nearly all first-generation digital set-tops accept only MPEG-2 transport streams, and protocol conversion back to MPEG-2 in the distribution network will be required to support these set-tops if ATM or IP are selected. (Figure 10-5 provides an example of this case.)

Media Servers

The server has a number of functions and can be broken down into a number of functional elements to aid description (however, note that a specific implementation might not follow these lines):

- Asset management—Each file stored on the media server is called an *asset*. Assets must be managed to allow them to be provisioned and retrieved by the streaming service.
- Streaming service—The streaming service delivers an asset or group of assets according to the requirements of the on-demand service.
- Directory service—The directory service provides a list of assets to the server application.
- Server application—The server application provides the intelligence and control of the media server. Different applications are used to provide different on-demand services.

Asset Management

Asset management is the function responsible for making sure that assets are available to the streaming service when they are required. Asset management supports a number of functions:

- Provisioning—Each asset must be downloaded onto the media server via the provisioning network. The asset is the movie file and related elements, such as the trailer video file, the poster image, the text description, the price, and so on.
- Storage management—Each asset must be placed into the media server storage. Multiple copies of assets might be required based on server design and viewing demand.
- Deletion—Assets must be deleted when they are no longer required.

Streaming Service

The streaming service delivers an asset or group of assets according to the requirements of the on-demand service. For example, to stream a movie requires that the video and audio streams are synchronized and delivered at the precise rate for the set-top decoder. The streaming service is often implemented with special hardware to satisfy the stringent real-time requirements for streaming MPEG-2 encoded assets.

Directory Service

The directory service provides a list of assets to the server application via an API. The directory service is responsible for keeping track of assets and liberates the application program from this task. A directory service is useful for providing asset search functions, for example, to locate a movie based on genre or actor.

Server Application

The server application allows the media server to be used for many different on-demand services—typically, there is a different server application for each on-demand service. For example, a movies-on-demand application might support functions such as providing a list of available movies, movie previews, movie purchase, fast-forward, pause, and so on.

Conditional Access

Conditional access (CA) is required for the distribution of any streaming media that have value and must therefore be protected from signal theft. There are two approaches to providing conditional access to streaming media from the server:

- Encrypt the signal at the output of the server. This approach follows the broadcast model and can conveniently use the same conditional access system that is already in place for digital broadcast signals. The conditional access system must support additional interfaces to support secure session establishment and key distribution to the on-demand client application.
- Encrypt the stored assets on the server. This approach requires no stream encryption at the headend because the preencrypted assets are streamed directly from the server storage. Secure key distribution to the on-demand client could use the broadcast conditional access system or a separate conditional access system. The disadvantage to preencrypted assets is that the encryption is static and might be less resistant to pirate attacks. Preencryption also does not allow statistical multiplexing because the MPEG stream is encrypted and cannot be reencoded. Finally, updating preencrypted content to fix expired keys places an additional load on the server.

Server Placement

In theory, the server can be placed at any point in the distribution network between the headend and the set-top. However, the server requires a controlled environment, and the practical server locations are the headend, the distribution hub, or the customer premises.

Server at Headend

Placing the media server at the headend allows it to serve the entire cable system. The distribution networks aggregate the traffic from all customers, and the law of large numbers allows efficient statistical multiplexing. In early deployment, when some distribution hubs support relatively few customers, centralizing the servers makes good sense.

However, a centralized server farm might grow to require considerable resources in terms of space and power. A centralized facility is also vulnerable to disasters such as fire or flood. In addition, the distance-bandwidth product of the distribution networks is much larger than when the servers are placed nearer to the customer. Consider that every asset must be transferred across the distribution network for all customers individually—even if they live next door to each other.

Despite these caveats, placing the media server at the headend is viable for cable systems with several hundred thousand subscribers. Distribution networks with sufficient capacity can be engineered using the almost unlimited bandwidth of fiber optic links, and the physical footprint and power requirements of media servers are being constantly reduced by Moore's Law.

Server at Distribution Hub

Placing the media server at the distribution hub reduces distribution network capacity at the expense of asset replication. The media server is closer to the set-top and effectively provides a cache function, holding all the assets that might be required by the set-top. This works for systems with relatively few assets, but the provisioning traffic and media server storage increases in direct proportion to the number of assets.

The media server must be designed for unattended operation and must be managed remotely if it is located at the distribution hub. Any regular maintenance of the media server necessitates travel to and from the distribution hub.

Server in Set-Top

With the advent of multigigabyte storage at affordable prices, why not put the VOD server in the set-top? The set-top server is dedicated to a single customer, and therefore its cost cannot be amortized across a number of customers like a centralized server. However, the server complexity is considerably reduced because it plays only a single stream at a time. Moreover, server failure affects only a single customer and redundant hardware is not required.

The main problem with placing the server in the set-top is the amount of storage and the provisioning bandwidth required. In a time-shifting application, where broadcast programming is cached by the server for subsequent playback, no incremental provisioning bandwidth is needed; but in an on-demand service, every asset that might be required by the customer must be provided, using one of two approaches:

- Popular assets—for example, new movie releases—are broadcast to all set-tops to reduce provisioning bandwidth.
- Random assets—for example, library video-clips—are delivered on-demand in real-time (or faster than real-time). Media servers are still required in the headend, and set-tops generate much the same traffic load as other on-demand approaches.

In the first approach, considerable set-top storage is required to provide customer choice. In addition, because every set-top contains a copy of each new movie release, piracy is a concern; the set-top server assets must be protected by a bulletproof conditional access system. In the second approach, there is little or no advantage to the cable operator except when assets are downloaded and then played several times.

In summary, placing the set-top in the server can provide only very limited on-demand selection unless servers in the network provide a second level of support.

Switching Matrix

With reference to Figure 10-1, the media server output is routed to the set-top via one of a number of distribution networks. (To understand why there are multiple distribution networks, please refer to the section Distribution Network, earlier in this chapter.) Therefore, a switching function is required to connect a media server to a set-top in a particular distribution network. In general, an *M* by *N*, nonblocking switching matrix is required, and Figure 10-1 illustrates the use of a such a switching matrix to allow any of the *M* media servers to be connected to any of the *N* delivery networks.

There are a number of approaches to the requirement for a switching matrix (these are described in the next sections):

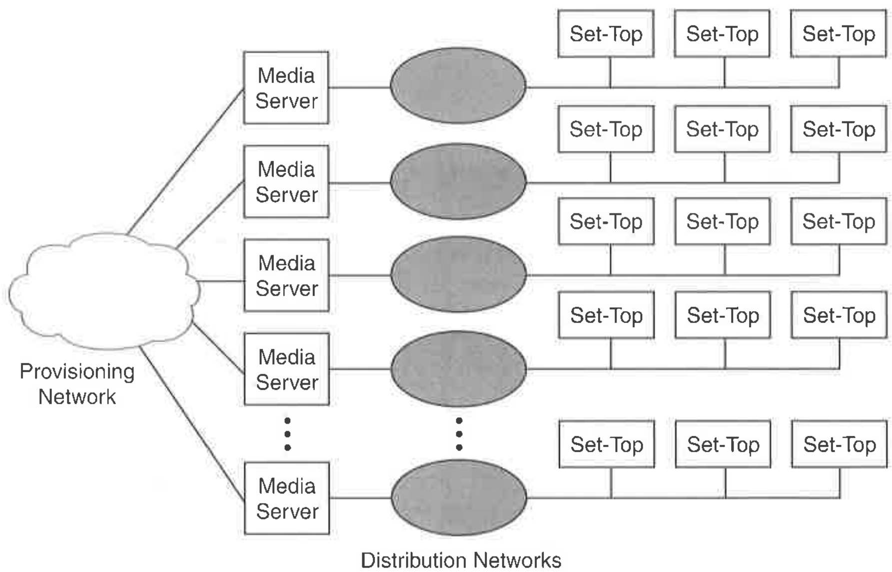
- Content replication—In the content replication approach, each media server holds a copy of all the potential assets required by the set-top. This allows the media server to be directly connected to the distribution network.
- Massively parallel server—Proponents of massively parallel media servers (notably, N-Cube) argue that the switching matrix can be best incorporated into a scalable media server. Such a server can output any asset on any output port and can be connected directly to the distribution network (at the headend or the distribution hub).
- ATM switching—ATM is an effective switching technology for the switching matrix. A connection manager is required to set up ATM connections from the media server to the distribution network.

- IP routing—Until recently, IP routing did not scale to meet the throughput demands required for the switching matrix. However, recent advances in multiple protocol label switching (MPLS) and IP QoS have made IP routing a potential technology for this application. The great advantage of IP is that it is self-routing—that is, no explicit connection management function is required.
- QAM matrix—It is possible to build a matrix of QAM modulators in such a way as to form a space/frequency/time switch. The switching matrix is connection-oriented, so it requires a connection management function similar to an ATM network.

Asset Replication

Asset replication places a copy of all assets on every media server and allows the media server to be directly connected to the distribution network, as shown in Figure 10-3.

Figure 10-3 *Asset Replication*



This approach is simple and eliminates the switching matrix but has a number of disadvantages that make it unsuitable for wide-scale deployment:

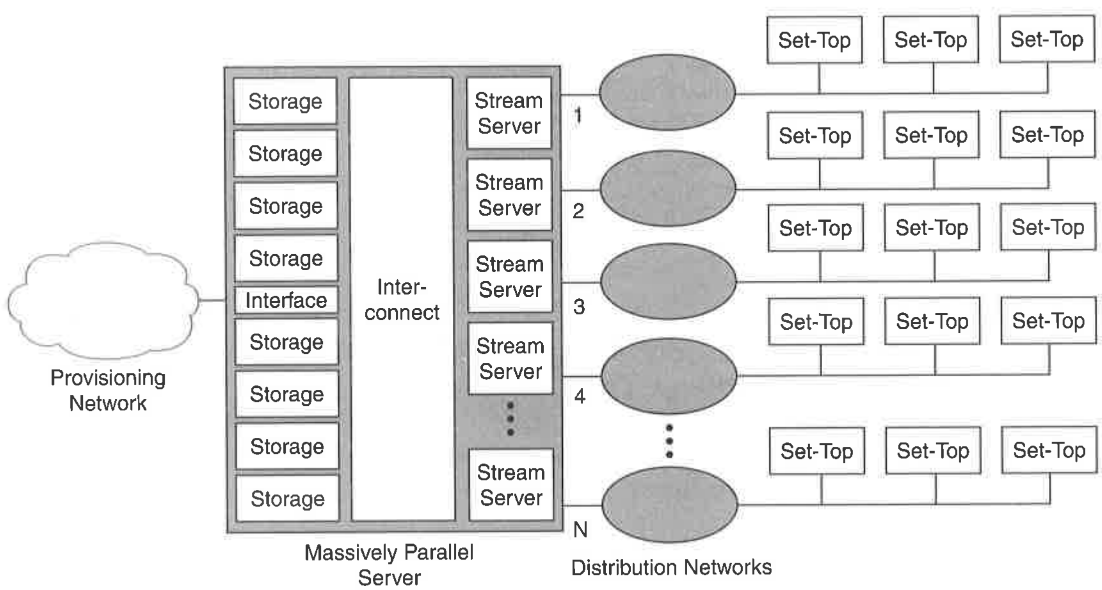
- Asset replication increases the amount of storage required and directly increases storage cost. In a limited movies-on-demand application, where only 10 titles are offered at any given time, asset replication is acceptable, but it does not scale to larger systems. For example, in a time-shifting or library application, asset replication in each media server requires massive amounts of storage. Worse still, the provisioning bandwidth increases linearly with the number of media servers and with the number of new assets. Eventually, as system size increases, asset provisioning generates most of the activity in the system for assets that might never be retrieved.

- The availability of such a system is the same as the availability of the media server; if it fails, no other path exists to the distribution network. This problem can be mitigated by using two media servers per distribution network, but this doubles the media server cost.
- For efficiency, the demand of each distribution network must be accurately matched to the capacity of the media server. This is difficult to achieve as the customer base grows.

Massively Parallel Server

In a massively parallel server, the switching matrix is incorporated into a large, scalable media server, as shown in Figure 10-4.

Figure 10-4 *Massively Parallel Server*



Such a server can output any asset on any output port and can be connected directly to the distribution network. Massively parallel servers provide an excellent solution to the switching problem but must satisfy rigorous availability metrics because of their design:

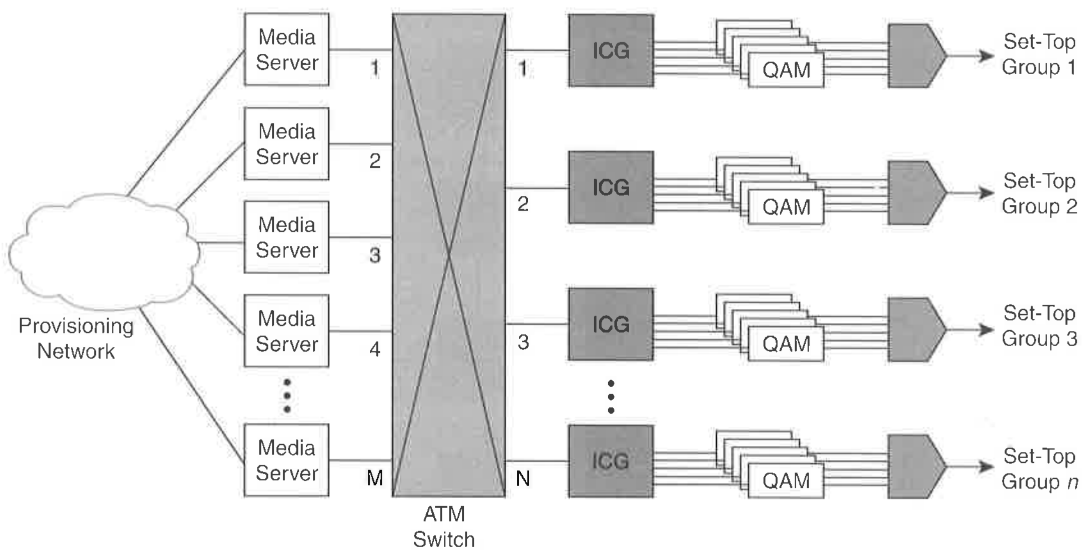
- Massively parallel servers must be highly available, because if they fail, no service is available to all customers.
- It must be possible to increase server capacity by increments while the server is online.
- The failure of individual disk drives, processors, memory banks, or power supplies cannot cause the server to fail (but might reduce total capacity).
- Massively parallel servers must be cost-competitive with smaller servers over the life cycle of their operation. In other words, they cannot be prohibitively expensive for early, lower-demand operation and cost-effective only in a fully subscribed system.

If massively parallel servers are built to satisfy these requirements, this technology will be very successful for the provision of on-demand services.

ATM Switching

Figure 10-5 illustrates the use of an ATM switch as a switching matrix. The ATM switching function can be distributed by building a network of switches located at the headend and distribution hubs.

Figure 10-5 *ATM Switching*



ATM is a connection-oriented protocol, and a connection manager is required to set up ATM connections from the media server to the distribution network.

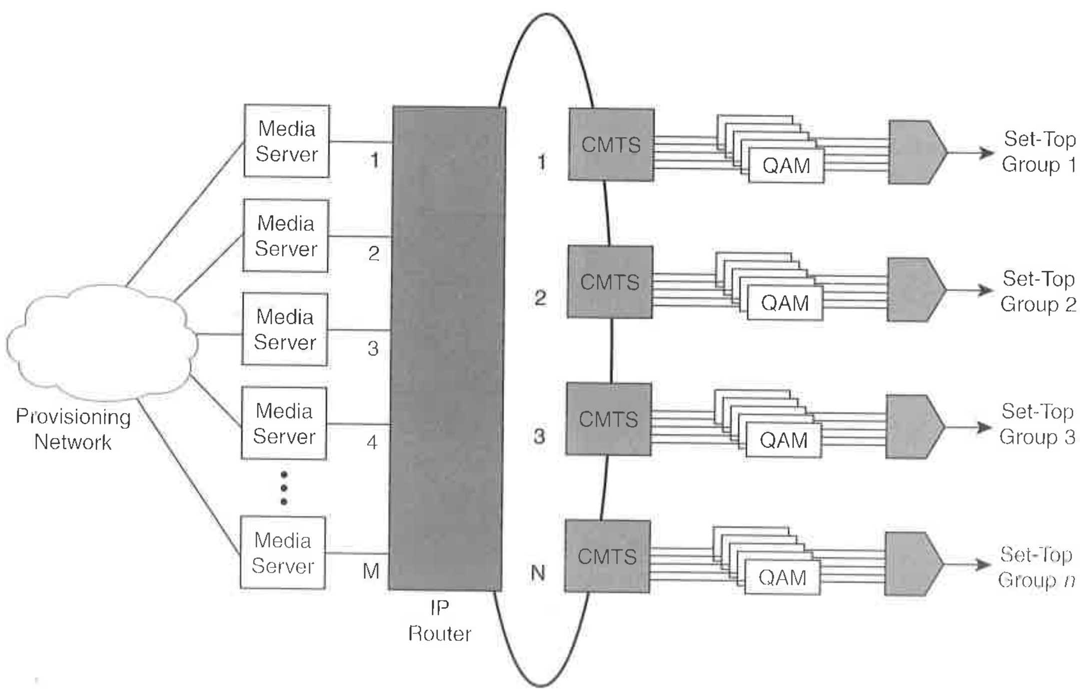
Incremental cost of ATM switching includes the adaptation of MPEG-2 packets to ATM cells and reassembly back into MPEG-2 packets before they are fed into the MPEG-2 decoder. In Figure 10-5, ATM adaptation is done by the output interface of the media server. MPEG-2 streams are reassembled by the Integrated Cable Gateway (ICG) before QAM modulation to support an MPEG-2 digital set-top. (See Chapter 11 for an ATM-to-the-home case study.)

ATM switching provides flexibility and efficiency for multimedia transport but requires sophisticated connection management services that are directly accessible from the on-demand application. Some approaches, notably X-Bind, show considerable promise toward meeting these requirements. (See "A Programmable Transport Architecture with QoS Guarantees," by Jean-Francois Huard and Aurel A. Lazar, in *IEEE Communications*.)

IP Routing

Figure 10-6 illustrates a routed network approach to media server to distribution network interconnection.

Figure 10-6 *IP Routing*



Until recently, IP routing did not scale to meet the throughput demands required for the switching matrix. However, recent advances in multiple protocol label switching (MPLS) and IP QoS have made IP routing a potential technology for this application. The great advantage of IP is that it is self-routing—that is, no explicit connection management function is required.

A routed design allows the switching matrix to be distributed by placing routers in the headend and hub locations. Figure 10-6 shows the headend router interconnected to the Cable Modem Termination System (CMTS) routers by means of an optical ring technology. Distributed routing provides a number of advantages:

- The same network can be used to provide the out-of-band channel support (see Chapter 5, "Adding Digital Television Services to Cable Systems").
- The same network can provide support for cable modem and IP telephony services.

This level of integration multiplexes cable modem, telephony, and on-demand traffic into each QAM channel. Although this is possible, there are several reasons why this level of integration might not be advisable:

- Some cable operators run their cable modem, telephony, and television services as separate businesses.
- The only practical way to integrate these traffic types is to use IP transport for all of them, which incurs increased overhead for MPEG-2 traffic.

Additionally, routed networks are still significantly more expensive than other approaches, although let's hope this is not a long-term trend. In addition, IP encapsulation of MPEG-2 transport packets is not very efficient. Finally, minimum bit rate guarantees must be provided by the routed network to ensure video and audio quality. (See "QoS Support for Integrated Services over CATV," by Richard Rabbat and Kai-Yeung Siu, in *IEEE Communications*.)

QAM Matrix

With the QAM matrix, it is possible to build a matrix of QAM modulators in such a way as to form a space/frequency/time switch, as shown in Figure 10-7.

CHAPTER 11

On-Demand Cable System Case Studies

This chapter discusses two on-demand cable systems—the Time Warner Full Service Network (FSN) and the Time Warner Pegasus program. These systems have already been discussed from an interactive services standpoint in Chapter 9, "Interactive Cable System Case Studies"; this chapter focuses on those aspects specific to on-demand services. The FSN and Pegasus are closely related; the same core team of engineers is responsible for both programs, and the Pegasus program has many of the same goals as the Full Service Network.

Time Warner Full Service Network

The Full Service Network (FSN), was conceived primarily as a vehicle for video-on-demand (VOD) services, and this chapter focuses on them. VOD was the major goal of the FSN for a number of reasons. First, VOD has been the Holy Grail of engineers for many years. The idea that video can be captured, stored, and manipulated using digital techniques is fascinating, if only because it is such a wonderful engineering challenge. Second, the limitations of pay-per-view programming can be frustrating, and there is some evidence to suggest that the customer really wants a VOD service and is prepared to pay for it. This evidence is backed up by the success of the video rental business. In a short time, the (once-laughable) idea of renting videotapes of movies to customers for a fee has become a multibillion-dollar-per-year business. (For more information, see the section FSN Network Architecture Goals in Chapter 9.)

Full Service Network Overview

The FSN is designed to provide full video-on-demand with instant access over a broadband HFC network to 4,000 customers. At any given time, up to 1,000 concurrent video streams from eight video servers must be delivered over 16 parallel distribution networks. Figure 11-1 illustrates that at the core of the FSN architecture is a single, large ATM switch that provides nonblocking interconnection of the servers to the distribution network.

Figure 11-1 *Full Service Network Overview*

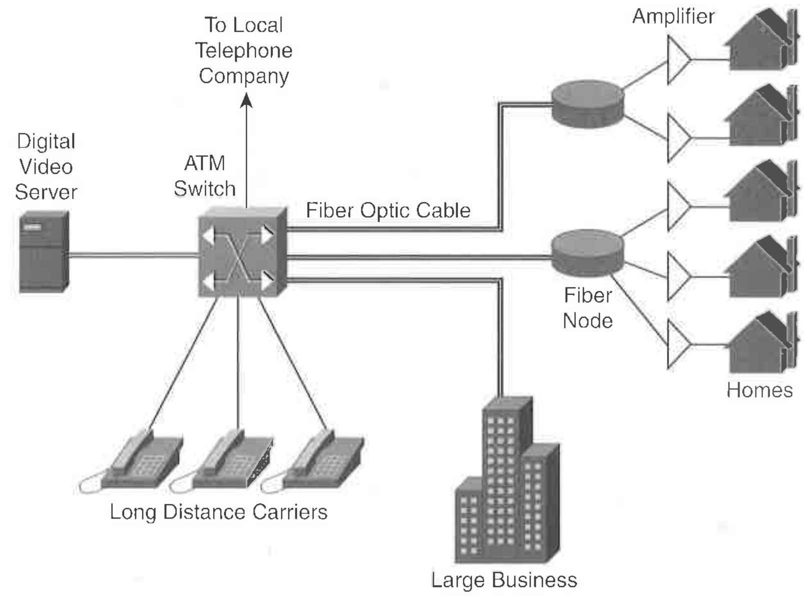
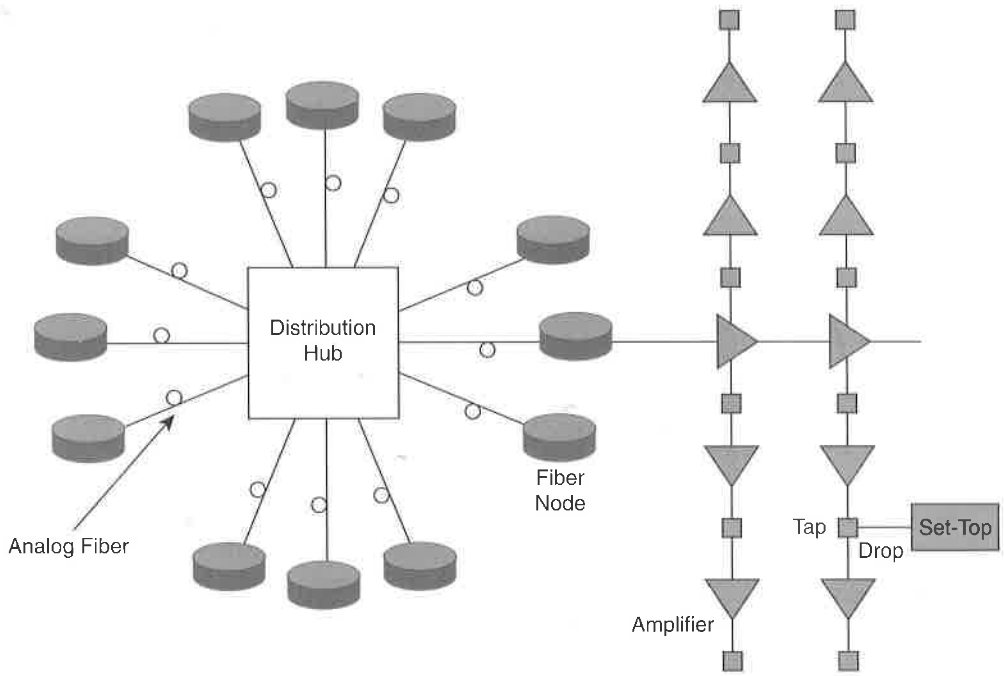


Figure 11-1 also explains why ATM was chosen as the core switching and transport technology for the FSN; the ATM switch provides an integrated solution for interconnection of telephony, data, and video services.

Basic Star Architecture

The FSN architecture places most of the equipment (media servers, ATM switch, and modulation equipment) in a network operations center (NOC). The NOC is located at a distribution hub site with the intention that it be replicated for every 20,000 homes passed. Figure 11-2 shows the basic star architecture that radiates from the distribution hub to the fiber nodes. From the fiber nodes, the signal is distributed over the coaxial portion of the network to the customer.

Figure 11-2 *Basic Star Architecture*



The NOC was located at the distribution hub because of the physical volume of the equipment that is required to deliver video-on-demand services. The media servers, storage vaults, ATM switching equipment, and modulation equipment was initially located in a computer room that measured approximately 60 by 22 feet, or 1320 square feet. This space was subsequently doubled with the addition of telephone switching and trunking equipment. Since 1993, most of this equipment has increased in density by a factor of between 5 and 10 (as in Moore's Law). Assuming this trend continues, this equipment may be centrally located at the headend to reduce operational costs (see the section Server Location in Chapter 10, "On-Demand Services").

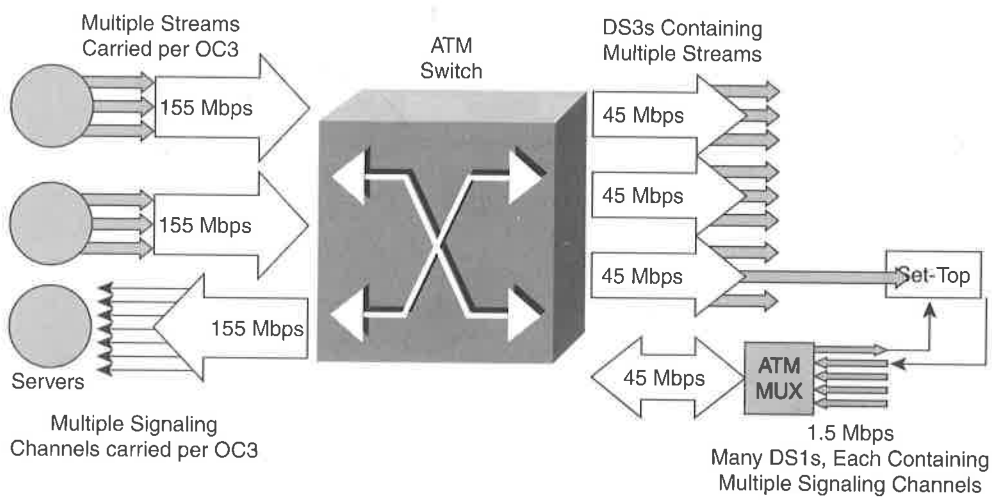
A second advantage of locating the NOC at the distribution hub is that it allows direct access to the distribution networks. In Figure 11-2, each fiber node is fed by a dedicated 1310-nanometer DFB laser over a dedicated fiber, effectively forming a separate distribution network for each 500 homes passed. Each fiber node receives a unique bank of on-demand channels from the equipment in the distribution hub allowing *spacial reuse* of that portion of the cable spectrum.

(For more information, see the section FSN Network Overview in Chapter 9.)

Logical ATM Connectivity

In the FSN network, the ATM switch is used to establish ATM connections from the servers to the set-top. Figure 11-3 shows the logical view of the ATM connection service.

Figure 11-3 *Logical ATM Connectivity*



For a video-on-demand stream, an end-to-end connection is established from the server to the set-top with the following characteristics:

- The connection provides a Constant Bit Rate (CBR) service at the rate required by the compressed MPEG-1 stream; in the FSN, full-motion video events were coded at 6 Mbps and movies were coded at 4 Mbps.
- The connection flows over a 155 Mbps OC3 link from the server to the ATM switch, followed by a 45 Mbps DS3 link from the switch to the set-top.
- The connection is unidirectional; almost all the traffic flow in the network flows from the server to the set-top, so the network is constructed with one-way OC3 and DS3 links. This is unusual because OC3 and DS3 links are designed for bidirectional operation in standard telecommunication applications.

Telecommunications equipment, which is designed for symmetrical traffic flows, is inefficient for video-on-demand applications. Each OC3 link is actually bidirectional at the physical layer to provide for SONET performance measurement and alarming functions, but, because traffic flow is unidirectional, only 50% of the link capacity is used. The ATM switch is constructed for symmetrical traffic and only 50% of its total capacity is used. Each DS3 link is unidirectional (alarm monitoring functions are disabled).

The ATM switch used by the FSN is an AT&T Globeview 2000 switch with a maximum capacity of 20 Gbps, but the total traffic capacity to the distribution networks is only 6.8 Gbps. A relatively small amount of capacity (about 600 Mbps) is used for control and signaling traffic, which *is* bidirectional. Overall, the maximum switch utilization is about 37%.

Figure 11-3 shows how control and signaling traffic uses the traffic aggregation and switching functions of the ATM network. The set-top requires relatively little signaling bandwidth and a 1.5 Mbps DS1 link is used. The DS1 link is formatted to carry ATM cells and is shared by about 24 set-tops. From each set-top to the server, an ATM connection is established for return signaling traffic with the following characteristics:

- The connection provides a constant bit rate (CBR) service at the signaling rate of 48 Kbps. A variable bit rate (VBR) service would be better for bursty signaling traffic, but the shared media access layer can support only fixed-rate TDMA access to the link (see Chapter 5, "Adding Digital Television Services to Cable Systems").
- The connection flows over a 1.5 Mbps DS1 link from the set-top to an ATM multiplexer, followed by a 45 Mbps DS3 link from the multiplexer to the switch, followed by a 155 Mbps OC3 link from the switch to the server.
- The connection is unidirectional because the DS1 links are unidirectional. The ATM multiplexer provides access to a DS1 link to the set-top to close the loop for timing and signal level adjustment.

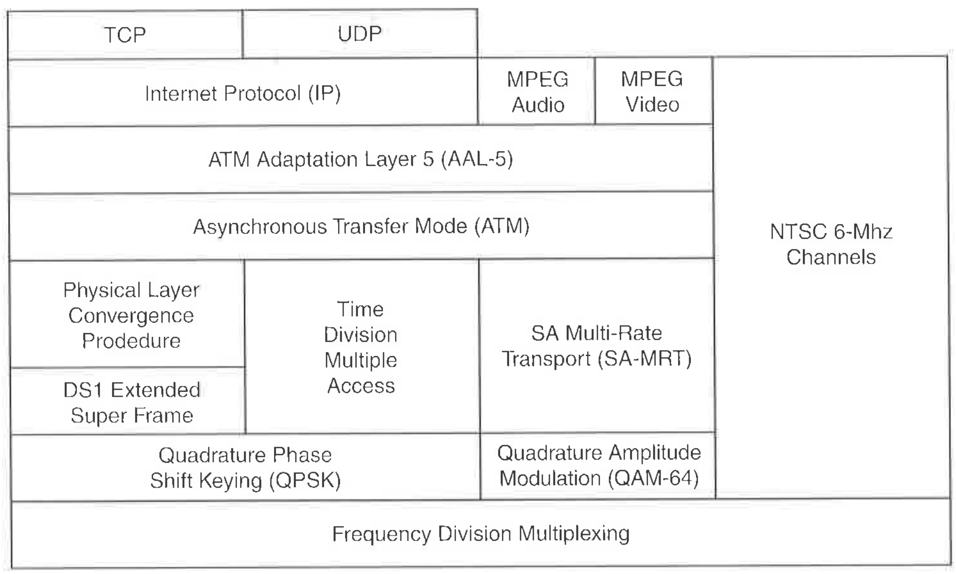
MPEG Mapping into ATM

Figure 11-4 shows the various protocol layers that are required to deliver MPEG streams over an ATM infrastructure. It also shows how ATM is adapted for transmission over a broadband, analog cable system.

At the base of the protocol stack is the frequency-division multiplexing layer; in this layer, multiple carrier frequencies separate the broadband spectrum into a number of channels. In the FSN, there are three channel types:

- NTSC—Existing analog television channels are carried according to the analog frequency plan.
- QAM—Digital services are mapped into Quadrature Amplitude Modulator (QAM) channels. QAM channels provide a high-capacity bit pipe that can be used for data, video, or audio traffic.
- QPSK—Signaling and control traffic are mapped into a quaternary phase shift keying (QPSK) channel. QPSK channels provide a medium-capacity bit pipe that is more robust than QAM modulation.

Figure 11-4 *Communications Stack*



For the QAM channel to carry MPEG audio and video, an adaptation layer is required to provide error-correction and framing functions; in the FSN, this adaptation function is provided by SA-MRT (Scientific Atlanta multi-rate transport). SA-MRT packs ATM cells into a framing structure so that the set-top can recognize the individual cells in the QAM bit pipe (see the section Error Correction and Protection in Chapter 4, "Digital Technologies"). SA-MRT allows ATM cells to be reliably delivered from the server to the set-top, but another adaptation layer is required to map the MPEG streams into ATM cells.

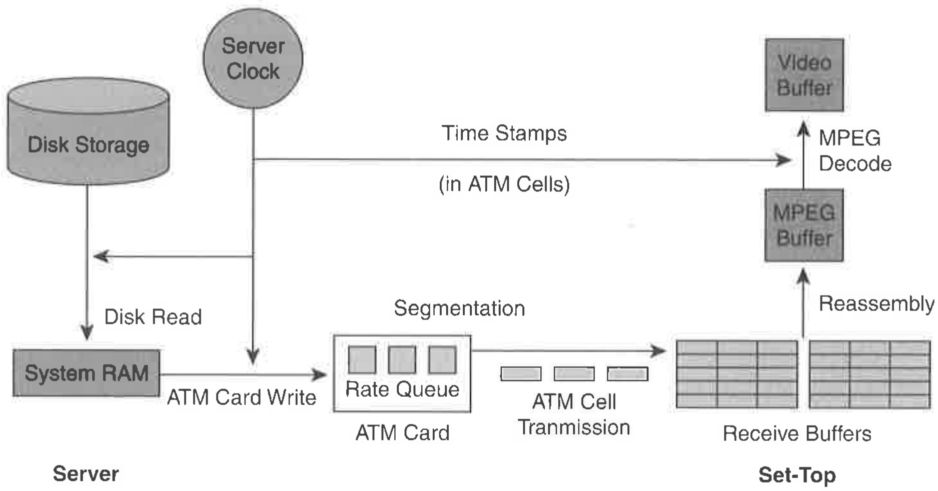
In Figure 11-4, the ATM Adaptation Layer (AAL) is provided by AAL-5 (see Chapter 4 for more details). AAL-5 allows large blocks of MPEG data to be segmented into cells for delivery through the ATM network. When the cells arrive at the set-top, AAL-5 is used to reassemble the original block of data, which is decoded to provide audio or video.

IP data blocks are segmented, transmitted, and reassembled using AAL-5 to provide data delivery from the server to the set-top. The set-top can distinguish between audio, video, and data by the Virtual Channel Identifier (VCI) carried in the header of every ATM cell; thus, a set-top can simultaneously receive audio, video, and data streams over a single QAM channel without confusion.

MPEG Delivery from Server to Set-Top

The delivery of MPEG video and audio streams in the FSN implementation had to be carefully controlled to ensure that the customer saw a smooth, high-quality video with correctly synchronized audio (Figure 11-5 shows how this is achieved):

Figure 11-5 *MPEG Delivery from Server to Set-Top*



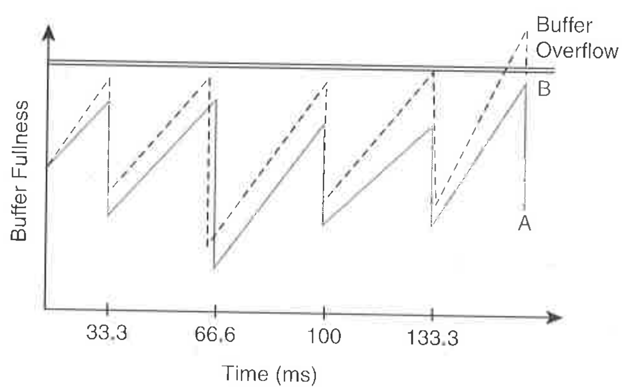
- The MPEG data is stored on a disk storage subsystem (called a *vault*). The MPEG data is fetched from the disk in large blocks to optimize access to the disks and is double-buffered so that the next disk read completes before the current block is exhausted.
- The MPEG data is written to the ATM output card. The ATM output card segments the MPEG data into cells for transmission over the network using the AAL-5 adaptation protocol. The card includes a rate queue designed to transmit the stream of ATM cells at a constant rate. If the cells are sent too fast, the set-top drops cells and video quality suffers.
- The set-top filters the ATM cells based on their VCI and selects only those cells for the chosen video flow. It receives those ATM cells and reassembles them into the original MPEG data blocks using the AAL-5 adaptation protocol.
- The MPEG data blocks are sent to the MPEG decoder, which reconstructs the original video signal.

Video signals are extremely time-sensitive, and the delivery of the MPEG data must happen at exactly the same rate as MPEG decoding. In analog video delivery, the horizontal and vertical synchronization pulses synchronize the television display to the transmitter; but there is no such mechanism in ATM networks because they use multiple, asynchronous physical links. This problem is solved in ATM by the transmission of timestamps from a master clock at the server:

- The server clock ensures that the disk reads and ATM card writes happen at the correct time to ensure that the MPEG data is played out of the server and of the network at the correct rate.
- At the set-top, timestamps from the server clock are received at regular intervals. The set-top has its own clock, which is driven by an accurate voltage controlled crystal oscillator (VCXO). It uses the timestamps to adjust the frequency of the VCXO so that its clock remains perfectly synchronized to the server clock.

In Figure 11-6, the MPEG buffer is designed to hold compressed MPEG data for the MPEG decoder. The fullness of this buffer must be carefully managed to ensure that it does not overflow or underflow. The unbroken trace (labeled A) shows how the buffer is designed to work: Data arrives at a constant rate from the server, and each time a frame is displayed, the MPEG decoder reads a variable amount of data from the buffer. The MPEG encoding process is designed to ensure that the decoder buffer will not overflow or underflow.

Figure 11-6 *MPEG Decoder Buffer Management*



The dashed trace (labeled B) illustrates the effect of the incoming data rate being slightly high. The buffer slowly fills up and overflows—the effect is exaggerated in the diagram, but over several hours the rate has to be extremely accurate to prevent this effect. Over shorter time intervals, more rate variance can be tolerated, but only if it averages zero over the longer term. If the display rate at the set-top is not exactly the same as the effective rate delivered by the server, the same effect (buffer overflow or underflow) occurs.

Lessons Learned

The Full Service Network provided some valuable lessons that are useful in on-demand service development:

- Simultaneous peak usage—The FSN was built to operate at a maximum peak usage of 25%. After accounting for navigation demands (which required *two* open streaming media sessions per set-top in the FSN), a more reasonable design goal is 10% peak usage.
- Required automation—In a deployable, large-scale VOD system, many tasks (for example, provisioning of new assets) must be automated to reduce operational costs.
- Fault tolerance—A VOD system must continue to operate during single component failures. Customers will become frustrated if an on-demand service is unreliable or unavailable.

FSN Summary

The FSN demonstrated the successful use of ATM to deliver interactive multimedia all the way to the home over hybrid fiber coax networks. ATM provides a single transport and switching protocol for video, audio, and data, but the flexibility of ATM is expensive:

- The basic overhead of ATM (mainly associated with the 5-byte ATM header) is about 12%. For unidirectional services (for example, video-on-demand), only half the capacity of current ATM equipment can be used, because it is designed for bidirectional operation.
- There is additional cost for ATM adaptation at the headend and in every set-top.
- Digital broadcast services are all based on the MPEG-2 transport protocol; this means that either the set-top must support both ATM and MPEG-2 transport protocols or, alternatively, every digital broadcast service must be adapted to ATM at the headend.

For these reasons, MPEG-2 transport is a better alternative than ATM for *integrated* delivery of digital broadcast and on-demand services.

Pegasus Phase 2.0

Pegasus Phase 2 adds on-demand services to the broadcast services of Pegasus Phase 1 (see Chapter 7, "Digital Broadcast Case Studies") and the interactive services of Phase 1.1 (see Chapter 9). The challenge in Pegasus Phase 2 is to add on-demand services to make best use of the infrastructure that is already in place. The existing infrastructure includes the following facilities:

- A broadband network with available channel capacity for on-demand services
- A real-time, two-way control and signaling network provided by the DAVIC OOB protocol

- A set-top with built-in MPEG-2 transport, MPEG-2 video decoding, and AC-3 audio decoding functions
- A multimedia operating system with support for interactive applications and the manipulation of video and audio streams
- An EPG that allows application sharing and application hand-off for additional services
- A digital conditional access system

Pegasus Phase 2 has a different focus from the FSN; the existing facilities dictate many of the technology choices for on-demand services. For example, the FSN set-top was capable of terminating ATM virtual channels, but this function was omitted in the Pegasus set-top (after much soul-searching) to reduce cost. The Pegasus set-top expects MPEG-2 transport streams and this dictates that the network send broadcast *and* on-demand services in MPEG-2 transport stream format.

FSN Learning Experience

Pegasus Phase 2 owes much to the FSN learning experience and differs from the FSN in a number of key architectural areas. Each change solves one set of technical issues but also creates new challenges:

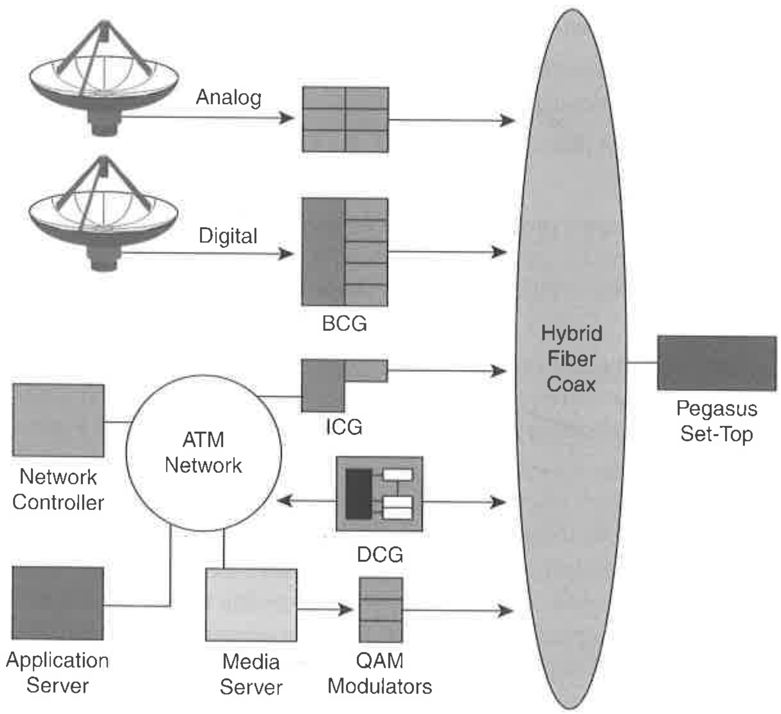
- Server location—In the FSN, the servers are located at the distribution hub, whereas the Pegasus architecture allows servers to be placed at the headend or distribution hub.
- Transport protocol—The FSN uses ATM as a switching and transport protocol, but ATM is replaced by MPEG-2 transport in Pegasus. MPEG-2 transport provides significant advantages, including the integration of broadcast and on-demand services into a single format and reduction in set-top cost. However, MPEG-2 transport assumes a constant delay network because it was designed for broadcast applications (see Chapter 4).
- Switching matrix—The FSN uses ATM to provide the switching function between the media server and the distribution network. ATM switching is very inefficient for unidirectional traffic and Pegasus replaces it with a distributed MPEG-2 transport switch. Nevertheless, there are limitations to this approach, including the maximum capacity of the matrix and its flexibility.

This chapter focuses on solutions to each of these challenges.

On-Demand Services

Figure 11-7 provides an overview of the Pegasus Phase 2 architecture. Pegasus Phase 2 reuses many components from the Phase 1 architecture and adds two new components for the support of on-demand services.

Figure 11-7 *Pegasus Phase 2 Architecture*



The following Phase 1 components are reused:

- The network controller provides provisioning, management, and conditional access support for on-demand services. A software module called the *interactive control suite* is added to provide additional services for on-demand services, notably creation of on-demand sessions over the network.
- The application server provides a platform for the server-side part of on-demand client/server applications. Multiple application servers may be used to provide load sharing or to support different on-demand or interactive services.

- The ATM network connects headend components, including the media server, and provides connection to a wide area network. The ATM network is used to provision on-demand assets (see Chapter 10).
- The interactive cable gateway (ICG) provides support for the broadcast carousel channels, which are used to deliver software applications code and data to the set-top.
- The data channel gateway (DCG) provides two-way, real-time control and signaling support to the set-top.
- The hybrid fiber coax distribution network is reused to add on-demand channels to the existing broadcast channels.

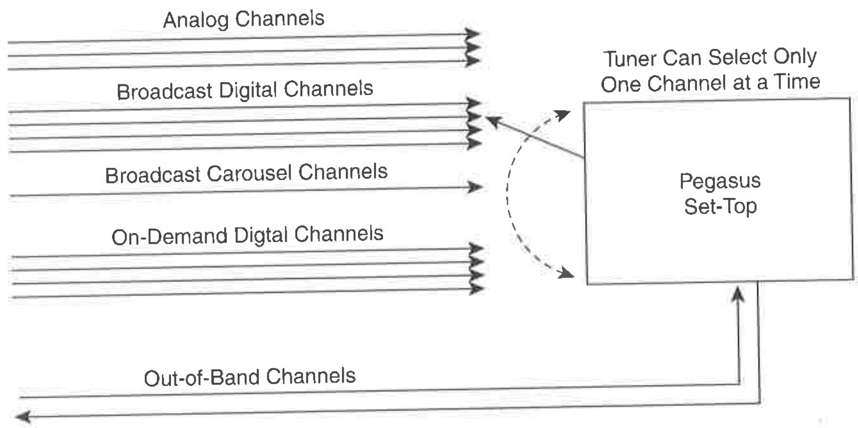
In addition to these Phase 1 components, the Phase 2 architecture adds two new components:

- The media server provides support for the streaming of on-demand services. Multiple media servers are used to provide scaling, load sharing, and redundancy. The media server uses the existing ATM network for provisioning of assets over a wide-area network.
- The QAM modulators are used to convert the output of the media servers into 6 MHz channels that can be distributed through the HFC network. The QAM modulator also provides digital encryption support for the conditional access system.

New Channels

Figure 11-8 illustrates the channel types available to the Pegasus set-top. Pegasus Phase 2 adds on-demand digital channels to the existing analog and digital broadcast channels and broadcast carousel channels. In contrast to the broadcast channels, which are shared by all customers, the on-demand channels provide dedicated services to individual customers. For example, a customer that purchases a video-on-demand event is allocated a dedicated stream from the media server that is carried in one of the on-demand channels. Sufficient on-demand channel capacity must be allocated to each group of customers so that the video-on-demand service is always available. How much on-demand capacity is required? And how many customers can share a bank of on-demand channels?

Figure 11-8 *Pegasus Channel Types*



The answer to these questions is based on the existing broadcast architecture of the HFC network (see Chapter 2, "Analog Cable Technologies"). In Time Warner Cable's upgraded systems, a single DFB laser at the distribution hub feeds approximately 2,000 homes passed. On average, about 60% of homes passed receive cable service, a total of 1,200 customers. Assuming that 50% of customers would like to sign up for on-demand services, up to 600 on-demand customers are fed from a single laser. Therefore, 600 is the *least* number of customers that can share a bank of on-demand channels. (More customers can easily be arranged by aggregating two or more lasers into a single customer group.)

How much on-demand capacity is required to support 600 customers? The answer depends on how much capacity is required by each customer and how many customers simultaneously request the on-demand service. Assuming that the peak-utilization is 10%, up to 60 on-demand streams are required. For standard definition material, a single on-demand channel can carry about 10 streams; therefore, a minimum of 6 on-demand channels are required per 600 customers. (Note: this math is linear and is easily calculated at various bit rates, modulation schemes, and channel allocations.)

Server Location

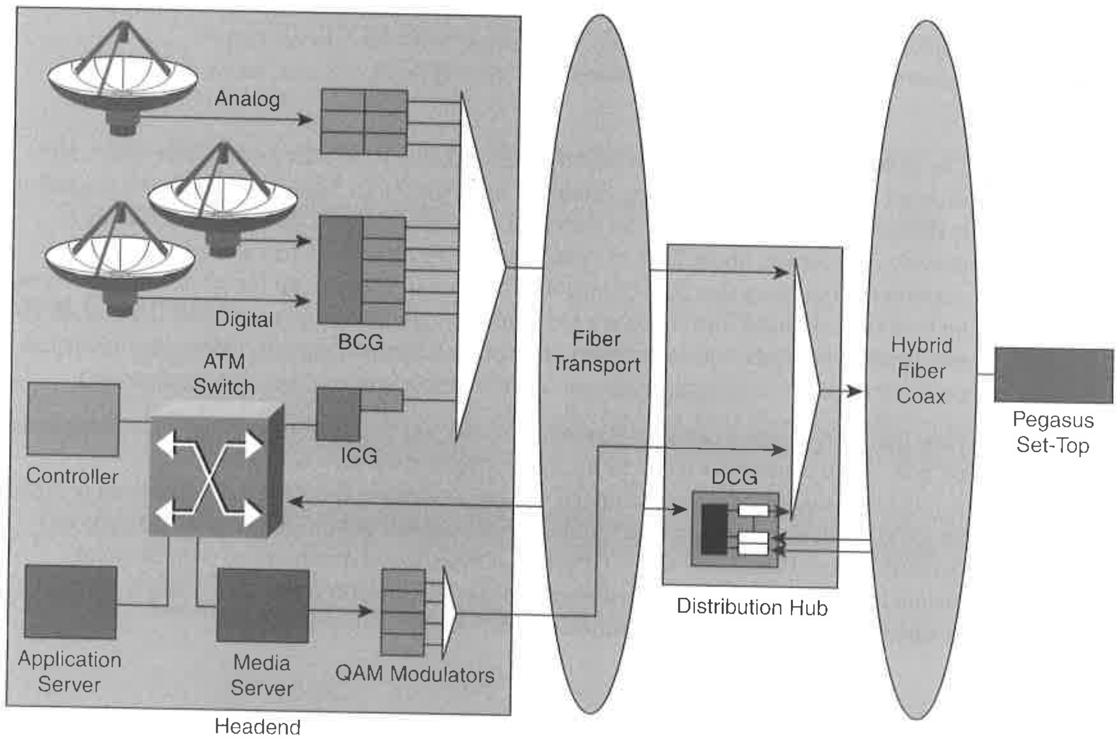
There are a number of advantages to locating the server at the headend; server operations and maintenance can be centralized and the statistics of load sharing are improved. This is particularly important if the customer demand is unevenly distributed across the system. In early deployment of on-demand services, it might be difficult to justify the cost of a server at a distribution hub with few customers, whereas serving all the customers from a single headend location can be viable even at low service penetrations.

Nevertheless, there are significant advantages to locating the server at the hub as service penetration grows. If a cable system has 100,000 *on-demand* customers, a headend server would require 1,000 on-demand channels from the headend to the distribution hubs (a payload of almost 40 Gbps!). Therefore, it becomes more cost-effective to locate the servers at the hubs at some level of service penetration.

Fiber Transport

Figure 11-9 shows how Pegasus Phase 2 transports the on-demand channels from the headend to the distribution hubs. Each bank of on-demand channels is modulated and combined at the headend before being sent over a fiber to the distribution hub.

Figure 11-9 *Pegasus Phase 2 Implementation*



In a system with 100,000 subscribers, 167 banks (each containing six on-demand channels) are required. This solution also requires 167 fibers—far too many in practice. However, there are a number of strategies to reduce the fiber count and reduce cost:

- If the number of on-demand channels in each bank is increased, the number of fibers and lasers at the headend can be reduced proportionately. However, there is only a certain amount of available spectrum for on-demand services; in a 750 MHz system they might be placed between 700 and 750 MHz above all the broadcast frequencies.
- If the full spectrum of the fiber link to the distribution hub could be used—from 50 to 750 MHz—many more on-demand channels could be over a single laser. However, the on-demand channels would require block conversion at the distribution hub to place them in the correct frequency band before being combined with the broadcast channels.
- DFB lasers are now available with different optical wavelengths (or colors). By combining eight or more wavelengths onto a single fiber, the fiber count can be dramatically reduced in most cases to one fiber per distribution hub. This approach is called wavelength division multiplexing (WDM).

The most promising solution appears to be WDM of the on-demand channels onto a single fiber.

Transport Protocol

The Pegasus set-top is designed to work with MPEG-2 transport streams and this dictates the transport protocol selection for the on-demand channels. In fact, this is the ideal choice for video-on-demand for the following reasons:

- The efficiency of MPEG-2 transport is superior to other transport protocols, such as ATM and IP.
- MPEG-2 transport includes support for synchronization, statistical multiplexing, and conditional access functions.

Nevertheless, on-demand services might include high-speed data transport as well as video and audio services. Fortunately, the designers of MPEG-2 transport included support for mapping arbitrary data into MPEG-2 private sections. In addition, the DSM-CC specification includes an efficient segmentation function for mapping large data packets into a series of MPEG-2 transport packets (see Chapter 6, "The Digital Set-Top Converter").

In summary, the choice of MPEG-2 transport streams is both efficient and flexible.

Switching Matrix

MPEG-2 transport was not designed as a wide-area network protocol. It does not include any connection management protocols or any connectionless routing mechanisms. Although MPEG-2 transport is ideal for broadcast applications, it has limited applications in switched networks.

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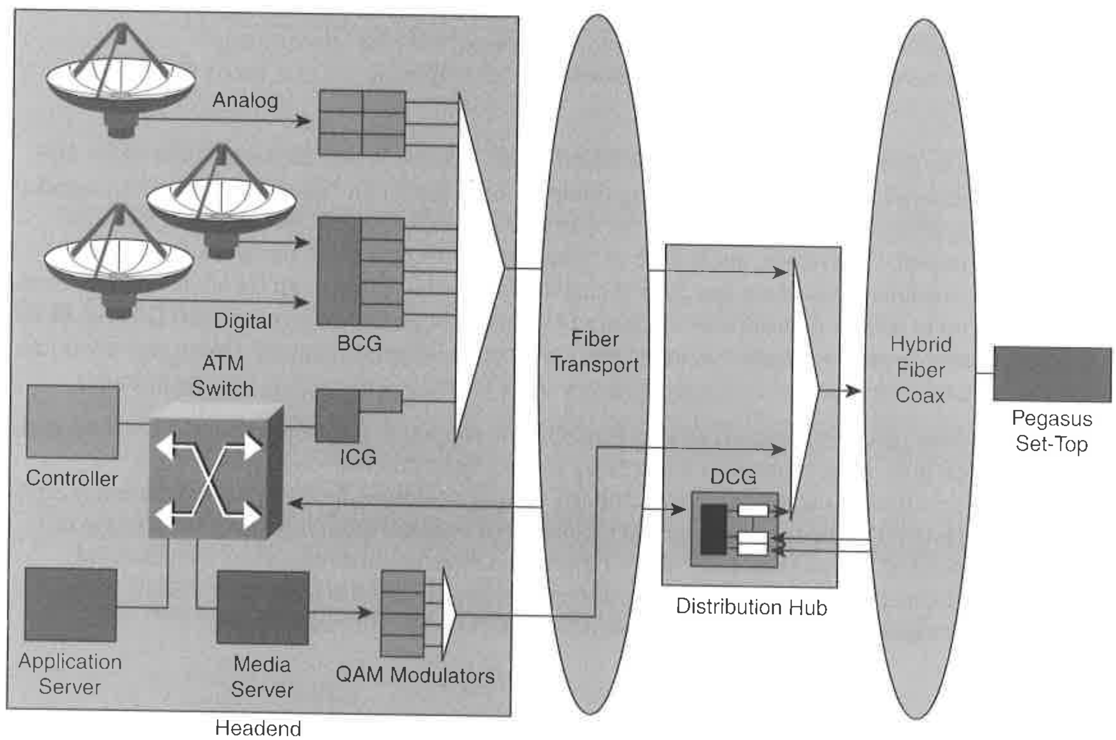

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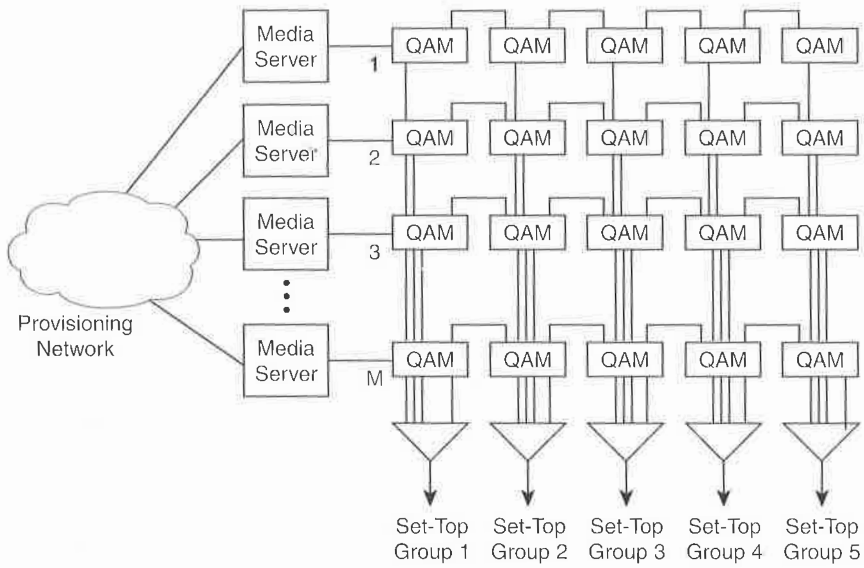
Nevertheless, an MPEG-2 transport switch can be constructed as shown in Figure 11-10. Each media server is connected to a row of QAM modulators using the DVB asynchronous serial interface (ASI) described in Chapter 6. This interface operates at a maximum payload rate of 216 Mbps and can saturate more than 5 256-QAM channels. Moreover, it is a native MPEG-2 transport interface and no protocol translation is required to meet the set-top requirements.

Figure 11-10 *QAM Switching Matrix*



Each set-top group shares a bank of on-demand channels, which contains M (between 6 and 8) QAM channels. A different media server feeds each on-demand channel in the bank to provide load balancing and redundancy. This arrangement provides the following advantages:

- If a media server fails, the on-demand capacity of any bank of on-demand channels is reduced by only one channel. Customers connected to a media server that fails will lose service but can recover by reordering the event and will be allocated to a different media server.
- Load sharing across media servers can be easily accomplished by choosing the least busy on-demand channel in the bank.
- On-demand channel selection can be used to connect a set-top to a server based on the requested asset, avoiding the need to replicate assets across all media servers.

The QAM matrix provides only limited switching because the dimensions of the switch matrix is determined by M, the number of on-demand channels in a bank, multiplied by N, the number of QAM modulators per media server, multiplied by the number of streams in an on-demand channel. In the Pegasus Phase 2 implementation, each QAM matrix supports approximately 320 streams, or 3,200 customers.

In addition, a connection manager must be implemented to support the QAM matrix. The connection manager algorithm is relatively simple; when an on-demand request is received by the network, the connection manager determines the best route according to media server and QAM loading.

Pegasus Phase 2 Summary

Pegasus Phase 2 is one of the first applications of MPEG-2 transport to deliver interactive multimedia over a switched network. MPEG-2 transport provides an integrated transport solution for broadcast and on-demand services, and provides the following advantages:

- The overhead of MPEG-2 transport is extremely low (approximately 2%), and it is designed for unidirectional services (for example, video-on-demand).
- The MPEG-2 set-top is capable of broadcast and on-demand services.
- MPEG-2 supports data as well as video and audio encapsulation using the private data section mapping.

For these reasons, MPEG-2 Transport provides an ideal solution for *integrated* delivery of digital broadcast and on-demand services.

Summary

This chapter has provided a brief overview of two on-demand systems:

- FSN—The Full Service Network used an ATM to the home network to provide a wide range of interactive and on-demand services, including video-on-demand. It provided a valuable research tool into customer behavior and the operational challenges of on-demand services. The network architecture was not very efficient, mainly because of the asymmetric traffic pattern generated by on-demand services.
- Pegasus—The Pegasus program adds incremental on-demand services to an existing broadcast digital network that supports real-time, two-way signaling. Significant transport cost reductions are made by using native MPEG-2 transport from media server to set-top and by using the network as a distributed switching matrix.

References

Standards

ISO-IEC 13818-6 DSM-CC.

Internet Resources

Pegasus requirements

http://timewarner.com/rfp

PART III

OpenCable

Chapter 12 Why OpenCable?

Chapter 13 OpenCable Architectural Model

Chapter 14 OpenCable Device Functional Requirements

Chapter 15 OpenCable Headend Interfaces

Chapter 16 OCI-N: The Network Interface

Chapter 17 OCI-C1: The Consumer Interface

Chapter 18 OCI-C2: The Security Interface

Chapter 12

Why OpenCable?

The old model of cable television, in which each cable system is an island of proprietary technology, is changing rapidly due to competition from Direct Broadcast from Satellite (DBS), recent government regulation, digital television, silicon integration, and the Internet. The Federal Communications Commission (FCC) regulations now provide for retail availability of the set-top (or *navigation device*) with the goal of reducing the cost to the customer by facilitating free-market competition. In a digital world, effective standards are required to provide compatibility between the cable system and consumer electronic devices. Silicon integration continues to produce cost-performance breakthroughs, particularly in set-top components, such as microprocessors and memory. Finally, the Internet is an interactive model that has shown explosive growth, and much of the same networking technology can be applied to enhance television services.

OpenCable is an initiative led by Cable Television Laboratories (CableLabs) on behalf of the cable operators. OpenCable seeks to set a common set of requirements for set-top equipment so that new suppliers from the consumer electronics and computer industries can start to build equipment for connection to cable systems.

The genesis of OpenCable is due to a number of factors:

- A sense that the advanced technology being developed by the consumer electronics and computer industries is not being made available by traditional cable suppliers
- The rapid growth of DBS competitors that have used digital technology to leapfrog the cable industry
- The observation that while other industries have thrived through interoperable standards, the cable industry has stayed relatively closed and proprietary in its approach to new technologies

These factors led to the standards-based approach of OpenCable. OpenCable specifies an architecture based on standards where they are already in place. Where no applicable standards exist, OpenCable will develop such standards that are necessary and pass them into the appropriate industry-approved standards organizations for adoption. (An example is the specification for a point-of-deployment module interface, initially proposed by OpenCable as document OCI-C2 and subsequently developed and adopted as the DVS 131 standard by the SCTE Digital Video Subcommittee. DVS 131 is discussed in detail in Chapter 18, "OCI-C2: The Security Interface.")

In addition, OpenCable defines functional requirements for equipment that connects to the cable system (see Chapter 14, "OpenCable Device Functional Requirements").

Goals of OpenCable

OpenCable was first conceived as a way to encourage new suppliers from the consumer electronics and computer industries to build products for the cable industry. However, the goals were soon expanded as a result of the FCC's Report and Order (R&O) in the proceeding implementing Section 304 of the Telecommunications Act of 1996. Section 304 called upon the FCC to adopt rules to ensure the commercial availability of navigation devices, while not jeopardizing the signal security of the cable operator.

The following summarizes the expanded goals of OpenCable:

- Encourage entry of new suppliers into the cable industry, particularly for set-tops.
- Support the introduction of new services, particularly those based on the convergence of the computing and entertainment industries.
- Support retail availability of set-tops.

New Suppliers

The entry of new suppliers, particularly for digital set-tops is intended to promote competition and to provide enhanced features at lower cost. Previous efforts by individual cable operators to broaden the supplier base failed, mainly because the cable marketplace is small and highly segmented. To address this, OpenCable started to work on a set of purchase requirements for an OpenCable set-top that were consistent across the cable industry (made possible by digital standards and the natural discontinuity due to introduction of new technology). The consistent purchase requirements are intended to make the entire North American cable industry a single, unified market with sufficient volume to generate interest from large consumer electronics and computer equipment vendors.

New Services

The cable industry experiences considerable difficulty in bringing new services to market, particularly those services that rely on Internet and computer technology. This has caused considerable frustration with those traditional cable suppliers that have been slow to adopt any technologies they did not invent themselves.

Retail Availability

The OpenCable initiative was already addressing many of the issues of separable security to enable the entry of new suppliers and services, and it was natural to use the OpenCable approach to propose a solution that could be used to satisfy the FCC's Report and Order in the proceeding addressing the retail availability of navigation devices.

Market Forces

The OpenCable initiative is a response to a number of competitive market forces and technical factors. The market forces include competition from direct broadcast satellite services, digital terrestrial broadcasting, and the Internet. DBS services provide an example of successful partnering between satellite operators and consumer electronics companies where the customer base has grown rapidly using retail distribution channels (in some cases, the satellite receiver is integrated into the television receiver). Digital terrestrial broadcast looks to the same model. The Internet has grown exponentially and follows the retail model because it relies on the customers' purchase of a personal computer. All these services plan rapid deployment of new services based on retail sales where new equipment features are used to generate increased sales and to enable new services.

Competition

Competition is a positive force for any industry as long as there is no fundamental or overwhelming advantage of one player over another. In a rapidly evolving digital world, the cable industry seems to have missed out on many technological breakthroughs that have been used very effectively by competing industries. In particular, the digital satellite broadcasting (DBS) companies have made significant inroads into cable's core video distribution business by the use of standard definition MPEG-2 compression. The broadcasters are swiftly following DBS and have persuaded congress to allocate a second channel so they can transition to high definition and multiple standard definition digital services. The Internet has generated explosive growth and is starting to look hungrily at the video distribution business as its next killer application, which it calls *streaming media* (see the Internet section in Chapter 10, "On-Demand Services").

Although the cable industry is holding up well in face of this competition it has been slow to upgrade its technology for these new battlefronts. (Chapter 1, "Why Digital Television?" details the advantages of digital television technology over analog technology.) To compete effectively, the cable industry needs to recruit new suppliers that are skilled in the art of these new technologies—not just digital television but also the latest computing and networking techniques.

DBS

DBS is, without doubt, the biggest competitive problem for the cable industry. DBS has been very effective in marketing digital television to differentiate its service from cable. The cable industry has responded by promising digital cable services but has been relatively slow to deliver on this promise. Currently, cable companies have a significant advantage over DBS in providing local channels, and this has been one of the biggest weaknesses of satellite-delivered television. The DBS industry continues to lobby for permission to retransmit local channels, and it is probably only a matter of time before they are successful. At the time of writing, bills have passed in both the Senate and the House and await a conference between the two.

The DBS companies have successfully allied themselves with the consumer electronics manufacturers and retailers—most satellite receivers are built by consumer electronics giants such as RCA and Sony, and are distributed by all major consumer electronics retailers. This strategy has generated several generations of satellite receivers while the cable industry has struggled to built its first-generation digital set-top.

Cable still has a fundamental advantage over DBS—its ability to deliver interactive and on-demand services by using real-time, two-way communications over the cable plant. However, the supplier of these services must be competent in advanced networking and computing disciplines, areas where existing cable suppliers are weak.

Digital Terrestrial Broadcasting

Digital terrestrial broadcasting is still in its infancy but promises to emerge as another competitive threat to cable. Digital compression allows the terrestrial broadcaster to transmit a single high-definition signal or four to five standard definition signals. The error correction techniques used by VSB-8 modulation can deliver a perfect picture when the customer is within the footprint of the transmitter, so snowy pictures will no longer force the customer to subscribe to cable (although there are still some significant problems due to multipath interference in cities). By transmitting four to five standard definition signals during certain times of the day, a typical market with six affiliates and independent television stations will provide 30 channels.

The broadcasters are aligned with the consumer electronics manufacturers and retailers to provide additional services to customers in exchange for generating new television sales. New services include built-in interactive program guides that use digital program guide information, which is transmitted as part of the MPEG-2 transport stream, and *datacasting* services, which use spare transport stream capacity to broadcast data. Datacasting services may include enhanced television and informational services.

Internet

The Internet has emerged as a powerhouse of rapidly developing services and has grown explosively since the introduction of the World Wide Web. Many of the services that were demonstrated by the Time Warner Full Service Network (see Chapter 9, "Interactive Cable System Case Studies") have arrived in lower-bandwidth, browser-based incarnations over the Internet. In particular, the Internet is supporting many thriving electronic commerce applications, such as electronic trading (led by E-Schwab) and electronic retailing (for example, Amazon.com).

The Internet is also starting to be viewed as an entertainment service by many subscribers. The development of streaming media protocols that can distribute audio and video over the Internet provides a threat to cable's core business (see the Internet section in Chapter 10).

Many of the services offered by the Internet can be provided as part of an interactive or on-demand television service provided by the cable operator. However, development has been slow compared with that of the Internet and the cable industry now has to play catch-up.

Technology

There are two main areas of technology where the cable industry is in danger of falling behind the competition: silicon integration and software. Silicon integration allows very complex functions to be placed on a chip and allows dramatic cost reduction, but the cost of developing integrated circuits is high and cannot be justified unless millions of units can be sold. Software technology is developing rapidly and requires more processor performance and memory space as it becomes more sophisticated.

Government Regulation

During the 1990s, the cable television industry has been subject to regulation from two acts of Congress, the 1992 Cable Act and the 1996 Telecommunications Act. The FCC is often the agency charged with interpreting and implementing the the applicable portion of these Acts into regulations. The FCC, created by the 1934 Communications Act, describes itself as "An independent government agency with a mission to encourage competition in all communications markets and to protect the public interest" (see the section Internet Resources at the end of the chapter).

When developing regulation, the FCC often will open a proceeding on the various aspects. This usually begins with a Notice of Proposed Rulemaking (NPRM) to solicit comments and reply comments from all affected parties. At the conclusion of this process, a Report and Order is issued that specifies the rules that must be adhered to. These rules are then incorporated into the Code of Federal Regulations (CFR). In some cases, affected parties petition for changes in the rules.

1992 Cable Act

Section 17 of the 1992 Cable Act, based on a bill first introduced the previous year by Senator Leahy (D-Vermont), was intended to promote compatibility between cable systems and consumer electronics devices. In particular, the so-called "Leahy amendments" were addressed:

- To allow unattended recording of multiple cable channels using the timer features provided by VCRs

- To allow simultaneous viewing and recording of different channels (known as *watch-and-record*)
- To allow the use of Picture In Picture (PIP) features provided by television receivers

The 1992 Cable Act directed the FCC to consider the cost and benefits to the consumer in their proceeding, but also to allow the cable operators to protect against signal theft. The FCC was given considerable authority over cable operators to permit or restrict scrambling of cable channels. The FCC was also directed to promote the commercial availability of set-top converters and remote controls, and to give the customer a bypass option to allow direct connection of televisions and VCRs to the cable system. In comparison, the FCC has considerably less authority over the consumer electronics industry; the FCC is allowed to specify only the technical requirements for a cable ready or cable-compatible receiver.

1994 FCC Report and Order

After going through the usual process of issuing a notice of proposed rule making, the FCC issued a Report and Order on May 4, 1994. The Report and Order does not allow scrambling basic channels and mandates a bypass option, but the cable industry was able to persuade the FCC that retail availability of de-scrambling equipment would cause increased signal theft, so that idea was abandoned. However, the option of a decoder interface, to allow retail equipment to use an external de-scrambler, was recommended as a longer-term measure. To address the Leahy requirements, the cable operators were told to make set-tops with multiple tuners and de-scramblers available. (In most cases, this is achieved in practice by connecting two set-tops with an umbilical link and modifying the set-top software to make them behave as a single, watch-and-record, set-top—see the section Data Port in Chapter 3, "The Analog Set-Top Converter.")

The FCC postponed the issue of digital compatibility of set-tops to a later order (see the July 1998 Report and Order). However, it did state the opinion that digital standards and methods should be used to avoid future compatibility problems.

1996 Telecommunications Act

The 1996 Telecommunications Act includes two sections that relate to compatibility between cable systems and consumer electronic devices: Section 301, known as the Eschoo Amendment, and Section 304 which addresses "Competitive Availability of Navigation Devices."

Section 301 reduces the scope of the cable compatibility requirements in the 1992 Cable Act, limiting action to "a minimum degree of common design and operation, leaving all features, functions, protocols and other product and service options for selection through open competition in the market." In other words, the FCC is not allowed to specify or choose particular standards for cable compatibility but must leave development of these to those industries involved. In practice, a joint approach between cable operators and consumer electronics manufacturers is required to develop these standards, and any such standards that are developed are voluntary (see the section Standards in Chapter 13, "OpenCable Architectural Model").

Section 304 introduces new FCC language for a cable set-top, describing it as a *navigation device*, presumably because it performs the task of navigating from one service to another. Another new term is *multichannel video programming distributor* (MVPD), which is used to describe all providers of video services, including cable and satellite operators. The main purpose of Section 304 is to make navigation devices available at retail. However, to promote competition, the act states that they must be available from manufacturers and retailers that are not affiliated with the MVPD (that is, the cable operator). In addition, the security of service should not be compromised by any FCC regulations.

1998 Report and Order on Competitive Availability of Navigation Devices

On June 24, 1998, the Commission released its Report and Order in this proceeding implementing Section 304 of the Telecommunications Act of 1996. Section 304 calls upon the Commission to adopt rules to ensure the commercial availability of navigation devices, while not jeopardizing the signal security of an affected MVPD. As part of that R&O, the Commission determined that one means of implementing these twin goals was to separate security (that is, conditional access) functions from nonsecurity functions and to require that only the nonsecurity functions be made commercially available in equipment provided by entities unaffiliated with the MVPD. The security functions would reside in a separate security module to be obtained from the MVPD.

In its decision, the Commission repeatedly referenced the ongoing effort of CableLabs to develop specifications for both a digital security module and a digital security module interface. That OpenCable effort is focused on digital set-top converters and cable ready digital televisions. After such specifications are developed and the interface is adopted as an industry standard, manufacturers can produce digital navigation devices with the standardized digital security module interface and make such equipment available at retail. Cable operators would then supply a compatible digital security module to the customer.

In the course of the navigation devices proceeding, the Commission requested from the cable industry a schedule of milestones by which the FCC could monitor CableLabs' progress in meeting the OpenCable forecast of September 2000 for having digital security modules available for cable operators. The schedule submitted to the Commission included milestones for the development of specifications for the digital security module and the digital security module interface. It also included a post-specification time-line for development and production of the digital security module.

The Commission adopted a more aggressive schedule than CableLabs and ordered that digital security modules be available to cable operators by July (not September) 2000.

Nevertheless, in the R&O, it also included (without change) the industry-provided schedule of interim milestones.

To "assure itself that the schedule was being met," the Commission ordered that eight multiple system operators (MSOs) involved in the OpenCable project, whose statements concerning their commitments to that project were included in the record of the proceeding, file semi-annual progress reports with the Commission. The Commission established filing dates of January 7, 1999, July 7, 1999, January 7, 2000, and July 7, 2000, for the MSOs to detail "the progress of their efforts and the efforts of CableLabs to assure the commercial availability to consumers [of navigation devices]."

Providers of DBS and open video services (OVS) are exempt from these provisions; in other words, they are directed specifically at cable operators. Moreover, only security functions used to provide conditional access to video services are included and the rules do not apply to Internet security functions such as privacy, encryption, and authentication.

Digital Carriage

Digital carriage regulation, so called *digital must-carry*, is as yet undecided. The FCC issued a wide-ranging notice of proposed rule-making on the carriage of digital broadcast television signals by cable television systems on July 9, 1998. The FCC tentatively concluded that it has "broad authority" under the Cable Act and the Balanced Budget Act of 1997 to define the scope of a cable operator's signal carriage of digital television signals during the transition period from analog to digital broadcasting.

The FCC has identified seven distinct options for dealing with the carriage of digital television signals during transition:

- No digital must-carry—In this case, it will be left to the broadcasters to work out retransmission agreements with the cable companies without government regulation.
- Deferral—Digital must-carry would be deferred until a specific date.
- Equipment penetration—Digital must-carry requirements would be triggered by a specific penetration of digital receivers (or digital-to-analog converters), for example, 10%.
- Either/or—A broadcaster could choose must-carry for either its analog or digital channel, but not for both.
- Phase in—A cable system's required addition of digital television channels would be limited to a specified number per year.
- System upgrade—Only higher-channel capacity (for example, 750 MHz) systems would be forced to carry digital television signals.
- Immediate carriage—Must-carry regulations would be enforced immediately.

In the meantime, digital retransmission agreements are being hammered out between the broadcasters and cable operators.

Emergency Alert Systems

The primary purpose of the emergency alert system (EAS) is to provide emergency communications from the President during times of national emergency; thankfully, the EAS system has never been used for this purpose. In practice, the EAS is used to notify customers of state and local emergencies (which is a voluntary service provided by the cable operator).

The FCC adopted new EAS rules on September 29, 1997. These rules incorporated an agreement between cable operators and the National Association of the Deaf. The rules vary according to the size of the cable system:

- Cable systems with 10,000 customers or more must implement full audio and video override on all channels by December 31, 1998.
- Cable systems with between 5,000 and 10,000 customers must implement full audio and video override on all channels by October 1, 2002.
- Cable systems with fewer than 5,000 customers must implement full audio override on all channels with video override on a minimum of one channel by October 1, 2002.

Retail Issues

The cable industry has been reluctant to support a retail model. As a result, premium cable services are generally available only through a proprietary set-top converter (see Chapter 3 and Chapter 6, "The Digital Set-Top Converter"), which is leased to the customer. Nevertheless, the cable industry relies heavily on analog cable ready televisions to deliver basic cable to more than half of all cable customers. As the television industry moves toward a more digital world, the cable industry has to decide whether to provide every customer with a digital set-top at enormous capital expense or to embrace the development of a digital standard for the attachment of retail devices to the cable system. This choice is very difficult to make because

- The cable industry is concerned about its ability to manage cable services going forward. Management of the customer relationship—in particular, the user interface—is critical to the cable operators.
- In the past, cable operators have made the investment in new technology and taken on the cost of deployment to drive new services with associated revenues. CE manufacturers might be less likely to incorporate new features without a proven service. How will cable operators influence feature definition in retail devices?

- The current suppliers to the cable industry have a vested interest in perpetuating proprietary systems to protect their market share. Does the cable operator have sufficient leverage with its current suppliers to force them to build to open standards? Can current suppliers anticipate the move to open standards and shift their business model to take advantage of the new environment?
- The potential for increased signal theft makes the cable operator understandably concerned about standardizing the interface to the cable system.

The following sections examine these concerns in more detail.

Cable Service Management

Cable operators have considerable influence over the features of a set-top converter that they purchase and subsequently lease to the customer. In particular, the user interface is precisely specified by the cable operator to ensure that it is as user friendly as possible and does not have a negative impact on the operation of the cable system. For example, one vendor initially designed a digital set-top to display an error screen containing a telephone number if a problem occurred when ordering an IPPV event. The cable operator asked the vendor to remove the telephone number, dryly remarking: "We have spent years trying to reduce our call volume and this error screen would double it overnight!"

Typically, a cable operator deploys only a single model of set-top (in a given market) to ensure the user interface is consistent across all customers; this also simplifies the job of the customer service representative in answering customer queries. Even minor differences in the user interface can result in operational costs from increased call volume to lost revenue.

The introduction of retail devices might lead to a proliferation of different user interfaces because vendors see the user interface as a way of differentiating their products. A cable customer will naturally call the cable customer service representative (and not the retailer or manufacturer) with any questions about operation of the device on the cable system.

The issues of look and feel are not limited to operational impacts; the navigation and presentation of services are an integral part of the cable service. For example, a retail device could change the display order of channels, make certain channels more accessible and others difficult to find. These concerns are usually answered by the old chestnut: "The market will decide." However, cable operators naturally fear a bumpy ride while the market is making up its mind!

New Services

Although the introduction of new cable channels into the cable industry has been rapid and innovative, introduction of advanced services has been slow. In the case of a new cable channel, there are few technical challenges—adding a new channel requires satellite distribution to the headend and spectrum on the cable system. An advanced service is a much more difficult proposition; new types of equipment might be added to the cable system, new channel types might be defined, and the functions of the set-top might be extended. Of these, functional changes to the set-top are the most difficult for the cable operator. Most set-tops are analog (see Chapter 3) and are hard-wired for a fixed set of functions. Although many efforts have been made to extend the functions of advanced analog set-tops by software download, the memory size and processor performance limitations make this very difficult. Even in those cable systems that have deployed digital set-tops, most set-tops are almost as limited in their functions when they end up in the customer's home.

Chapter 8, "Interactive Services," and Chapter 10 describe the architectural models for advanced services on cable systems. It should be clear from these chapters that, although they often require additional set-top features, these types of services also require additional hardware and software components in the cable system itself. The following is current engineering practice:

- The cable operator specifies the new service, including any new system and set-top features that are required.
- The cable operator subcontracts design, implementation, integration, and testing of an end-to-end system from a single vendor.

In the retail model, the set-top is no longer built as part of an integrated system. The interface to the set-top must be specified precisely and frozen, so that it can be designed, built, and tested independently. How can new services be offered in a retail environment with these limitations?

Existing Suppliers

There is considerable resistance from existing cable suppliers to the migration to retail set-tops, which is hardly surprising because they face considerable erosion of their market share. An analogy is the development of the NTSC color standard; within a fairly short time, nearly all American television suppliers were wiped out by imports. The dominant suppliers of set-tops to the cable industry are General Instrument, with about 60% market share, and Scientific Atlanta, with about 30%. Both GI and SA are much smaller than the consumer electronics giants such as Sony, Toshiba, and Panasonic and fear that they will not be able to compete with them. (Sony owns 5% of GI.)

The existing suppliers to the cable industry have developed highly integrated cable systems that feature a headend controller that is tightly coupled to the set-top converter. The controller development cost is often subsidized by set-top sales, and the cable operator typically pays only a small fraction of its true cost. The interfaces between the controller and the set-top are highly proprietary, and it is questionable whether they are even fully documented in some cases. In particular, the conditional access system is kept a closely guarded secret in an attempt to combat signal theft.

The business relationships between the suppliers and the operators are often symbiotic, and many senior executives have moved from supplier companies to operator companies. Cable suppliers have an intimate understanding of the operator's requirements gleaned through many years of working closely together. The suppliers provide a full-service, turnkey solution to the operator, including new feature development, on-site maintenance and support, and even funding. In some cases, the operator has considerable equity ownership in the supplier, and stock warrants have been used as an inducement to sell set-tops. In short, the customer-supplier relationship in the cable industry is a complicated web of intricate business deals that might be hard to unravel. (See *The Billionaire Shell Game* by L. J. Davis.)

Signal Theft

Theft of service was estimated to have cost the cable industry $6 billion in 1997, and cable piracy has become big-business with multimillion-dollar companies pitting their wits against the cable and satellite operators (see Web resources on piracy). Nationally, 11.5% of homes passed do not pay for basic services and 9.23% do not pay for premium services. As a result, an Anti-Theft Cable Task Force has been created and has conducted focus groups to better understand the customers' attitude to signal theft. (See the article, "Task Force Outlines Stats, Initiative," by Thomas Umstead in *MultiChannel News*.) The focus group results indicated that

- Most cable consumers are not concerned about the problem and don't believe that cable operators are either.
- There is little visible enforcement of legal penalties against perpetrators.
- Cable employees are the most accessible source of *free* cable.
- Signal theft is a *victimless crime*.

In this environment, the cable operator is in a continuous struggle to control signal theft and is usually only one step ahead of the pirates. To protect revenues from premium services, cable operators rely on the conditional access system, which grants selective access to those services in exchange for payment from the customer (see Chapters 3 and 6). If the conditional access system is compromised, the cable supplier changes the conditional access to defeat the pirate set-tops while maintaining service to paying customers. (A standard conditional access system would be hacked and rendered useless in weeks, if not days.) There is justified concern that the deployment of retail set-tops might compromise the ability of the cable operator to introduce remedies in the case of a breach to the conditional access system.

OpenCable Solutions

Solutions to all the issues described in the previous section do not yet exist. Nevertheless, the OpenCable initiative has made considerable progress in a number of areas, notably the separation of security functions and the cable network interface. Other areas, such as the development of a portable software environment, are still under study.

Chapter 13 describes the OpenCable architecture in detail, and the remaining chapters of this book describe and discuss each of the OpenCable interfaces. It is helpful to look at some of the OpenCable initiatives in more general terms to show how they are intended to address the issues raised in this chapter.

The OpenCable initiative addresses these issues in a number of ways:

- OpenCable provides the cable industry with a process that makes it possible to address these issues in a concerted and industrywide manner.
- OpenCable specifies an architectural framework to enable new technologies to be structured into the existing cable systems and allow evolution to future cable systems.
- OpenCable also specifies set-top and system specifications that communicate the cable industry requirements to new and existing suppliers.
- OpenCable provides a blueprint for retail availability of navigation devices.

The following sections discuss each of these facets of OpenCable in more detail and serves as a preamble to Part III, "OpenCable."

The OpenCable Process

The OpenCable process is based on the following guiding principles:

- Embrace open standards—Accurate and complete standards are very important in a digital world, because a digital system cannot tolerate slight imperfections in the same way as an analog system. A digital system generally has only two major operational states: *working perfectly* and *not working at all*. Chapter 13 discusses the standards organizations that are most relevant to cable systems.
- Include installed systems—The currently deployed cable systems represent the *existing practice* of the cable industry. (An equally used, but less popular, term is *legacy systems*.) The OpenCable process is designed to support existing practice and allow gradual migration toward fully OpenCable-compliant systems.
- Seek input from all quarters—There are many interested parties in the OpenCable process, including the FCC, cable operators, equipment suppliers, retailers and broadcasters, and the customer. The OpenCable process is designed to allow each of these interested parties to have their say by issuing a series of document drafts and providing for review periods according to a published schedule.

- Develop and maintain a specification—The OpenCable specification is broken into a number of parts and actually forms a hierarchy of documents. The major specifications include the OpenCable device functional requirements and specifications for the major interfaces defined by the OpenCable architecture.
- Submit to standards bodies—When the OpenCable interface specification is complete, the specifications are submitted to the public standards process. (See Chapter 13 for more details.)
- Test interoperability—An important part of the OpenCable process is to test and verify interoperability of different implementations to the common set of specifications. The complexity and ambiguity inherent in specification documents often leads to slightly different implementations that are not interoperable. Interoperability testing allows any bugs to be discovered and resolved in a controlled laboratory environment and prevents them from reaching the real world.
- Certify compliance—Finally, after successful interoperability testing has been completed, products are certified as being OpenCable-compliant.

The OpenCable Architecture

The OpenCable architecture is based on the existing practice of modern cable systems:

- Hybrid fiber coax is recommended for systems that adopt the OpenCable architecture, because this can be used to support additional services such as video-on-demand. Nevertheless, the OpenCable architecture is applicable to any cable system that can support digital carriage.
- The OpenCable architecture is designed to take advantage of real-time, two-way capabilities of cable systems if they exist.
- In September 1997, the two largest suppliers of digital set-tops (General Instrument and Scientific Atlanta) agreed to cooperate on the use of a set of common digital transmission formats. The Harmony agreement specifies the modulation, encryption, system information, and transport protocols used across the network interface. OpenCable specifies these formats as OCI-N, the network interface (see Chapter 16, "OCI-N: The Network Interface").
- The OpenCable architecture does not specify any microprocessor and operating system (OS) choice.
- The OpenCable architecture is intended to provide a flexible software platform to support new services (based on new software applications). This part of the architecture is still under study and is described in Chapter 14.
- The OpenCable architecture is designed to be extensible to allow evolution. New techniques and initiatives will be layered onto the baseline OpenCable specifications over time.

The OpenCable Specifications

The OpenCable process generates a set of specifications that are published and submitted into the standards process if appropriate. The current suite of specifications envisioned by OpenCable includes

- Specifications for a family of set-tops, or *OpenCable devices*—The baseline specification is described in Chapter 14.
- OpenCable Interface Specifications for the headend, network, and consumer interface—These interface specifications are fundamental to OpenCable and are known as the OCI series specifications. The three headend interfaces defined (OCI-H1, OCI-H2, and OCI-H3) are described in Chapter 15, "OpenCable Headend Interfaces." The network interface (OCI-N) is described in Chapter 16. The interface to consumer electronics equipment (OCI-C1) is described in Chapter 17, "OCI C-1: The Consumer Interface," and the security interface (OCI-C2) is described in Chapter 18.
- Future OpenCable interfaces might be defined to allow further evolution.

Retail Availability

OpenCable represents the cable industry's chosen strategy to address FCC regulations as a result of the 1996 Telecommunications Act and the subsequent Report and Order in 1998. These include the following issues:

- Retail strategy—OpenCable is the strategy to enable the development of competitive devices for sale at retail for connection to the cable system.
- OpenCable provides solutions for digital and high definition connection of the set-top to the display device. This is the purpose of the OCI-C1 specification (see Chapter 17).
- Portability across cable systems—To support retail availability of devices, the issue of portability must be solved. In other words, it must be possible for customers to move from one cable system to another and still be able to use the retail devices that they have purchased for connection to the cable system. Portability is addressed by the OCI-N and OCI-C2 specifications.
- Point-of-deployment (POD) module specification—The POD module provides replaceable security functions in a small format PCMCIA module. The POD module is specified and purchased by the cable operator and is leased to the customer to provide access to encrypted services. The POD module is described in Chapter 18.

Summary

This chapter discussed the cable industry's reasons for initiating the OpenCable process, which are summarized in Table 12-1.

Table 12-1 *Issues and OpenCable's Response*

Issue	Description	OpenCable Response
Competition	Competition is growing from DBS, Terrestrial Digital Broadcast, and the Internet.	Publish baseline specifications to promote new services on cable.
Consumer compatibility	Digital television requires new interfaces.	OCI-C1 specification.
Retail availability	The 1998 Report and Order mandates "Competitive Availability of Navigation Devices."	OCI-N specifies network interface. OCI-C2 specifies separable security.
Digital cable ready	FCC has mandated the development of a cable ready digital television.	OCI-N specifies network interface. OCI-C2 specifies security module interface.
New suppliers	New suppliers find entry difficult because of the proprietary nature of cable systems.	Publish baseline specifications for an OpenCable device.
New services	Introduction of new services has been slow.	Define new services and adopt industry protocol specifications.
New technology	Introduction of new technology has been slow.	Encourage new suppliers skilled in these technologies to enter the cable industry through the RFP process.
Service management	Cable operators might lose their ability to manage the user interface and the look-and-feel of retail devices.	Educate new suppliers through OpenCable process whether they supply to the cable operator or directly to the customer. Foster business relationships between cable operators and CE manufacturers.
Digital carriage	Regulations are unclear, but digital carriage is expected for the cable industry.	Not specifically addressed by OpenCable.
Signal theft	Cable industry loses $6 billion per year to signal theft.	Specification of POD replaceable digital security that remains the property of the cable operator.

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Internet Resources

Federal Communications Commission Web site

http://www.fcc.gov

OpenCable Web site

http://www.opencable.com

CHAPTER 13

OpenCable Architectural Model

The OpenCable initiative is designed to provide solutions to many of the following issues, which were described in Chapter 12, "Why OpenCable?":

- Competition in the marketplace is growing due to the emergence of new players, including DBS, terrestrial broadcasters, and the Internet. Competition is healthy for the cable industry, but cable can compete effectively over the long term only if it can harness digital technology.
- The cable industry represents a fragmented marketplace to new suppliers looking at the potential of supplying digital technology because of the proliferation of proprietary interfaces and the lack of generally accepted standards. This tends to block entry of new suppliers.
- New services are becoming more and more software-intensive, and it is critical that the cable industry develop a software application strategy to support introduction of new services.
- The recent acts of Congress have mandated the competitive availability of navigation devices, but the consumer electronics manufacturers need specifications to enable them to build navigation devices that will work when connected to cable systems.

To address these issues, OpenCable defines an architectural model, an approach that is often used in the standards development process. A reference diagram serves to define the major interfaces in a cable system and to identify a set of defined interfaces between system components (the network interface, the point at which the cable system arrives at the customer's home, is the most important). In addition, OpenCable defines a set of baseline functional requirements for any device that attaches to the cable at the network interface. A device that meets the baseline functional requirements is considered to be OpenCable-compliant.

The OpenCable specification addresses the issues listed at the beginning of this section:

- Competition—By specifying the reference diagram and interfaces, OpenCable provides a clear strategy for incorporating digital technology into cable systems.

- Marketplace fragmentation—Although there are many cable operators, there is considerable consensus within the cable industry about how digital technology should be applied within cable systems. OpenCable captures and formalizes this consensus so that new suppliers can build to it. This has the effect of unifying the marketplace and making it more attractive to new suppliers.
- Software application strategy—The OpenCable baseline functional requirements provide a platform specification that is capable of supporting downloaded software applications.
- Retail—OpenCable defines the network interface to the cable system and also defines the separation of security functions into a separate Point Of Deployment (POD) module. The OpenCable specifications have been presented to the FCC, and a process is in place to deliver the first POD modules by the FCC target date of July 2000.

In many ways, the OpenCable process has formalized initiatives, which were already in progress (and still continue), between some cable operators and the computer and consumer electronics industries. It is important to recognize that OpenCable is intended to promote innovation and, therefore, OpenCable does not completely specify how to build digital cable systems. Instead, OpenCable provides an architectural model that can be extended by implementers to provide considerable flexibility and promotes competition between suppliers on the basis of features and performance.

OpenCable History

The OpenCable history started with a series of high-level meetings between the cable and computer industries in April 1997. The computer industry executives expressed an interest in entering the cable marketplace, specifically in providing advanced set-top devices that would look more like network computers than consumer electronics products. The computer industry's pitch was very attractive: a hardware platform that could be supplied for close to the cost of its components, a software architecture that enabled rapid innovation, and development time-scales measured in *Internet years*—of which there are seven in a normal calendar year.

To investigate the potential of the computer industry's proposals, an Advanced Set-top Taskforce was formed under the auspices of CableLabs. The taskforce drew its members from the larger cable operators (Time Warner Cable, TCI, Cox, Comcast, and Rogers) and started work on a Request For Information (RFI) for an advanced set-top. The RFI, which was modeled on Time Warner Cable's Pegasus RFP for convenience as much as anything, was issued in September 1997. The RFI was deliberately very brief (11 pages) to not limit the imaginations of the respondents. The introduction outlined the goals as follows:

> The goal of the OpenCable specifications process is to explore the range of costs of the variety of products, ranging from *Digital Cable Ready TVs* and *VCRs* to *Digital Set-tops* to *Cable Ready Digital PC cards*, that may be connected to the cable system. Information is presented in this document in order to help define the

range of capabilities and applications that can be supported by digital set-top boxes. Further, the requirements contained in this document are intended to help us qualify the vendor authors for developing the OpenCable specifications."

(The functional requirements for the OpenCable device are described in Chapter 14, "OpenCable Device Functional Requirements.")

The last sentence of the introduction introduces the concept of *vendor authors*, which are a means to solicit help from the vendor community in the development of OpenCable specifications. Cable operators are notoriously understaffed in senior technical positions and often lack the necessary personnel to author specifications. As a result, cable operators have come to rely on their traditional suppliers for technical advice and it is natural to extend this model to the OpenCable process.

Twenty-three companies responded to the initial OpenCable RFI. Most of the responses were in the form of PowerPoint presentations and none were judged complete enough to provide a solution. The OpenCable process was established to provide more guidance to responding companies by developing a set of specifications. The 23 respondents to the initial OpenCable RFI were

- ACTV/Sarnoff
- Criterion Software
- General Instrument
- IBM (IP issues only)
- Intel Group—Cisco, Netscape, Network Computer Inc. (NCI) Oracle, Thomson CE
- Intel/NCI
- Lucent Technologies
- Microsoft
- Oracle/NCI/Netscape
- Panasonic
- Pioneer Digital
- Samsung
- Scientific-Atlanta
- Scientific-Atlanta Group—IBM, Pioneer Electronics, PowerTV, Sun, Toshiba
- SCM Microsystems
- Sony
- Texas Instruments
- Thomson CE/NCI

- Thomson Sun (OpenTV)
- Wink Communications
- Worldgate Communications
- Zenith Electronics

OpenCable Process

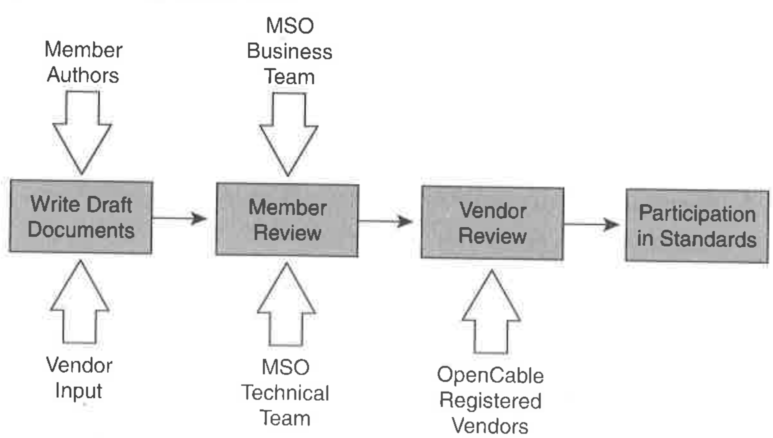
The OpenCable process is highly collaborative, allowing input from the cable operator and vendor communities throughout the development of OpenCable specifications and implementations. The OpenCable process is managed by the Advanced Platforms and Services organization, which is part of CableLabs. The OpenCable process is divided into two main parts:

- Specification development
- Interoperability

Specification Development

The specification development process is illustrated in Figure 13-1. Initial drafts of OpenCable documents are written by *member authors*, that is, by the technical staff of cable operators, which are members of CableLabs. Input from vendors is solicited at this stage either by an OpenCable RFI or by direct consultation with companies that have previously responded to an OpenCable RFI.

Figure 13-1 *Specification Development Process*



The next step is member review by the OpenCable Technical and Business teams. Technical and business staff of cable operators, which are members of CableLabs, make up these teams. This step is particularly important because it tends to drive consensus across the cable operators and allows compromises to be made that impact existing practices. A cable operator naturally fears the economic consequences of a migration to a standard that might cause operational changes and ultimately affect the bottom line. Discussions often center on the long-term benefits for the cable industry versus short-time pain for individual operators. Fortunately, most cable operators are just starting the process of introducing digital services into their cable systems and have some flexibility in their digital strategy.

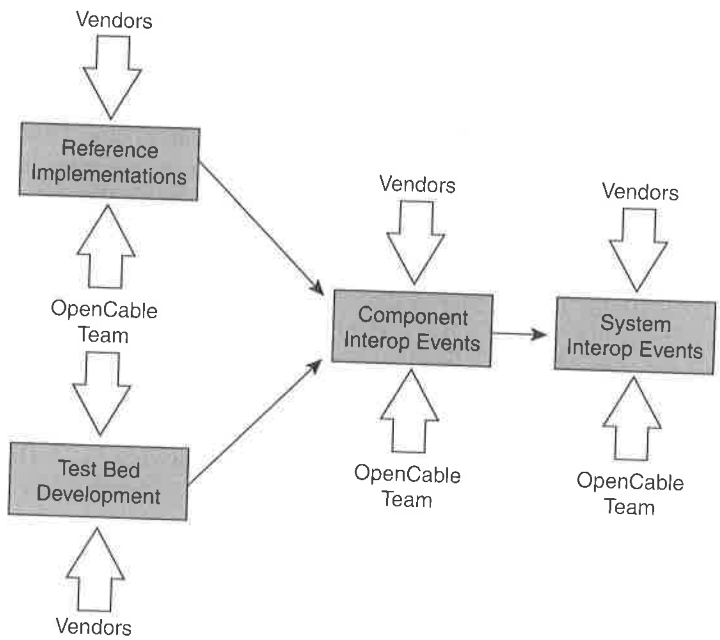
The next step in the process is vendor review, which allows OpenCable registered vendors to submit comments of any specification. Any vendor is welcome to register with CableLabs; to date, several hundred vendors have completed the registration process.

The final step is to generate a standard for the specification. This is not a rubber-stamp process by any means, and a good example is the OCI-C2 specification (see Chapter 18, "OCI-C2: The Security Interface"), which was introduced to SCTE DVS as DVS-131. The DVS-131 document went through seven revision cycles before being approved as a U.S. cable standard. The standards forum requires considerable attention to the nuances of language and must consider input from all the participants regardless of which industry or faction they represent.

Interoperability

The interoperability testing process is illustrated in Figure 13-2. Reference implementations, as well as test beds, are used to demonstrate interoperability. These are developed by cooperation between the OpenCable technical team and the OpenCable vendors. To provide focus and visibility, interop events are scheduled; in the case of the OCI-C2 interface, the cable operators have committed to a schedule of interop events that were adopted as part of the FCC's Report and Order on the commercial availability of navigation devices (see Chapter 18 for more details).

Figure 13-2 *Interoperability Testing Process*

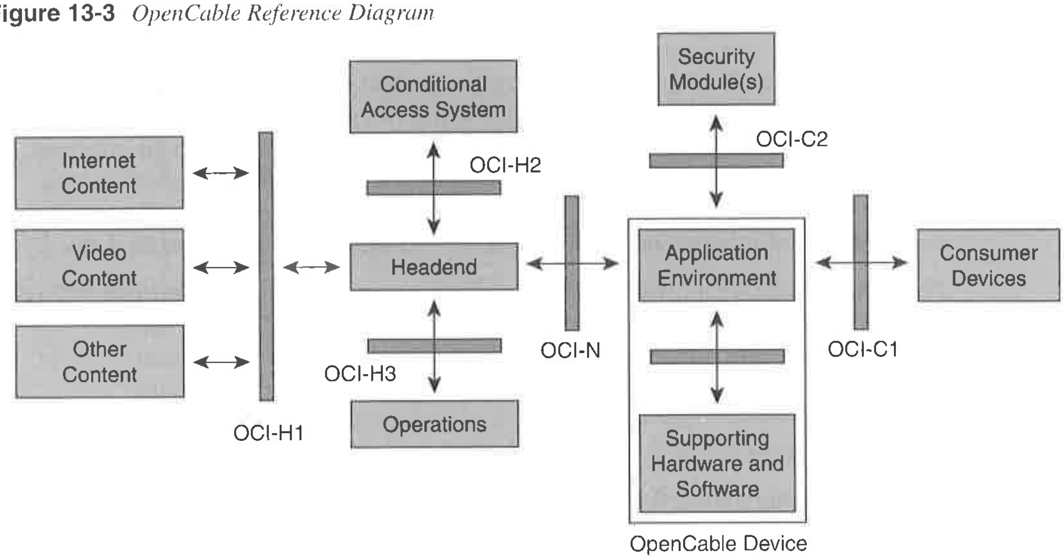


Interop events are divided into two stages that demonstrate component and system-level interoperability. The interop process is modeled on the DOCSIS cable modem incubator laboratory.

OpenCable Reference Diagram

Figure 13-3 shows the OpenCable reference diagram. The reference diagram describes the system at a very high level and deliberately hides much of the detail of a *real* cable system; for example, the cable delivery network is abstracted away completely. A cable system is reduced in the diagram to a small number of *black-box* components, and most of the complexity is hidden inside these components. An exception to this rule is the *OpenCable device*, which is modeled as a *gray box* to describe some of its internal mechanisms.

Figure 13-3 *OpenCable Reference Diagram*



The importance of the OpenCable reference diagram is that it specifies a number of standard interfaces between the components of a cable system. By specifying these interfaces, it is possible to replace certain components with others without redesigning the entire system. The most important interfaces are the OCI-N, OCI-C1, and OCI-C2 interfaces because they allow substitution of a wide range of different products that satisfy the functional requirements of the OpenCable device.

Specified Interfaces

OpenCable defines three headend interfaces (OCI-H1, OCI-H2, and OCI-H3), a network interface (OCI-N), and two consumer interfaces (OCI-C1 and OCI-C2). Each of these interfaces is very broad in scope and each includes several different interface specifications that meet the information transfer requirements. For example, the OCI-C1 interface function can be performed by an analog or digital link between the OpenCable device and the consumer device. Therefore, each OpenCable interface is a family of interface specifications, which can be extended to include new members over time.

Each OC-series interface will be discussed in more detail in the following chapters:

- Chapter 15—OCI-H1, OCI-H2, and OCI-H2
- Chapter 16—OCI-N
- Chapter 17—OCI-C1
- Chapter 18—OCI-C2

OCI-H1 Interface

The information flow across the OCI-H1 interface in Figure 13-1 consists of *programming content*, which has three main sources. Internet content is generally received from a wide-area network (WAN) and represents a two-way flow of information, although, in the case of Web browsing, the flow is predominantly from the content provider to the customer. Video content is a one-way flow of information and arrives from a number of content providers over satellite, terrestrial, or wide-area networks. Finally, other content represents any other kind of information that arrives at the headend, which has yet to be defined.

The OCI-H1 interface is divided into three subtypes according to the content interfaces that are defined for the content information flows:

- Internet content
- Video content
- Other content

In many cases, the content flows transparently through the headend to the network; in other words, its appearance is not changed by the headend even though its physical format may be changed. For example, a QPSK signal received from satellite encrypted with DigiCipher II conditional access might be transcoded into a QAM signal encrypted with PowerKEY conditional access, but the customer is generally unaware of this fact when viewing the content. In the case of Internet content, the appearance of the content often depends on the software application at the OpenCable device; for example, a Web browser resizes and reformats content to fit the screen. Nevertheless, the headend acts as merely a relay point in the network established between the content provider and the customer.

In the case of on-demand services, the headend provides temporary storage of the content without changing its appearance. In the case of video-on-demand services, the entire movie title is provisioned on a server at the headend (see Chapter 10, "On-Demand Services") so it can be streamed out to the customer when requested. In the case of Internet services, it is becoming more common to cache Web pages on a server at the headend or hub.

In some cases, the content might be created by the cable operator, but this is really a case of vertical integration of the business, and the reference diagram in Figure 13-1 still represents the flow of content from the content provider to the customer over the network.

OCI-H2 Interface

The OCI-H2 interface provides for the separation of the conditional access function from the rest of the headend functions. This interface is the headend equivalent of the OCI-C2 interface. In both cases, the security function must remain as secure as possible and relies on shared secrets in the headend conditional access system (CAS) and the point-of-deployment (POD) security module. The definition of the OCI-H2 and OCI-C2 interfaces must provide for a number of contingencies:

- CAS upgrade—The conditional access system might require periodic upgrade, either to combat signal theft or to add new features.
- CAS replacement—The complete replacement of the conditional access system might be required under certain circumstances.

OCI-H3 Interface

The OCI-H3 interface provides operational and control flows between the headend components and the other systems that are required to operate the cable system, including billing systems, subscriber management systems, operational support systems, network management systems, and so on. These systems might be located in the headend or at a nearby business office, or they might be remote from the cable system. In any case, the interface requirements are similar, and include

- Subscriber management
- Event provisioning
- Purchase collection
- Network management

OCI-N Interface

NOTE The OCI-N interface is discussed in detail in Chapter 16, "OCI-N: The Network Interface."

In network design, the User-Network Interface (UNI) is often standardized to allow different kinds of equipment to attach to the network. The OpenCable UNI is designated as OCI-N. A standard OpenCable UNI is essential to support a family of OpenCable devices, where each family member can be built by multiple vendors to a set of open standards.

Unfortunately, in today's cable networks, the UNI is not uniform across all cable system providers; to use a telephone analogy, a telephone connected to one network would not work when connected to another network. The *existing practice* (or *legacy*) of deployed cable systems makes selection of an OCI-N standard difficult. Why are there so many variations in existing practice?

The telephone analogy is an oversimplification because a cable UNI is far more complicated than a telephone UNI. This complexity allows considerable implementation choice:

- The cable UNI is a broadband interface (whereas the telephone UNI is a narrowband interface). The frequency spectrum extends from about 5 MHz up to 870 MHz.

- The cable UNI is channelized into a large number of frequency bands (whereas a telephone UNI uses a single frequency band). This provides tremendous capacity and flexibility, but it also allows each cable operator to build differences into the UNI.
- Each channel defined across the cable UNI can be of a number of different types, and some services use multiple channel types (see Chapter 5, "Adding Digital Television Services to Cable Systems").
- The information content provided in the channel has an intrinsic value, and the cable operator generates revenue by charging for service rather than bandwidth. In contrast, most UNI definitions in the telecommunications and data communications provide a connection, where the tariff is dependent merely on the information capacity and endpoints of the communications link.

These factors have caused the cable UNI to evolve differently across different cable systems. Fortunately, there are also a number of forces that have provided some standardization across the UNI:

- The Joint Engineering Committee of the EIA and NCTA developed a standard frequency plan for cable, which is now an ANSI-approved standard EIA-542. (See *Modern Cable Television Technology; Video, Voice, and Data Communications* by Walter Ciciora and others, page 354.)
- The Joint Engineering Committee of the EIA and NCTA developed a standard RF interface for cable, EIA-23 to meet the FCC Part 76 regulations for cable (47 C.F.R. Part 76) and the FCC Part 15 regulations for television receiving devices (47 C.F.R. Part 76).
- CableLabs announced the Harmony agreement in October 1997. The Harmony agreement, reached between Scientific Atlanta and General Instrument at the prompting of the cable industry, formalized the acceptance of five open standards, including MPEG-2 video, Dolby Digital audio, MPEG-2 transport, ASTC system information, and ITU-J83 Annex B modulation.

OpenCable builds on these standards and agreements to provide a single UNI specification that is compatible across all cable systems. Although there are some differences to support variations in existing practice, these are accommodated by options to a baseline specification. For example, one of three different out-of-band signaling choices can be selected at the option of the cable operator.

OCI-C1 Interface

NOTE The OCI-C1 interface is discussed in detail in Chapter 17, "OCI-C1: The Consumer Interface."

The OCI-C1 interface connects the OpenCable device to any consumer electronics devices in the home, including a television, a VCR, and any external audio systems. As with the other interfaces, OCI-C1 is a family of analog and digital interfaces (as described in the section Set-Top Outputs in Chapter 6, "The Digital Set-Top Converter"), which are

- RF channel 3/4 output
- Baseband video
- Baseband audio
- Component video
- IEEE-1394
- S/PDIF digital audio

The OCI-C1 interface must support consumer electronics compatibility as defined by the 1992 Cable Act. In addition to standard definition television signals, cable requires a solution to high definition interconnect. For both standard and high definition interfaces, the OCI-C1 must support copy protection mechanisms designed to prevent illegal copying of the signal.

OCI-C2 Interface

NOTE The OCI-C2 interface is discussed in detail in Chapter 18.

The OCI-C2 interface provides the interface to a Point Of Deployment (POD) module for digital signals provided over the cable system. The POD module is a PCMCIA-format device supplied by the cable operator, which provides two important functions:

- Separation of security—The FCC Report and Order on the Retail Availability of Navigation Devices mandates the separation of security and navigation functions in a navigation device by July 2000. Moreover, cable operators will not be allowed to deploy set-tops with integrated security after January 1, 2005. The POD module is designed to satisfy the FCC requirements for separable security.
- Signaling support—The greatest variation in existing practice is in the choice of out-of-band signaling protocol. The POD module terminates the lower layers of the signaling protocol and adapts a navigation device to the signaling scheme for that cable system. The POD module supports signaling according to DVS 167 and DVS 178 (see Chapter 5).

A third aspect of the OCI-C2 interface is that it transfers programming content across a digital interface. In recognition of the concerns of the Motion Picture Association of America (MPAA), the OCI-C2 interface supports a copy protection technology designed to ensure that copyrighted material sent over this digital link is protected from illegal copying.

Specified Components

The OpenCable architecture specifies the functional requirements for two components, the OpenCable device and the POD module.

OpenCable Device

NOTE The functional requirements for the OpenCable device are discussed in detail in Chapter 18.

The OpenCable device performs all the functions of a hybrid analog/digital set-top converter (see Chapter 6). It terminates the OCI-N interface; it hosts the OCI-C2 interface; it provides tuning, demodulation, navigation, and decoding functions; and it supports outputs, as specified by the OCI-C1 interface. A set-top converter might perform the functions of an OpenCable device, or the functions might be incorporated into a television receiver or VCR, or even by a card designed to be inserted into a personal computer.

There is a wide range of possible OpenCable device designs that support different advanced features and services. For this reason, the OpenCable device functional requirements specify a set of *core requirements* that must be satisfied by all OpenCable devices. The core requirements specify an OpenCable device that approximates the functions of digital set-tops currently being deployed (that is, the General Instrument DCT-series set-tops and the Pegasus set-top—see Chapter 6).

OpenCable also specifies *extension requirements* for the OpenCable device, which are supplemental to the core requirements. These requirements specify a wide range of additional features and services that might be required by individual cable operators.

There are a number of important receiver performance requirements that *all* OpenCable devices must satisfy:

- Connection of an OpenCable device must not adversely affect the operation of the cable network.
- The OpenCable device must meet certain RF performance requirements according to EIA-23.
- In addition, the cable operator has a long list of performance parameters specified in the OpenCable device functional requirements.

POD Module

NOTE The Point Of Deployment (POD) module is discussed in detail in Chapter 18.

The Point Of Deployment (POD) module adapts a single device to any cable system. This is possible largely because of standardization of the OCI-N interface. However, there are a number of options built into the OCI-N interface to account for variations in the existing practice of different cable operators. The most significant of these are the out-of-band signaling protocol and the conditional access system.

Standards

OpenCable is committed to the use of open standards—that is, international standards (for example, ISO standards), North American standards (for example, standards approved by ANSI), or *de facto* industry standards. All standard interfaces must be in the public domain or must be freely available on payment of nominal licensing fees. OpenCable will avoid use of closed, proprietary systems.

OpenCable draws on many existing standards. Many standards are optional, so it is important for OpenCable to make the use of them mandatory. This provides vendors with explicit guidance on the appropriate set of standards used by the cable industry. By making these standards universal and mandatory across all cable systems, OpenCable promotes portability from one system to another.

Where no standards exist, OpenCable will develop appropriate standards by submitting the applicable specifications to standards bodies. In the case of the OCI-C1 and OCI-C2 interfaces, submissions have already been made to SCTE DVS and have resulted in approved SCTE standards.

Relevant Standards Bodies

There has been an explosion of activity in standards over the past decade, and the section Internet References, located at the end of this chapter, provides a partial list of Web sites of relevant standards bodies for digital television. The OpenCable process focuses on cable systems, so it is appropriate that the Society of Cable Telecommunications Engineers (SCTE) Digital Video Standards (DVS) subcommittee is the primary vehicle for standardization of OpenCable documents. In addition, the work of the Joint Engineering Committee (JEC), which is a group sponsored by the National Cable Television Association (NCTA) and the Consumer Manufacturers Association (CEMA), is also relevant to OpenCable. Finally, the Advanced Television Systems Committee (ATSC) is very active in the development of standards for television.

SCTE DVS

The SCTE mission statement includes the development of training, certification, and standards for the broadband industry. The SCTE was formed in 1969 to promote the sharing of operational and technical knowledge in cable television and broadband communications. Since that time, it has worked to promote technical awareness in the industry and to establish standards and practices. (See the NCTA paper "SCTE's Digital Video Subcommittee: Introduction and Update," by Paul J. Hearty.)

In August 1995, the SCTE was granted accreditation as a standards-setting body by ANSI (American National Standards Institute). On April 19, 1996, the SCTE established the Digital Video Subcommittee (DVS). The original mandate assigned to the DVS was

> to explore the need for SCTE involvement in the development of standards for digital video signal delivery...

In its inaugural meeting on June 9, 1996, the DVS affirmed the need for timely standards in a number of areas. To meet this need, the subcommittee established five *working groups*, each chaired by a cable operator, a programmer, or an employee of CableLabs. The working groups (WGs) are as follows:

- WG-1 Video and Audio
- WG-2 Data (Transport Applications)
- WG-3 Networks Architecture and Management
- WG-4 Transmission and Distribution
- WG-5 Security

The subcommittee meets approximately six times per year. The membership includes system operators, equipment manufacturers, programmers, and service providers. At last count, more than 50 companies and organizations are taking part in the work.

Each submission to SCTE DVS is assigned to one or more working groups according to the following work plan. To date, there have been approximately 200 submissions to SCTE DVS.

Working Group 1

- Video profiles and levels
- Video formats
- Audio specification
- MPEG-1 support
- Statistical multiplexing support
- Video user data (for example, VBI) applications

Working Group 2

- Base system information (SI)
- SI extensions for cable and satellite
- Program guide
- Subtitling methods
- Transport data services
- Program navigation requirements

Working Group 3

- Network/headend architectures and interfaces
- Functional requirements
- Emergency alerting requirements and methods
- Bit stream editing and commercial insertion—an *ad hoc* working group has been formed to consider Digital Program Insertion (DPI)

Working Group 4

- Cable modulation and forward error correction
- Out-of-band modulation (forward and reverse path)
- Satellite modulation and forward error correction
- Other media modulation

Working Group 5

- Core encryption
- Security interfaces

JEC

The Joint Engineering Committee is jointly sponsored by the National Cable Television Association (NCTA) and the Consumer Manufacturers Association (CEMA) and was formed in 1980. The JEC developed the EIA-542 Cable Television Identification Plan (frequency plan) and the EIA 105 Analog Decoder Interface Standard. The JEC has two subcommittees actively working on cable standards, which are

- National Renewable Security Standard (NRSS) subcommittee—NRSS developed two alternatives for a replaceable security module known as NRSS EIA 679 Part A and Part B. The EIA 679 Part B standard forms the basis for the OpenCable POD module.
- Digital Standards Sub-Committee (DSSC)—Until recently, this group was a working group (DSWG) but it became a subcommittee in early 1999. The DSSC has the mandate to consider requirements for a cable ready digital television.

ATSC

The Advanced Television Systems Committee (ATSC) was formed to establish voluntary technical standards for advanced television systems, including high definition television (HDTV). The ATSC is not ANSI-accredited but operates under ANSI procedures.

Summary

This chapter described the broad structure of the OpenCable architecture and the relevant standards bodies for OpenCable. Later chapters in this book describe specific details of OpenCable in more detail. This chapter described the following four major sections:

- History—The OpenCable initiative was started in 1997 with the creation of an Advanced Set-Top Taskforce. The initial 23 respondents have since grown to more than 300 vendors that are now involved in the OpenCable specification process.
- Process—The OpenCable process is a collaborative effort between CableLabs, cable operators, and vendors. The process generates a set of interface and device specifications, and includes a series of interoperability tests.
- Reference diagram—the OpenCable reference diagram defines a set of headend interfaces (OCI-H1, OCI-H2, and OCI-H3), the network interface (OCI-N), the consumer interface (OCI-C1), and the security module interface (OCI-C2). In addition, the OpenCable device (for example, a digital set-top, a cable ready digital television, or a cable ready personal computer) is defined. Specifications for OCI-N, OCI-C1, OCI-C2, and the OpenCable device have been released by OpenCable.
- Standards—The most relevant standards bodies to OpenCable are the SCTE Digital Video Standards subcommittee (DVS), the NCTA Joint Engineering Committee (JEC), and the Advanced Television Systems Committee (ATSC).

References

Books

Ciciora, Walter, James Farmer, and David Large. *Modern Cable Television Technology; Video, Voice, and Data Communications*. San Francisco, CA: Morgan Kaufmann Publishers, Inc., 1999.

Paul J. Hearty. "SCTE's Digital Video Subcommittee: Introduction and Update." *1997 NCTA Convention Technical papers*. NCTA, Washington, D.C.

Internet Resources

OpenCable Web site

http://www.opencable.com

CableLabs Web site

http://www.cablelabs.com

The International Organization for Standardization (ISO) is a worldwide federation of national standards bodies from 130 countries, one from each country. ISO is a nongovernmental organization that was established in 1947. The mission of ISO is to promote the development of standardization and related activities in the world with a view to facilitating the international exchange of goods and services and to developing cooperation in the spheres of intellectual, scientific, technological, and economic activity. ISO's work results in international agreements that are published as International Standards.

http://www.iso.ch/welcome.html

Founded in 1906, the International Electrotechnical Commission (IEC) is the world organization that prepares and publishes international standards for all electrical, electronic, and related technologies. The IEC was founded as a result of a resolution passed at the International Electrical Congress held in St. Louis (USA) in 1904. The membership consists of more than 50 participating countries, including all the world's major trading nations and a growing number of industrializing countries.

http://www.iec.ch/

The ITU, headquartered in Geneva, Switzerland, is an international organization, within which governments and the private sector coordinate global telecom networks and services.

http://www.itu.int/

The American National Standards Institute (ANSI) has served in its capacity as administrator and coordinator of the United States private sector voluntary standardization system for 80 years. Founded in 1918 by five engineering societies and three government agencies, the Institute remains a private, nonprofit membership organization supported by a diverse constituency of private and public sector organizations.

http://web.ansi.org/default.htm

SMPTE is the preeminent professional society for motion picture and television engineers, with approximately 10,000 members worldwide.

http://www.smpte.org/

European Digital Video Broadcasting Web site

http://www.dvb.org/

Dolby Web site of technical information on audio compression and related matters

http://www.dolby.com/tech/

The Advanced Television Systems Committee (ATSC) was formed to establish voluntary technical standards for advanced television systems, including digital high definition television (HDTV). The ATSC is supported by its members who are subject to certain qualification requirements.

http://www.atsc.org

The Advanced Television Technology Center is a private, nonprofit corporation organized by members of the television broadcasting and consumer electronics products industry to test and recommend hardware solutions for delivery and reception of the new U.S. terrestrial transmission system for digital television (DTV) service, including high definition television (HDTV).

http://www.attc.org/

CHAPTER 14

OpenCable Device Functional Requirements

The OpenCable device performs all the functions of a hybrid analog/digital set-top converter (see Chapter 6, "The Digital Set-Top Converter"). It terminates the network interface (OCI-N); hosts the POD module interface (OCI-C2); provides tuning, demodulation, navigation, and decoding functions; and supports the interface to the display device (OCI-C1). The functions of an OpenCable device might be built into a set-top converter, integrated into a television, or incorporated into a PC expansion card. When an OpenCable device is integrated into a television, it is called a cable ready digital television (CR-DTV). When the OpenCable functions are integrated into a PC, the result is a *cable ready personal computer (CRPC)*—a new term that is not yet clearly defined.

There is a wide range of possible OpenCable device designs that might support different advanced features and services. For this reason, the OpenCable technical team has concentrated on specifying the *core requirements* for an OpenCable set-top terminal that approximates the lowest common denominator functions of digital set-tops currently being deployed (that is, the General Instrument DCT-series set-tops, Scientific Atlanta Explorer-series set-tops, and Pioneer Voyager-series set-tops—see Chapter 6).

In addition, extended functional requirements for the OpenCable device have been discussed and specified, but it is more difficult to reach agreement on them. Naturally, vendors are free to innovate as to which extended features they include into more advanced OpenCable devices, and customers will make their decision to purchase based on their personal preferences. This is an excellent model to promote competitive availability at retail, but there are also some reasons for caution:

- The features and functions of an OpenCable device depend on the cable system, and cable networks will not universally support extended features in the foreseeable future. For example, a customer who buys an OpenCable device that provides video-on-demand functions will be able to use those functions only on cable systems that support video-on-demand.
- Portability from one cable system to another is not guaranteed for the same reason, and there is potential for customers to be stuck with a stranded investment if they move.

Nevertheless, these restrictions are also true today for DOCSIS cable modems purchased at retail. The important thing is to manage customers' expectations so that these limitations do not come as a surprise. Moreover, the OpenCable process is designed to support the existing leased model as well as a retail model.

Goals

The overall goals of the OpenCable specification process are clearly stated in the OpenCable Set-top Functional Requirements specifications [CableLabs]. It is worth discussing how these goals relate to the OpenCable device requirements in some detail because they are often more difficult to achieve in practice than in theory:

- Integrated service environment—The OpenCable device must provide consistent services to those provided by existing set-tops and all other types and models of OpenCable device when deployed, side by side, in the same cable system.
- Open and interoperable—The OpenCable device shall use *open* computing and network architectures, wherever possible, to reduce costs and incorporate new technologies as they are developed.
- Portability—The OpenCable device must be portable across OpenCable-compliant cable systems.
- Renewable security—The OpenCable device must support renewable security by means of the OCI-C2 interface.
- User interface—The OpenCable device must provide some means for displaying information relating to the navigation and access of services (video, Internet, and so on) that are offered by the cable operator.
- Scalable—The OpenCable device must continue to function (to its *original* specification) in cable systems during the migration to real-time, two-way systems providing interactive and on-demand services.
- Efficient application and network design—The OpenCable device must follow certain network behavior rules that are designed to ensure the efficient use of network resources.
- Operational compatibility—The OpenCable device must be compatible with existing operational, customer support, and billing systems.
- Backward compatibility—The OpenCable device must be backward-compatible and interoperable with the embedded base of existing set-top terminals.

Provide for Integrated Service Environments

This goal is designed to allow the cable operator to provide a broad range of services tailored to the cable system using a range of different OpenCable device models and existing set-tops. (This is a logical extension of the existing cable industry business model, where new services have been introduced using new set-tops; for example, advanced analog set-tops were introduced to provide EPG and IPPV functions.)

The tiered service model allows programming services to be packaged into groups of services according to marketing requirements. An integrated service environment preserves the cable operator's ability to tier services independently from the technology that is used to deliver them. For example, HBO is often delivered as an analog channel, but digital technology allows the cable operator to provide the multichannel HBO multiplex. The transition must be seamless from the customers' standpoint even though both packages are offered at the same time over the same cable system.

As interactive and on-demand services are offered, it is an important marketing requirement that they can be packaged alongside, or with, existing services. An integrated service environment allows the service to be separated from the technology used to deliver it and enables a smooth migration to enhanced television services over time.

Open and Interoperable

OpenCable is committed to the use of open standards—that is, international standards (for example, ISO standards), North American standards (for example, standards approved by ANSI), industry standards (for example, standards approved by SCTE), or *de facto* industry standards. All standard interfaces must be in the public domain or must be freely available on payment of nominal licensing fees. OpenCable avoids the use of closed, proprietary systems except where required to protect copyrighted material or preserve the presentation format.

The specification of the OCI-series interfaces draws on existing standards where possible (see Chapter 15, "OpenCable Headend Interfaces," through Chapter 18, "OCI-C2: The Security Interface"). In addition, the technologies used to build OpenCable devices must be available competitively to minimize costs. For example, the OpenCable specifications do not specify the use of a particular operating system, so each vendor can choose to purchase or build this technology.

Network interoperability of the OpenCable device is achieved through standard interface specifications of the OCI-N, OCI-C1, and OCI-C2 interfaces. To provide service interoperability is more challenging because it involves interoperability at the software applications layer. The Internet defines standards for text, graphics, and portable applications. Groups such as ATVEF, W3C, and DASE are using Internet standards to extend the existing content standards for broadcast digital television.

Portability

Although the 1996 Telecom Act and the subsequent FCC Report and Order on Navigation Devices did not require portability, portability is a requirement reflecting OpenCable's (and subsequently the cable industry's) commitment toward making retail successful. The OpenCable device requirements for interoperable standards at the OCI-N interface provides the basis for portability, but is not sufficient to achieve full portability. The reason is that there are fundamental differences between the specific set of interfaces used by different cable operators. The Harmony agreement (see Chapter 13, "OpenCable

Architectural Model") was designed to provide as much convergence as possible between digital systems provided by Scientific Atlanta and General Instrument, but there remain fundamental differences in security, out-of-band signaling mechanisms, and user interfaces.

OpenCable addresses this issue by allowing a *point-of-deployment* (POD) decision to accommodate these differences. The first two differences (security and out-of-band signaling) are hardware functions and are solved by a replaceable POD module, which is supplied by the cable operator (see Chapter 18). The third difference (user interface) can be solved by downloadable applications software but requires agreement on a common application environment for OpenCable devices.

Renewable Security

This goal supports the 1998 FCC Report and Order on Navigation Devices mandating the separation of security from non-security functions (see Chapter 12, "Why OpenCable?"). Renewable security accommodates multiple requirements in the OpenCable device:

- Making the security system renewable allows it to be replaced in case of a breach of security.
- Making the security system renewable allows it to be provisioned according to the particular security system selected by the cable operator, thus allowing a point-of-deployment decision.
- Making the security system renewable separates all the security functions from the other functions of the navigation device and satisfies the FCC requirements for separation of security.

User Interface

The cable operator needs to be able to provide navigation and access information to services offered by the cable system. (The issues associated with the management of the user interface are discussed in the section Retail Issues in Chapter 12.) Often, access to services is as important as the services themselves. The electronic program guide (EPG) in advanced analog set-tops increased customer acceptance of the set-top and customer satisfaction with the service.

Naturally, the cable operator would like to provide the same navigation functions on an OpenCable retail device (for example, a cable ready digital television) as are provided on a leased digital set-top. There is a significant technical challenge and business challenge in doing this. The technical challenge includes porting and provisioning of the software applications that provide the user interface. The business challenge is to reach agreements with the suppliers of the OpenCable devices to allow the cable operators' applications to run.

Scaleable

The cable network capabilities are expected to migrate toward a more general availability of real-time, two-way signaling and the introduction of interactive and on-demand services. It is important that the OpenCable device continues to function in these environments. Newer models with extended requirements will be required to take advantage of extended network capabilities in most cases. Software upgrade of the OpenCable device is a goal in the longer term.

Efficient Application and Network Design

The set-top is an integral part of the larger, interdependent network created by the cable system. It is important that the OpenCable device requirements support an efficient network design. For example, it is possible to build an OpenCable device that uses dedicated resources while providing only a broadcast service, and this approach must be discouraged to prevent network resources from being wasted. In other words, not all the services have to be interactive and not all the services have to be broadcast. A balance is required. And as technology progresses, decision points will most certainly change.

Operational Compatibility

The OpenCable device must be compatible with existing operational, customer support and billing systems. In existing cable systems, a headend controller provides the bridge between the set-top and these systems (see Chapter 7, "Digital Broadcast Case Studies"). The OpenCable device is physically split into two separately managed components:

- The POD module—This module is responsible for all conditional access functions, including the authorization of service and collection of purchase records. The POD module is supplied by the cable operator and is managed by the existing headend controller.
- The OpenCable host—The OpenCable host is responsible for all other functions. Service provisioning and user interface parameters must be separately managed. (In the Pegasus system, this is achieved by a separate applications server for each application provider.)

Backward Compatibility

The OpenCable device must be backward-compatible and interoperable with existing set-top terminals. There are a number of aspects to this requirement:

- The OpenCable device must be able to support existing services using existing technologies. For example, a digital-only OpenCable device would be useless to a consumer, because many services are available only in analog form.

- The OpenCable device must not interfere in any way with the operation of existing set-tops. This is ensured at the physical level by the performance parameter specification.

Goals for the OpenCable Set-Top Terminal

The specific goals for the OpenCable set-top terminal are

- To enable new digital broadcast services and support on-demand services in the future
- To be application developer–friendly
- To support nonscrambled analog services as well as encrypted or nonencrypted digital services.
- To be sold through retail channels directly to the consumer
- To be upgradable for support of additional features by the cable operator or the customer when required via the extensions defined in the OpenCable specification process.

OpenCable Device Models

OpenCable devices can be categorized according to a number of different characteristics: whether they are leased or sold at retail, whether they support two-way communications, or whether they are integrated into a digital television or VCR. There are three main types of OpenCable devices:

- OpenCable set-top—This represents the traditional approach of using a separate set-top to provide OpenCable functions. Such a set-top could be leased to the customer by the cable operator or made available at retail.
- OpenCable ready digital television—This incorporates the OpenCable functions into a cable ready digital television or VCR. Such devices would be available only at retail.
- OpenCable ready personal computer—This incorporates the OpenCable functions into a personal computer by means of an expansion card. Such devices would be available only at retail.

In all these types, the security functions are separated into a separate security module called the point-of-deployment (POD) module. The POD module is leased by the cable operator to control conditional access functions. Please refer to Chapter 18 for specific details of the POD module and its interface to the OpenCable device.

The first OpenCable device that has been specified is the OpenCable set-top, and the next sections concentrate on the function requirements for it. The other OpenCable devices have yet to be specified, and the following sections discuss the open issues and choices to be made.

All OpenCable devices fit into two main categories: leased and retail. There are some fundamental differences in requirements between these two categories of devices that follow from the leased or retail model.

Leased

If the OpenCable device is leased, it is a pretty safe assumption that it is a digital set-top. It is unlikely that set-tops will become obsolete, because they provide some distinct advantages to the cable operator and the cable customer.

The advantages for the cable operator of a set-top are

- The digital set-top can be rigorously specified in terms of performance and operation. This includes every aspect of the digital set-top behavior, from the out-of-band signaling protocol to the user interface.
- As new services are developed, new digital set-top hardware and software is often required. The cable operator can provide the digital set-top and the service (although the set-top lease charge must be shown separately on the cable bill by law, it can be blended into the *equipment basket* to reduce the impact to early adopters).
- Less advanced set-tops, which do not support a new service offering, can be redeployed to customers who do not subscribe to the new services. This is a well-established tenet of cable operations where nothing is wasted.

For the customer, this model also has advantages:

- The cable customer does not have to be concerned about owning obsolete equipment—if he subscribes to a new service, either his existing set-top will work or it will be replaced by the cable operator.
- The customer service support can help the customer with any equipment and service issues related to the set-top hardware or the new service, because each customer has the same hardware and software configuration.

This model is being challenged because the consumer electronics manufacturers are continuously adding new features to televisions and VCRs. Sometimes these features do not work with a set-top and the customer is disappointed. In addition to analog compatibility problems that led to language in the 1992 Cable Act (see Chapter 12), there are some new compatibility issues associated with digital television that have to be addressed:

- As yet, most digital televisions have no provision for a digital connection to a set-top. The cable industry and NAB have agreed that a baseband digital interface between the set-top and the digital television is required for cable ready operation (see the FCC Roundtable on Compatibility between Digital TV and Cable). However, not all consumer equipment manufacturers are in favor of putting a baseband interface on every television set, saying it is too expensive. The OpenCable specification for a base-band digital interface is called the host digital network interface (HDNI) and is part of the OCI-C1 specification (see Chapter 17, "OCI-C1: The Consumer Interface").

- There is a requirement from the Motion Picture Association of America (MPAA) for some means of copy protection for premium content. The HDNI specification uses the digital transmission content protection (DTCP) scheme but here again, not all consumer electronics manufacturers are in full suppport of this technology.

Nevertheless, new services will likely appear first on leased digital set-tops before they migrate to a retail digital set-top or cable ready digital television.

Retail

If the OpenCable device is sold at retail, it will probably be incorporated into a digital television or a personal computer, because relatively few additional components are required to make such devices OpenCable-compliant. This can readily be seen in Figure 14-1; the additional components required for a digital television are

- A 64/256 QAM demodulator
- An out-of-band QPSK tuner and demodulator
- An interface to support the POD module
- An HDNI interface

It is expected that these components would be integrated into future television designs and that silicon integration of the functions would reduce the cost premium to the manufacturer. The additional components required to make a PC OpenCable-compliant are

- A 6 MHz cable tuner
- An NTSC demodulator
- A 64/256 QAM demodulator
- An out-of-band QPSK tuner and demodulator
- An interface to support the POD module
- An HDNI interface

Although this is slightly more than the digital television, these components could easily be placed on an expansion module and sold separately at retail.

The issues associated with providing an OpenCable-compliant DTV or PC are that only basic services are currently defined by OpenCable specifications. Services currently not standardized include

- Extended navigation—Although basic tuning functions are supported by in-band PSIP carriage and DVS-234 out-of-band service information (see Chapter 16, "OCI-N: The Network Interface"), rich guide functions offered by the cable operator on digital set-tops require more work. Two potential solutions exist: First, the cable operator could support DVS-234 profile 4 or higher for all services; second, the

OpenCable device could download and execute a guide application provided by the cable operator. In either case, because the guide information is not the property of the cable operator, some kind of business relationship needs to be established.

- Impulse pay-per-view (IPPV)—The POD module specification (see Chapter 18) defines a method for purchase of IPPV events and a mechanism for collection of purchase information using the RF return path. However, the same issues exist for navigation with regard to the user interface. In addition, the OpenCable device must include a return transmitter.
- Video-on-demand (VOD)—The OpenCable team is developing a set of signaling protocols for video-on-demand services. The POD module supports a two-way signaling channel (if the OpenCable device supports a return transmitter), but a VOD software application is required in addition to the signaling framework. Therefore, the OpenCable device must support a download and execution environment.
- Interactive services—A wide range of interactive services could be supported by an OpenCable device, but like VOD, a download, application sharing, and execution environment must be supported by the OpenCable device.

Why is it so difficult to define a standard mechanism to download and execute applications on an OpenCable device? The main issue is software portability; the retail OpenCable device must be able to download and execute applications from any cable operator, and to do this a common software environment must be defined and agreed to by all OpenCable members. Although groups such as ATVEF, W3C, and DASE are making considerable progress on portable application environments, these environments are only now becoming practical. There are considerable technical challenges to overcome:

- Applications must run on all OpenCable devices so that advanced features and functions are used if they exist, but the application still functions on less capable devices.
- There must be no possibility that a faulty application or virus could affect the basic operation of an OpenCable device.
- Portable applications typically require considerably higher levels of processor performance and more memory than embedded applications.

Nevertheless, the advantages to the customer of an integrated OpenCable device make this effort potentially invaluable:

- The customer can expect an unprecedented level of integration of functions provided by the DTV (or PC) and the services provided by the cable operator—for example, a single remote control that provides access to all features and the potential that new features, such as video-on-demand, will just show up as the cable operator invests in the necessary infrastructure.

There are also advantages for the cable operator and the consumer electronics manufacturers. However, it will take time to work out the necessary business relationships to enable this level of integration.

Set-Top Core Requirements

The core requirements for the set-top are similar to first generation set-tops being deployed by the cable industry (see Chapter 7). In addition, any features that are mandated by law or FCC regulation (for example, emergency alert system support) are part of the core requirements.

Core Services

The core services provided by the basic OpenCable set-top are

- Analog NTSC video—Because there is no support for analog de-scrambling in the basic set-top, only in-the-clear analog channels are supported.
- Digital television—In-the-clear digital television services (for example, terrestrial digital broadcast retransmission) are supported. In addition, encrypted digital television is supported by means of a POD module supplied by the cable operator. The encrypted services are limited to subscription and reservation pay-per-view services because the basic set-top does not include a reverse transmitter.

The core services provided by a basic OpenCable set-top are very limited but do provide considerably more functionality than a cable ready analog television.

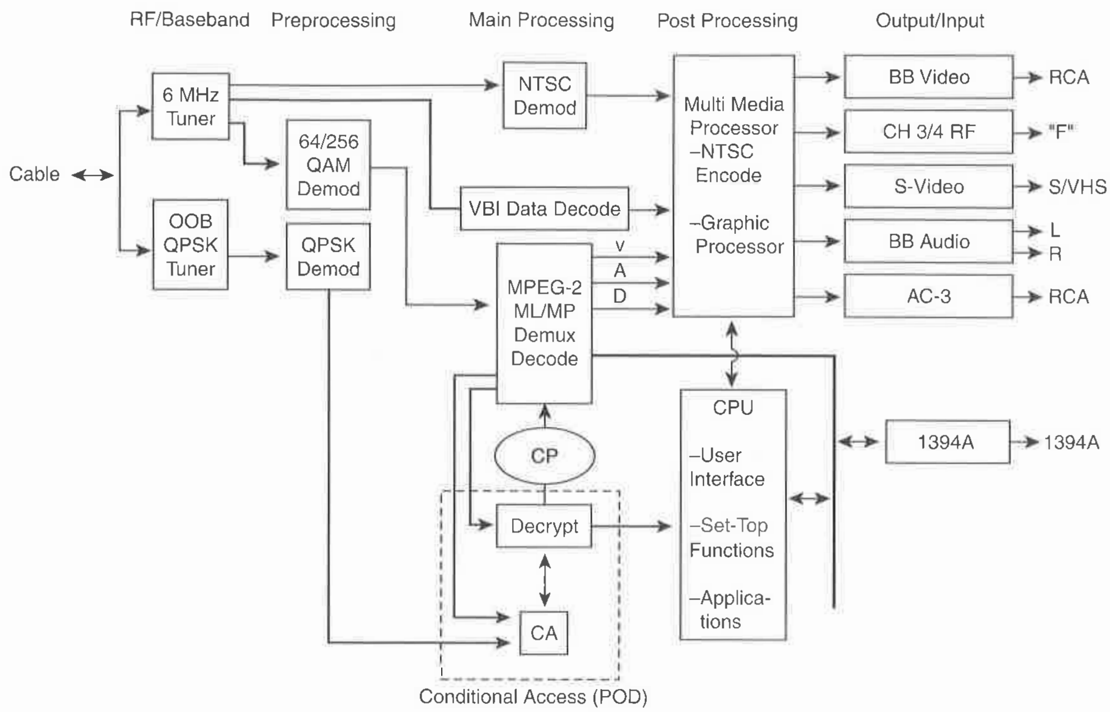
Core Functions and Features

The core functional requirements for the OpenCable set-top are illustrated by Figure 14-1. The block diagram is derived from the Pegasus set-top (see Figure 6-1 in Chapter 6) and has a single, 6 MHz tuner that is shared for analog and digital channels. The most importance difference from Pegasus is the separation of security functions into the POD module.

Figure 14-1 can be subdivided into the same major sections as Figure 6-1:

- The cable network interface (functions labeled as RF/Baseband and Preprocessing in Figure 14-1)—The interface circuitry between the cable system and the set-top includes the cable tuner, NTSC demodulator, and QAM demodulator and an OOB receiver. The interface to the cable system is a 75 ohm F-connector.
- Transport processing (labeled as Main Processing in Figure 14-1)—This function is required to break the transport multiplex into the specific streams that are required for the selected service. Transport processing is linked into the conditional access system because different services in a multiplex are typically encrypted using different session and working keys.

Figure 14-1 *The Core OpenCable Set-Top*



- Conditional access (POD)—The means by which access to specific services is granted to the user based on payment for those services. A digital decryption circuit (Decrypt), in conjunction with a secure microprocessor (CA), performs the conditional access functions for digital services. There is no provision for analog conditional access in OpenCable.
- Video and graphics processing (these functions are labeled as Main Processing and Post Processing in the Figure 14-1)—This subsystem is responsible for MPEG-2 transport de-multiplexing and decoding and on-screen display generation. In the OpenCable set-top, an additional function, copy protection (labeled CP), is required to protect the digital programming content that flows across the POD module interface.
- Audio processing (not shown in Figure 14-1)—This subystem includes a Dolby AC-3 decoder.

- Microprocessor subsystem (labeled CPU in Figure 14-1)—The microprocessor subsystem is the brains of the set-top. This subsystem typically includes a microprocessor together with ROM, Flash, NVRAM, RAM memory, LED display, and keypad.
- Outputs—All OpenCable set-tops have an F-connector output for an NTSC channel modulated at broadcast channel 3 or channel 4. In addition, the set-top has baseband (BB) video and audio, S-Video, AC-3, and IEEE 1394A outputs to allow the customer to realize higher-quality picture and sound than is possible via the channel 3/4 output.
- Remote control (not shown in Figure 14-1)—This is not specified by OpenCable.

The functional requirements for the set-top can be accurately and completely specified for hardware functions, such as tuner performance, MPEG-2 transport functions, and so on. But as the higher-layer functions of the set-top are specified, it becomes more and more difficult to agree on and accurately specify requirements. For this reason, the OpenCable set-top functional requirements are silent on higher-level functions.

The higher-level functions include the user interface and the software behavior of the set-top and are the most visible aspects of the set-top from the customer's point of view. In the case of a leased set-top, the cable operator will completely specify these aspects of the set-top, whereas in a retail set-top it is still unclear whether these will be under the control of the manufacturer or the cable operator.

The Cable Network Interface

The cable network interface (CNI) is designed to meet the OCI-N specification (see Chapter 16). In addition to the basic parameters defined by the OCI-N specification, the OpenCable functional requirements specify the performance parameters of the cable network interface.

There is a clear distinction between the OCI-N specification and the performance parameters of the set-top. This is best explained by example; the OCI-N specification specifies the channel bandwidth (6 MHz) and the frequency plan (EIA-542), but this information is not sufficient to build a set-top. The performance parameters specify the sensitivity of the tuner (its input level range), the local oscillator leakage (into the cable plant), the adjacent channel rejection ratio, and so on. Thus, for successful operation both an interface specification and the performance parameters are required.

The OpenCable set-top performance parameters specify 35 parameters for RF and Modulation Performance, which include the parameters of the cable network interface and the channel 3/4 outputs. Some of these parameters are covered by FCC Part 15 and FCC

Part 76 requirements and are legally required; for more information on FCC requirements, see Chapter 13 of *Modern Cable Television Technology; Video, Voice, and Data Communications* by Walter Ciciora and others.

Tuner

The OpenCable set-top requirements specify a single, 54 to 860 MHz tuner to support the widest frequency range to which cable systems are currently being built. Tuner performance is specified to support NTSC, 64-QAM, and 256-QAM channels over a range of input levels normally found in cable plants.

Input levels are specified for analog carriers by FCC Part 76 requirements as

- >= 3dBmV at the end of a reference 100-foot drop cable connected to any subscriber tap port
- >= 0dBmV at the input to each subscriber's television

In practice, the tuner performance must exceed these requirements for digital carriers because they are typically transmitted at 6 to 10 dBmV lower signal levels than analog carriers to reduce overall RMS power loading of the HFC plant.

QAM Demodulator

The block labeled QAM demodulator in Figure 14-1 is actually responsible for a number of related transmission functions, as specified by DVS-031:

- Adaptive equalization of the received signal to compensate for reflections introduced by the cable plant
- 64-QAM or 256-QAM demodulation according to the type of channel tuned
- Trellis code interpolation (see Chapter 4, "Digital Technologies")
- Deinterleaving (see Chapter 4)
- Forward error correction (see Chapter 4)

The output of the demodulator is a baseband digital stream at 27 or 38.8 Mbps per 6 MHz channel.

NTSC Demodulator

The NTSC Demodulator is carefully specified to provide acceptable video performance.

Out-of-Band Channel Termination

There are two alternative out-of-band channel specifications currently being used in North America:

- DVS 178, as specified by General Instrument
- DVS 167, as specified by DAVIC

(Please refer to Chapter 5, "Adding Digital Television Services to Cable Systems," for a detailed description of the out-of-band channel.)

The out-of-band channel type is one of two major differences between the two digital systems that have been deployed in North America (the other is conditional access). The General Instrument DigiCable system uses a proprietary out-of-band channel definition (which is now specified in DVS 178), and the Scientific Atlanta Digital Broadband Delivery System (DBDS) uses the DAVIC out-of-band channel definition (which is specified in DVS 167). The two out-of-band channel types are fundamentally different and cannot interoperate although they are used for very similar purposes in the two systems.

In a leased set-top, the manufacturer can simply build the set-top to one out-of-band specification or another based on the order received from the cable operator, and this is the case for currently deployed digital set-tops. However, this model clearly does not work in a retail environment:

- When a customer purchases a set-top, he must make an informed decision based on his cable system operator. Moreover, the retailer must stock double the inventory to accommodate two types of every set-top.
- If a customer moves from one type of system to another, the set-top will no longer work. In other words, the set-top is not portable.

The OpenCable solution to this problem is to make the out-of-band termination decision a point-of-deployment choice. There are a number of ways to make a point-of-deployment choice in OpenCable:

- When a cable operator leases a set-top, he has made the point-of-deployment choice for the customer.
- When the customer buys a set-top, the point-of-deployment choice is deferred until the set-top is connected to the cable system (that is, it is deployed).

In the second case, the set-top either must contain both types of out-of-band termination and dynamically adapt to the cable system, or the out-of-band circuitry can be separated into a replaceable module. The OpenCable specification allows a set-top manufacturer to make this decision based on economic considerations.The mechanisms to support replaceable out-of-band circuitry are described in Chapter 18.

Out-of-Band Receiver

The out-of-band channel can be one-way or two-way. An out-of-band receiver is required in either case, and all digital set-tops include an out-of-band tuner and QPSK demodulator.

Figure 14-1 shows that the output of the QPSK demodulator is fed to the POD module. The out-of-band front end is specified to receive at two rates—1.544 Mbps (DVS 167) and 2.048 Mbps (DVS 178)—and the appropriate type of POD module adapts the set-top to the signaling system used in the cable system.

An alternative approach is to build a dual-standard, out-of-band termination circuit into the set-top (at least one silicon vendor believes this to be feasible). In this case, the out-of-band termination interfaces directly with the CPU, and the CPU forwards conditional access messages to (and from) the POD module (please refer to Chapter 18 for more details).

Out-of-Band Transmitter

Figure 14-1 does not include an out-of-band transmitter because this is not part of the core functional requirements for the OpenCable set-top. There are a number of reasons for this omission:

- One-way plant—Many cable operators have not yet upgraded their cable systems to support two-way operation.
- DOCSIS—Some cable operators believe that the OpenCable device can share a DOCSIS channel (deployed for cable modem service). The POD module supports the use of a DOCSIS modem for two-way operation (see Chapter 18).

An out-of-band transmitter is required for two-way operation of the out-of-band channel. Two-way signaling supports impulse-pay-per-view (IPPV), video-on-demand (VOD), and interactive applications.

An out-of-band transmitter is optional for set-tops deployed in a one-way cable plant, although if an upgrade to two-way is planned it makes good economic sense to deploy a set-top with an out-of-band transmitter.

Media Access Control

The media access control (MAC) function supports the out-of-band transmitter and allows a number of set-tops to share a common return path. In the OpenCable set-top, the MAC circuit might be embedded into the POD module or implemented by the set-top.

Telephone Modem

A telephone modem provides an alternative to the out-of-band transmitter in a one-way plant. The POD module interface supports the use of a telephone modem if it exists. The telephone modem is then used off-hours for non–real-time data transfers, such as IPPV buy collections.

Conditional Access System

The conditional access system provides the means by which access to specific services is granted to the user based on payment for those services. The OpenCable digital conditional access system is contained in a POD module that connects to the OpenCable device by means of the OCI-C2 interface (see Chapter 18).

OpenCable does not provide any means for analog de-scrambling. Although a standard for replaceable analog security exists in the EIA-105 specification, it has never been implemented. Recently, the FCC has reconsidered its requirements for separable conditional access for analog-only set-top boxes in recognition of the fact that there is no retail market for this type of device.

The digital conditional access system is described in Chapter 6. This discussion will focus on the differences relating to the separation of security.

POD Module

The POD module contains all the conditional access system components within a single PCMCIA module. The input to the POD module is an encrypted MPEG-2 transport stream. The POD module performs the following operations on the transport stream:

- The POD decrypts services in the transport stream for which it is authorized.
- The POD applies copy protection to those services that have copy control information indicating there are copy restrictions.

In addition, the POD module supports a generic impulse pay-per-view API that allows the OpenCable device to purchase, cancel, and view history for pay-per-view events. For the support of IPPV, the POD requires a return channel resource.

Video and Graphics Processing

The OpenCable device provides MPEG-2 main profile at main level (MP@ML) de-multiplexing and decoding in accordance with DVS-241 and DVS-033. Support for high-level decoding (that is, high definition television) is an optional extension. However, the OpenCable device must support high definition pass-through to the IEEE 1394A output port.

Graphics processing requirements for on-screen display are not directly specified by the functional requirements, but certain minimum capabilities are required to support the DVS-194/EIA 775 output standard required at the IEEE 1394A output port (see Chapter 17 for more details).

Audio Processing

The OpenCable device provides Dolby AC-3 digital audio decoding according to ATSC A/53 Annex B.

Microprocessor Subsystem

The core OpenCable functional requirements do not specify any performance requirements for the microprocessor subsystem. Future extensions to the OpenCable specifications might set minimum performance and memory footprint parameters for a portable software execution environment.

Remote Control

The OpenCable device specification does not include any requirements for a remote control, although it is expected that a remote control would be supplied with the OpenCable device.

Extension Requirements

The extended requirements for the set-top are effectively unbounded and will be defined by OpenCable as part of the continuous improvement process. Although the extensions have not been finalized, there are a number that have been discussed:

- Two-way support by means of a QPSK transmitter or DOCSIS modem
- Impulse pay-per-view
- Multiple tuners for picture-in-picture operation
- High definition television support
- Software download, application sharing, and execution environment
- Video-on-demand
- Internal hard drive for local video record and playback functions

Performance

The OpenCable functional requirements include a table of about 120 performance parameters. These parameters are designed to ensure that the set-top meets FCC part 15 requirements and that all OpenCable set-tops provide a consistent standard of video and audio quality.

Summary

The OpenCable device can take a number of different forms: a set-top, a cable ready digital television, or a cable ready personal computer. The core requirements for an OpenCable set-top have been published in draft form by CableLabs, and it is expected that requirements for an OpenCable-compliant cable ready digital television will follow.

The functional requirements for the OpenCable device are very broad and include support for the following:

- FCC-mandated requirements for separable security, competitive availability of navigation devices, and cable compatibility
- Performance parameters to ensure acceptable network operation and audio and video quality
- Digital conditional access support by means of a replaceable POD module
- Out-of-band signaling
- High definition pass-through to a IEEE 1394A connection
- Copy protection that meets MPAA requirements for premium programming

As yet, the OpenCable device functional requirements do not specify mechanisms for download and execution of software applications. This capability is required for many advanced services in a retail environment, and until they are specified, a leased set-top will continue to bridge the gap for new services.

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Internet Resources

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http://timewarner.com/rfp

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Chapter 15

OpenCable Headend Interfaces

The OpenCable headend interfaces allow interconnection between the headend and other components of the cable system using standard interfaces. Three headend interfaces are defined in the OpenCable reference architecture:

- OCI-H1, programming content—The headend provides a central point in a cable system where programming is received, from satellite or a wide-area network (WAN), and is then converted into a standard format for transmission over the network interface (OCI-N) to the customer. The OCI-H1 interface is a family of interfaces for content provisioning. Broadcast content can arrive in analog or compressed digital formats to be streamed in real-time over OCI-N. Interactive and on-demand services make use of stored content that is usually copied from the content provider to a server in the headend. Finally, Internet services provide a real-time, two-way stream of HTML pages, Java applets, and streaming media (and many other data types) over a session between the customer and the Internet content provider.

  In all cases, content interchange standards are essential to ensure that the content can be efficiently managed and converted into the desired OCI-N format.

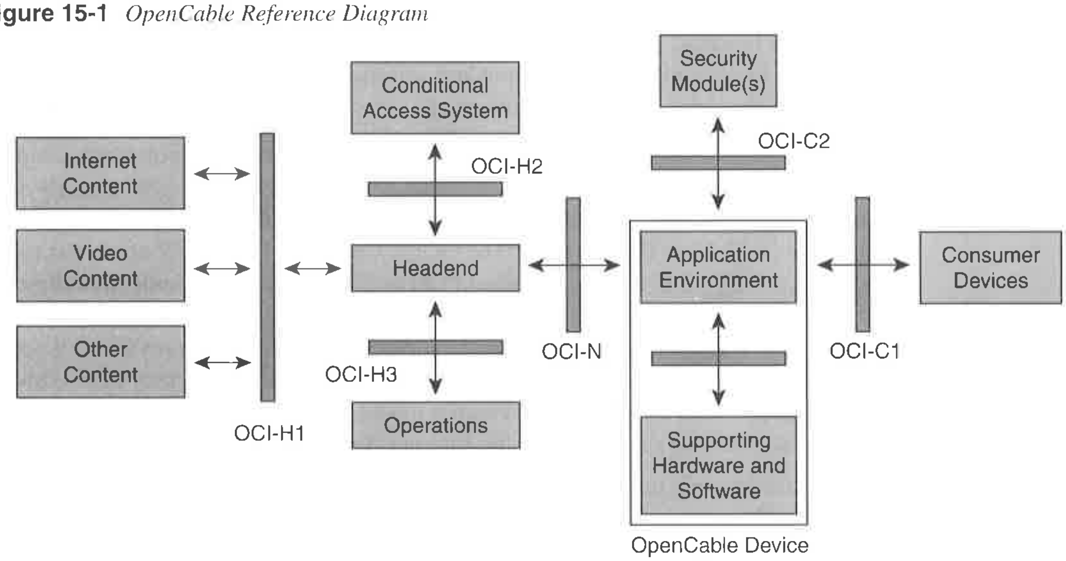
- OCI-H2, conditional access system—In nearly all headends deployed in North America, the conditional access system (CAS) is integrated into the headend equipment, forcing the cable operator to choose the same supplier for the headend and the CAS. In contrast, the European Digital Video Broadcast (DVB) model defines a separation of CAS from other headend functions, allowing one or more independent CAS vendors to connect to the headend equipment via a standard interface. The OCI-H2 interface follows a similar approach to support multiple CAS vendors.
- OCI-H3, billing and operational support—All services require an interface into the billing and operational support system. This interface must be able to support the existing billing systems and the existing operations of deployed digital cable systems. It must also be extensible so that new services can be introduced without requiring new development by the billing vendor. Standardizing the OCI-H3 interface also allows migration from one billing system to another.

OpenCable has defined only OCI-H1 at the current time. However, there is growing interest in OCI-H2 and OCI-H3.

OCI-H1

The information flow across the OCI-H1 interface in Figure 15-1 consists of *programming content*, which has three main sources. Internet content is generally received from a wide area network and, although there is a two-way exchange of information, the flow is predominantly from the content provider to the customer. Video content is a one-way flow of information and arrives from a number of content providers over satellite, terrestrial, or wide-area networks. Finally, other content represents any other kind of information that arrives at the headend, which is yet to be defined.

Figure 15-1 *OpenCable Reference Diagram*



The OCI-H1 interface is divided into three sections for the following content types:

- Internet content
- Television (video and audio) content
- Other content

In many cases, the content flows transparently through the headend to the network; in other words, its appearance is not changed by the headend even though its physical format might be changed. For example, a QPSK signal (containing MPEG-2 compressed video) received from a satellite encrypted with DigiCipher II conditional access might be transcoded (and transmodulated) into a QAM signal encrypted with PowerKEY conditional access. The customer is generally unaware of this fact when viewing the content. In the case of Internet content, the appearance of the content often depends on the software application at the OpenCable device; for example, a Web browser resizes and reformats content to fit the screen. Nevertheless, the headend acts as merely a relay point in the network established between the content provider and the customer.

In the case of on-demand services, the headend provides temporary storage of the content without changing its appearance. In the case of video-on-demand services, the entire movie title is provisioned on a server at the headend (see Chapter 10, "On-Demand Services") so that it can be streamed out to the customer when requested. In the case of Internet services, it is becoming more common to cache Web pages on a server at the headend or hub. This takes advantage of the high-speed link between the home and the distribution hub to allow the most popular content to be accessed quickly.

Goals

The goal of the OCI-H1 interface is to define a standard content format for all digital services. A standard format for content eases delivery from the content provider to the headend and enables retransmission agreements between content providers and cable operators. Standard content formats help enable rapid deployment of new services by providing a standard framework for which new services can be designed. Because the range of digital content types is much broader than in analog systems, more standardization is required.

Issues

There are many issues that must be resolved to achieve the goal of defining a standard content format for all digital services. For example:

- Audio levels—The encoding of digital content does not specify a consistent audio level. This means that on channel change from analog to digital, there can be a substantial difference in the audio level.
- Progressive refresh—The encoding of video with the MPEG-2 standard allows a great deal of flexibility at the encoder. The General Instrument encoder does not encode I-frames like most other MPEG-2 encoders, but distributes intracoded macro-blocks throughout the frames. This is easy to observe on channel change because the picture progressively builds with a tiling effect. Progressive refresh makes it more difficult to splice one MPEG program to another, a technique that is used for digital program insertion.
- Meta-data—Preencoded material, such as movies, requires considerable descriptive and promotional information to be packaged with the compressed video and audio. The format of this *meta-data* (data about data) needs to be defined for electronic interchange of on-demand assets.
- Integration of digital video and Internet content—Many interactive services (see Chapter 8," Interactive Services") blend digital video and Internet techniques to enhance the viewing experience. There is currently no standard way of integrating digital video and Internet content.

Reference Architecture

Figure 15-2 illustrates some of the interfaces required to supply programming content to a modern digital headend. Starting from the top of the diagram, the types of content available to the headend are

- NTSC analog video—Sources for analog video are satellite and off-air programming.
- Compressed digital video and audio—Sources for digital video and audio are satellite and off-air programming.
- On-demand assets—An example is compressed movies or other programming intended for delivery as an on-demand service.
- Commercial insertion assets—Commercials that have been produced and edited and are ready for commercial insertion.
- Internet assets—This includes any Web-based, streaming media or other content that can be accessed with the appropriate applications software for interactive services.
- Wide-area networking—The two-way communications resource can be viewed as a type of asset because it enables services such as email and chat.

NTSC Analog Video

For analog video, a composite IF signal (intermediate frequency 41 to 47 MHz) carrying NTSC with BTSC audio provides the standard interface between equipment in the headend.

The two main sources for analog video are satellite-delivered (C-band) feeds, local broadcast (off-air) programming and the locally generated public access, education, and government (PEG) channels. Satellite channels are transmodulated, and other channels are fed through signal processors so that they are suitable for transmission over the cable plant. (See Chapter 7 of *Modern Cable Television Technology; Video, Voice, and Data Communications* by Walter Ciciora and others.)

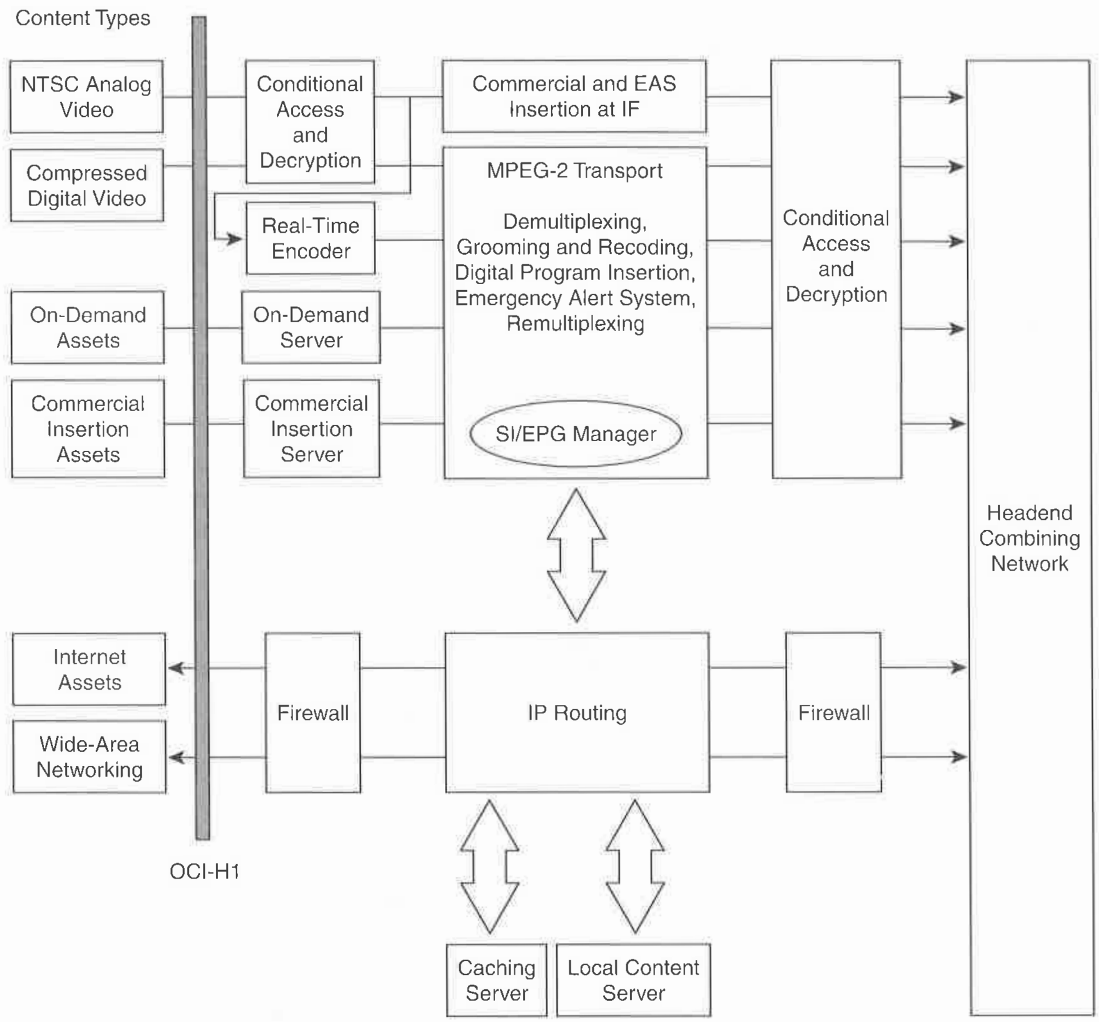
In the case of satellite feeds, which are usually scrambled, an authorized satellite receiver is required to obtain a clear signal.

The signal might be switched (at IF) before it is sent to the plant for three main reasons:

- Shared-use channels—In some cases, a cable channel is fed by one of two input sources according to the time of day.
- Commercial insertion—Many advertiser-supported channels allow the cable operator to override a national advertising slot with a locally generated ad.
- Emergency alert system (EAS) overrides—The cable operator is obliged to provide override of all channels to support the national EAS.

Finally, the signal might be scrambled before it is sent out over the cable plant.

Figure 15-2 *External Content Reference Model*



Compressed Digital Video and Audio

For digital video and audio, a number of different physical protocols can be used to support the MPEG-2 multi-program transport stream (see the section Baseband Transmission in Chapter 4, "Digital Technlogies"):

- The two main sources for compressed digital video and audio are satellite-delivered (C-band and Ku-band) feeds and local digital broadcast (off-air) programming. In both cases, the channels are demodulated to baseband digital signals for subsequent processing before they are sent to the cable plant (see Chapter 7, "Digital Broadcast Case Studies," for two case studies).
- Conditional access and decryption—This removes any encryption used to secure satellite links and provides an in-the-clear baseband digital signal.
- De-multiplexing—Each source digital channel is actually a multi-program transport stream (MPTS), which is de-multiplexed into its discrete components.
- Grooming—Individual single-program transport streams (SPTS) can be dropped by deleting the packets used to carry them. (In practice, this is often done by replacing the packets with null packets, which are discarded in the re-multiplexing process.) PID remapping is often required as part of grooming to avoid PID conflicts when SPTSs from different source MPTSs are re-multiplexed together.
- Reencoding—The bit rate of individual MPEG-2 elementary streams can be modified by reencoding the stream in real-time. This technique allows a tradeoff of quality versus bit rate (see *Rate-remultiplexing: An Optimimum Bandwidth Utilization Technology* by Richard S. Prodan and others).
- Digital program insertion (DPI)—Many advertiser-supported channels allow the cable operator to override a national advertising slot with a locally generated ad. Unlike the analog case, which is a relatively simple switch, sophisticated DPI techniques are required to replace the video and audio components so that the MPEG-2 decoder in the set-top continues to function normally (see SMPTE 312M).
- Re-multiplexing—Finally, the various inputs are combined into 27 or 38.8 Mbps channels suitable for modulation into a 6 MHz QAM channel.
- Conditional access and encryption—Conditional access (CA) provides selective access to the content and supports the premium channel subscriber business model. CA uses encryption of the digital channels to secure them over the cable system.
- In addition to the process steps required to produce the digital channels themselves, it is necessary to describe the channel lineups to support tuning and navigation. The service information/electronic program guide (SI/EPG) manager is responsible for generating and inserting information to support the navigation application.

This process can be used to combine compressed digital feeds, the output from real-time encoders, and the output from on-demand servers. However, in some architectures the on-demand server outputs are handled separately (see Chapter 11, "On-Demand Cable System Case Studies").

On-Demand Assets

On-demand assets include compressed movies or other programming intended for delivery as an on-demand service. The audio/video component of the asset is quite straightforward and could be specified as a compressed digital video source. However, there are many other related pieces of information associated with the movie or program, which is collectively known as the meta-data:

- Video meta-data includes duration, aspect ratio, MPEG-2 profile and level, data rate, closed captioning, and so on.
- Audio meta-data includes duration, language(s), data rate, number of audio channels, and so on.

The meta-data must also contain a complete description of supporting material, such as

- MPAA rating (G, PG, R, NC-17, NR) or television rating (TV-Y, Y7, 14, MA)
- Window of availability—the start and end dates when the program might be shown
- Title
- Credits (actors, director, producer, music, and so on)
- Plot summary

All the information about an on-demand asset must be organized as a self-describing data structure so that the entire asset can be provisioned at the on-demand server by means of a file copy (see Pegasus Functional Requirements for Video-On-Demand (VOD) Systems V2.0).

Commercial Insertion Assets

Commercial Insertion is an automated process that allows overriding of the national advertising in special time slots (called *ad. avails*). However, the asset distribution is currently a manual process that usually involves sending videotapes from the content provider to the headend.

However, as targeted advertising and narrow-casting becomes more common and as assets are distributed in digital (rather than analog) form, the same techniques described for on-demand assets will be applied to commercial insertion assets. The meta-data will require some new fields:

- Insertion schedule—a list of times, channels and duration when the asset is to be inserted
- Demographics—a description of the targeted audience for the commercial

In addition, a cue message is used in addition to the schedule control to trigger the insertion of a particular commercial (see the DPI Ad Hoc Working Group, Preliminary V8.5).

Internet Assets

The Internet provides both a source of programming content and a communications resource. The content is structured around the World Wide Web (WWW) framework, which is created by an open, extensible set of de facto protocols, specified by the Internet Engineering Task Force (IETF) through the Request for Comment (RFC) process:

- Internet Protocol (IP)
- Transmission Control Protocol (TCP)
- Hypertext Transmission Protocol (HTTP)
- Hypertext Markup Language (HTML)

Many WWW extensions rely on the download of applications to enable local execution at the client. These include such applications as QuickTime, Shockwave, Macromedia Director, RealMedia and Pointcast, which are application-specific. Internet applications often use software-based video and audio decoders designed for low bit rates because of the bandwidth limitations of the Internet. In addition, the Java virtual machine (JVM) allows arbitrary, portable applications (called *applets*) to be downloaded to the client and executed within the JVM.

At the headend, the Internet content must pass through a firewall before streaming to the network or being provisioned or cached onto headend servers. The firewall provides protection from hackers who might otherwise be able to access and corrupt the headend servers.

There is a second firewall between the cable access network and the headend computer resources, which provides protection from hackers and also restricts access to services according to customer profile; this is the online equivalent to conditional access of television channels.

Wide-Area Networking

The Internet is an example of a wide-area network (WAN) that provides both a source of programming content and a communications resource. The wide-area communications are provided, at the physical layer, by a variety of interfaces, from T1 and T3 carriers through to SONET facilities at OC-3, OC-12, and OC-48 rates. The facilities may support frame relay, asynchronous transfer mode (ATM) or packet over SONET (PoS).

Content Convergence

Figure 15-2 shows a double-ended arrow between the MPEG-2 Transport and IP Routing functions; this indicates that the migration to digital television allows content exchange, or convergence, between digital television and personal computer users. This convergence is enabled by

- The ability to adapt IP-based content into MPEG-2 transport streams for delivery to the OpenCable device
- The ability to stream video and audio assets to personal computers using IP-based streaming media protocols (for example, RealMedia)

Although the transport protocols exist to support content convergence, many advanced content representations require extensions to the set-top or PC. In the PC world, extensions are incorporated in the browser or downloaded and installed as plug-ins, or applications, by the user. The set-top environment is more constrained by ease-of-use and memory space considerations. To provide content convergence, a standard software environment for the download and execution of applications is required.

Development Status

The OCI-H1 interface is at first-draft level. The current document summarizes the current standards that exist for content interchange. At the time of writing, there is still considerable work needed to define the interfaces to support more sophisticated types of content, such as interactive and on-demand content.

OCI-H2

The OCI-H2 interface provides separation of the conditional access function from the rest of the headend functions. This interface is the headend equivalent of the OCI-C2 interface at the OpenCable device. In both cases, the security function must remain as secure as possible and relies on shared secrets in the headend conditional access system (CAS) and the point-of-deployment (POD) security module. The definition of the OCI-H2 and OCI-C2 interfaces must provide for a number of contingencies:

- CAS upgrade—The conditional access system might require periodic upgrade either to combat signal theft or to add new features.
- CAS replacement—The complete replacement of the conditional access system might be required under certain circumstances.

Goals

The goal of the OCI-H2 interface is to define a standard interface that supports the separation of conditional access functions from service delivery functions. By separating conditional access, the OCI-H2 interface provides the option of supporting multiple conditional access systems with a single cable system. This mode is called *simulcrypt* operation.

Issues

There are a number of issues that must be resolved to achieve the goal of separation of conditional access functions:

- Separation in currently deployed systems—In existing practice, the conditional access is tightly coupled into the other headend functions.
- Definition and agreement of interfaces—Work has not yet started on the OCI-H2 interface definition.
- Separation of conditional access from programming and features—This task has not yet started.

Reference Architecture

Figure 15-3 illustrates an approach to separation of the conditional access functions based on the European DVB simulcrypt model (see ETSI TS 101 197—DVB Simulcrypt Specification Part 1). The main difference is the delivery of entitlement management messages (EMMs), which are sent to the OpenCable device via an out-of-band channel (rather than in-band as described by DVB).

Figure 15-3 *DVB Simulcrypt Model*

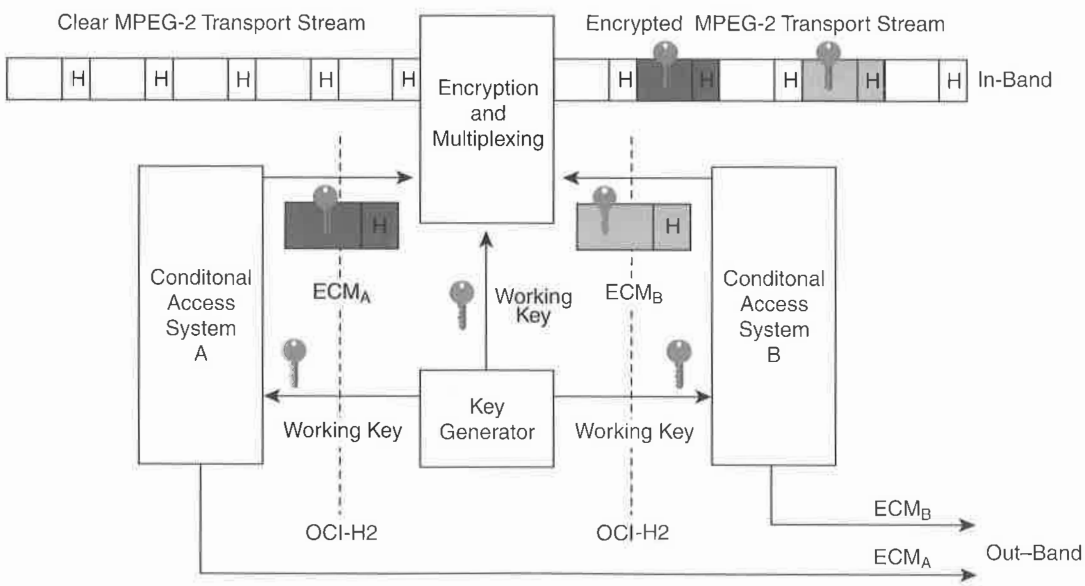


Figure 15-3 shows an example of simulcrypt operation, in which two conditional access systems can be used simultaneously. In this arrangement, the MPEG-2 multi-program transport stream is encrypted and sent once to all OpenCable devices using an agreed common encryption algorithm. In Europe, the DVB consortium licenses the common scrambling algorithm (CSA) for this purpose. In North America, General Instrument and Scientific Atlanta have cross-licensed the Harmony encryption algorithm to allow *key sharing* (simulcrypt) operation.

The system works by sharing a single key generator—a source of random *working keys* that are used to encrypt the MPEG-2 transport stream (in practice, different working keys are used to encrypt each service). The working key is also sent to the conditional access system(s). The job of the conditional access system is to authorize each customer for those services for which he has paid. This is done by sending an encrypted working key in an in-band entitlement control message (ECM). The ECMs are sent in-band so that they can be changed frequently to increase security and so that they can quickly be acquired on channel change.

In Figure 15-3, each conditional access system sends its own ECM stream to an MPEG-2 multiplexer for insertion periodically (usually about 10 times per second) in the multi-program transport stream. The conditional access system also sends entitlement management messages (EMM) to the OpenCable device via the out-of-band channel. The EMM contains the key that the OpenCable device uses to decrypt the ECMs and provide access to a service. The EMMs are addressed to individual OpenCable devices, and CAS_A sends EMMs to OpenCable devices with only CAS_A security in them. Likewise, CAS_B sends EMMs to OpenCable devices with only CAS_B security in them.

Development Status

At the time of writing, the OCI-H2 interface is undefined by OpenCable. There is considerable work to define all the interfaces to make separation of conditional access functions a reality.

The Open Conditional Access group (OpenCAS) is a collection of companies working together to define open interfaces to conditional access components for U.S. cable headends and U.S. broadcast installations.

The OpenCAS charter is

"Define interfaces between Head-End (HE) equipment and Conditional Access (CA) equipment. Interface should allow for systems to be interoperable, separable and replaceable. Provisions should be made for CA data to be delivered via in-band and out-of-band channels. The defined system and interfaces must be considered for compatibility with over-the-air (satellite and terrestrial) systems and achieve consumer friendliness. The group will deliver finished document(s) to ANSI-sanctioned standards bodies (SMPTE & SCTE) for due-process standardization. In keeping with the ANSI standardization model, participation in the group is open to all parties interested in fulfilling this charter. The group does not intend to specify interfaces to billing systems or specify a scrambling algorithm."

For more information on OpenCAS, see the OpenCAS Web site (http:/www.opencas.com).

OCI-H3

The OCI-H3 interface provides operational and control flows between the headend components and the other systems that are required to operate the cable system, including billing systems, subscriber management systems, operational support systems, network management systems, and so on. These systems might be located in the headend, at a nearby business office, or might be remote from the cable system. In any case, the interface requirements are similar, and include

- Subscriber management—This interface allows the selective enabling of service to each subscriber. It provides the interface between the subscriber management system and the conditional access system.
- Event provisioning—This interface allows the definition of pay-per-view events (which have a specific start and end time) and on-demand events (which have flexible start and end times). This interface is between the event scheduling system and the conditional access system.
- Purchase collection—This interface allows purchase reports to be sent to the billing system. Purchase reports are collected by the conditional access system.
- Network management—This interface provides the network management view into the headend, hub, and customer premises components of the cable system. This interface is designed to support an external network management system.

Goals

The goal of the OCI-H3 interface is to define a standard interface that supports all the operational functions for the cable system. This interface should be able to support the existing billing systems and the existing operations of deployed digital cable systems. Standardizing the OCI-H3 interface provides ease of migration from one billing system to another. The OCI-H3 interface must also be extensible to allow new service definitions to be added over time.

Issues

There are a number of issues that must be resolved to achieve the goal of standard operational interfaces:

- Support of legacy deployments—In existing practice, most operational interfaces are pair-wise proprietary agreements between headend system suppliers and billing system suppliers. This causes a proliferation of interfaces and limits flexibility.
- Definition and agreement of interfaces—There is much work to do to define a standard interface definition for OCI-H3.

- Support of new billing models (for example, VOD and e-commerce)—the current operational interface for billing recognizes only subscription and pay-per-view events. The operational interface must be flexible enough to support new types of service that have different billing models.

Development Status

At the time of writing, the OCI-H3 interface is undefined by OpenCable. There is considerable work to make a standard operations interface a reality. However, an initiative by Time Warner Cable and Scientific Atlanta has defined a standard Billing and Operational Support System (BOSS) interface, which is supported by all of Time Warner Cable's billing system vendors.

Summary

This chapter summarized the current issues and development of the OpenCable headend interfaces. Three headend interfaces were defined:

- OCI-H1, programming content—The goal of the OCI-H1 interface is to define a standard content format for all digital services. A standard format for content eases delivery from the content provider to the headend and enables retransmission agreements between content providers and cable operators.
- OCI-H2, conditional access—The OCI-H2 interface provides separation of the conditional access function from the rest of the headend functions. This interface is the headend equivalent of the OCI-C2 interface. The OpenCAS group is actively working on these interfaces at the time of writing.
- OCI-H3, billing and operational support—The goal of the OCI-H3 interface is to define a standard interface that supports all the operational functions for the cable system. This interface must support the existing billing systems and the existing operations of deployed digital cable systems. Scientific Atlanta's BOSS interface is becoming the *de facto* standard for billing system interfacing.

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http://timewarner.com/rfp

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http://www.opencas.com

European Telecommunications Standards Institute (ETSI) Web site

http://www.etsi.org

CHAPTER 16

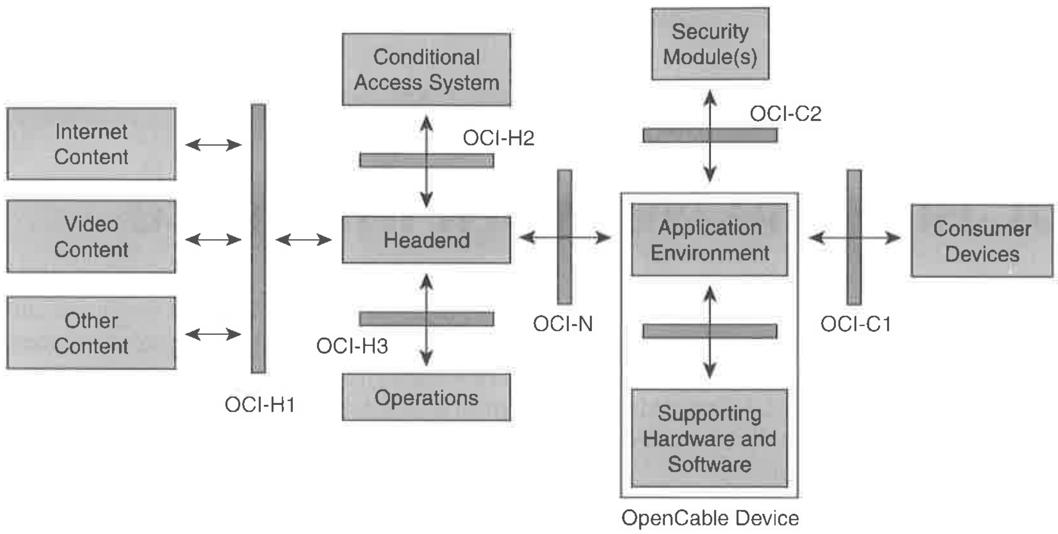
OCI-N: The Network Interface

The OpenCable Network Interface (OCI-N) is the most important of all the OpenCable interfaces because it supports plug-and-play of set-tops, cable ready digital televisions, or other devices to the OpenCable network (see Figure 16-1). Standardizing the OCI-N interface allows different kinds of equipment to attach to the network, supporting a family of *OpenCable devices*, where each family member can be built by a different vendor to a set of open standards.

This chapter describes the OCI-N interface as follows:

- Scope—The scope of OCI-N includes all analog and digital channels used for television services.
- Issues—The OCI-N specification raises many issues related to performance and protocols. Performance specifications must be agreed to by all devices connecting to the cable network. Protocol specifications must be agreed to for all network interface functions.
- Frequency-domain view—The OCI-N interface is a broadband interface that allows many channels to coexist within the passband of the HFC network.
- Channel types—The OCI-N interface defines several channel types: in-band channels that carry an analog NTSC channel or a 64-QAM or 256-QAM channel and forward and reverse out-of-band channels that are used to provide a two-way data communications link between the headend and the OpenCable device.
- Protocol layering—Each of the different channel types is described using a layered protocol model. The protocol layers for in-band channels follow a single standard. In contrast, three alternatives exist for out-of-band channels: DVS-167 (DAVIC OOB V1.2), DVS-178, and DOCSIS V1.0.

Figure 16-1 *OpenCable Reference Diagram*



Scope of OCI-N

The OCI-N defines all the digital channels (in-band and out-of-band) and in-the-clear analog NTSC channels. OCI-N defines all aspects of the network interface that are common to cable systems and that are based on open standards. The conditional access system protocols are not fully defined by the OCI-N interface, but this is acceptable because they are terminated by the point-of-deployment (POD) module.

Issues

The network interface to a cable system is evolving from a variety of proprietary protocols toward a more standards-based approach. There are still many issues associated with the definition of the OCI-N interface that are at various stages of resolution:

- Performance parameters—In an HFC broadband network, the performance of each terminal device that attaches to the network affects the performance of the shared-media network. Thus, one terminal device can adversely effect the service to many customers. Consumer electronics (CE) manufacturers and cable operators will probably continue to disagree about the stringency of performance parameters; the CE manufacturers are focused on cost and the cable operators are more concerned about performance. An example of this can be found in the EIA-23 standard (see EIA-23 RF Interface Specification for Television Receiving Devices and Cable Television Systems), which contains two different values for the signals between 30 and 54 MHz because no agreement could be reached after years of negotiations. The CE and cable proposals from Annex A of EIA 23 are shown in Table 16-1. As you can see, the cable-proposed levels are higher, which makes the tuner design more difficult and costly. The reason is to reject spurious signals generated by return transmitters in set-tops and cable modems.

Table 16-1 *Maximum RMS Value for 30–54 MHz Individual Signals*

Frequency Range	CE Proposal	Cable Proposal
30–41 MHz	+24 dBmV	+35 dBmV
41–48 MHz	0 dBmV	0 dBmV
48–54 MHz	–10 dBmV	–10 dB relative to channel 2 visual carrier or + 10 dBmV

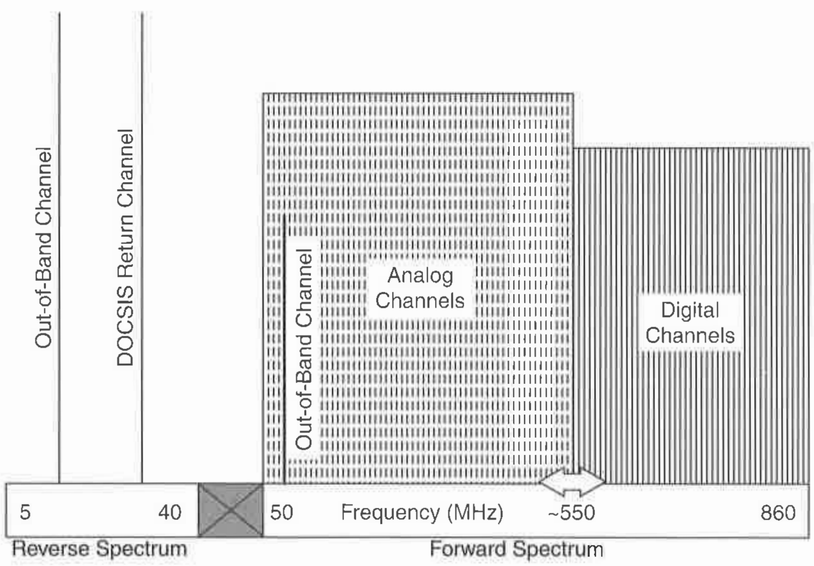
- Service information (SI)—There has been considerable discussion regarding the SI standard for OCI-N. The existing practice is based on ATSC standard A/56 and is part of the Harmony agreement. The standard for terrestrial broadcast was changed and extended as A/65 after the cable industry had adopted A/56. As a result, there are now two competing standards for service information.
- Program guide information—As each cable vendor developed electronic program guides (EPG), they created or licensed one of several different proprietary guide formats. The guide information itself is purchased by the cable operator and sold as part of a package that includes the set-top, which decodes and displays the EPG. Thus, an OpenCable device would have to support multiple guide formats to be truly portable across multiple cable systems.
- Emergency alert system (EAS)—All cable operators with more than 10,000 subscribers are required to support EAS override for all channels (analog and digital) as of January 1, 1999. Video override of compressed digital channels is technically more complex because of the transport multiplexing layer. Moreover, a digital set-top might be *tuned* to a Web page or an e-mail session, so the concept of video override does not always make sense.
- Network management—Digital set-tops provide network management features, such as reporting signal levels and error rates. However, set-tops might use proprietary protocols and have varying network management capabilities.
- On-demand services—On-demand services have special signaling requirements, as described in Chapter 10, "On-Demand Services," to create on-demand sessions and to provide stream control. Although the Digital Storage Management—Command and Control (DSM-CC) standard (ISO-IEC 13818-6) provides a framework that is widely adopted for on-demand service, there are many variations from one implementation to another.

- Interactive Services—No standards have yet been agreed on for the description of interactive services that do not conform to traditional broadcast content–oriented services. A proposal for an application service protocol (DVS-181) to advertise all services, such as broadcast, e-mail, Web browsing, e-commerce, and games, has been submitted to the SCTE Digital Video Standards subcommittee but there has been little progress toward adoption of this as a standard.

The Frequency-Domain View

Figure 16-2 shows the frequency-domain view of a typical upgraded cable system, which is capable of supporting up to 135 6-MHz channels in the forward path (providing a maximum information rate of more than 5 Gbps!). The forward spectrum is divided between analog channels and digital channels, the latter usually occupying the higher frequencies above 550 MHz. The boundary between analog and digital channels is flexible and, over time, analog channels will be retired and replaced with digital channels. The digital channels can be transmitted at a lower signal level (about 6 to 10 dB lower) to reduce overall loading on the HFC system.

Figure 16-2 *OCI-N at the F-Connector*



The frequencies of the forward channels are defined by the Cable Television Channel Identification Plan (EIA-542). (See Chapter 8 of *Modern Cable Television Technology; Video, Voice, and Data Communications*, by Ciciora and others.)

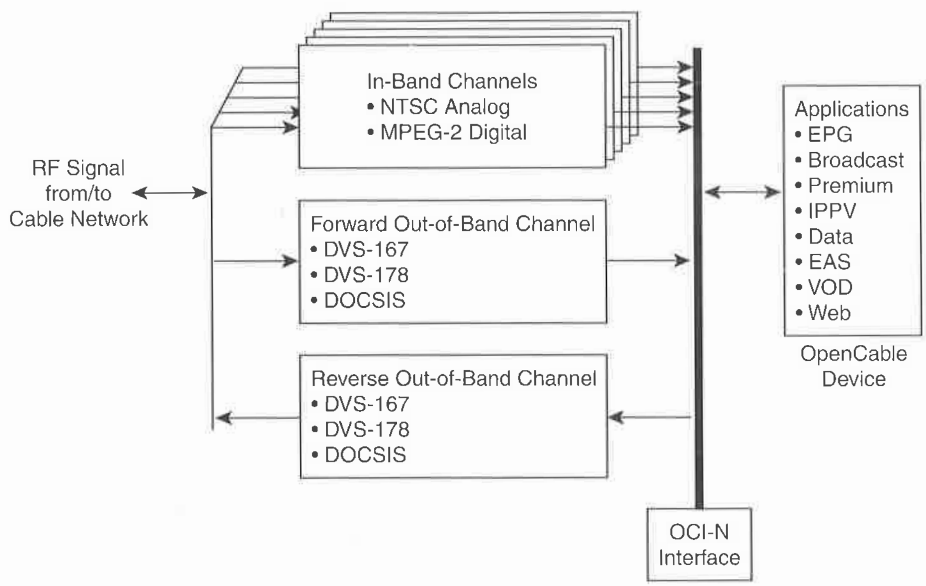
Some cable systems support two-way operation by providing a return path from the home to the cable network. A passband of 5 to 42 MHz is typical although there are variations between different systems. The return spectrum is used predominantly for digitally modulated carriers generated by set-tops, cable modems, and cable telephony equipment. As illustrated in Figure 16-1, considerable amplitude is required to send these signals back through the cable system, due to attenuation at the tap by as much as 29 dB.

There are, as yet, no standards for frequency allocation in the return spectrum, and cable operators are specifying agile transmitters in new equipment so that the return spectrum can be used efficiently.

Channel Types

The broadband cable system allows the luxury of defining a number of different channel types that are used for different purposes (see Figure 16-3).

Figure 16-3 *OCI-N Channel Types*



As shown in Figure 16-3, there are three main types of channels:

- In-band channels—These are further subdivided into analog and digital subtypes. These channels are 6 MHz in bandwidth in North America and Japan (or 8 MHz in Europe), and are called in-band channels because usually only one channel is tuned at any given time.

- Forward out-of-band (OOB) channel—The forward and reverse OOB channels work together to provide a two-way data communications link across the OCI-N interface. These channels are called out-of-band channels because they are always tuned by the OpenCable device, providing *always-connected* properties similar to a local area network.
- Reverse out-of-band (OOB) channel—The reverse OOB channel works in conjunction with the forward OOB channel. The reverse OOB channel is optional according to the requirements of the cable operator, but it provides the resource for many advanced services, including impulse PPV, on-demand, and interactive services (see Part II, "Interactive and On-Demand Services").

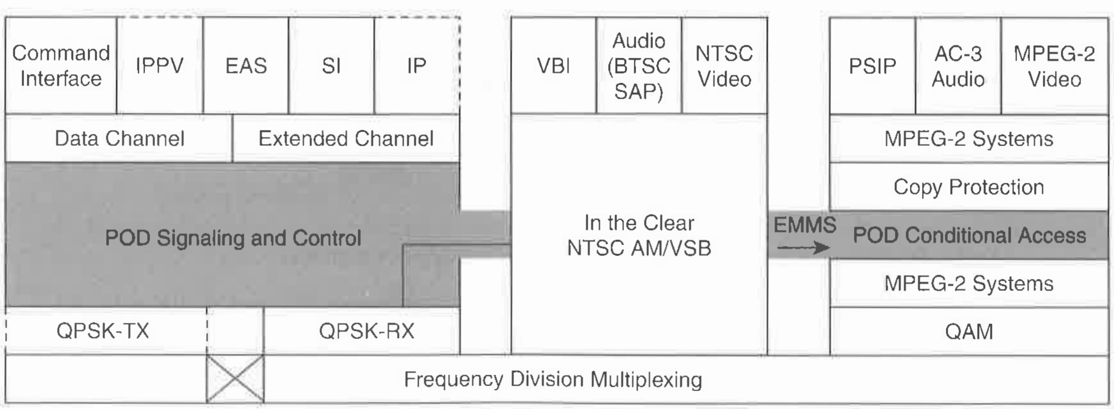
As shown in Figure 16-3, there are three choices for the out-of-band channel pair:

- DVS-167—A narrow-band QPSK-based format developed by DAVIC and used by the Pegasus system. (See Chapter 5, "Adding Digital Television Services to Cable Systems.")
- DVS-178—A narrow-band QPSK-based format developed by GI and used in the DigiCable system. (See Chapter 5.)
- DOCSIS—A 6 MHz QAM-based forward channel is combined with a narrow-band QPSK or QAM-16 return channel. DOCSIS provides considerably more bandwidth than DVS-167 or DVS-178 and is supported by higher-end set-tops, such as the GI DCT-5000 and SA Explorer 6000.

OCI-N Protocol Layering

Figure 16-4 illustrates the OCI-N from both a frequency-domain and protocol-layered perspective. At the base of the diagram is the frequency-division multiplexing layer that supports a large number of channels, which may be of different types.

Figure 16-4 *OCI-N Protocol Layers*



The left side of Figure 16-4 illustrates the protocol stack for the DVS-167/DVS-178 out-of-band channels. The modulation layer (QPSK) is used to adapt the baseband signal to the analog network (see Chapter 4, "Digital Technologies," for QPSK operation). Above the QPSK layer, the data-link and network layer protocols for the DVS-167/DVS-178 out-of-band channel are implemented in the point-of-deployment (POD) module because multiple standards exist (see Chapter 18, "OCI-C2: The Security Interface"). The POD effectively hides this complexity from the OpenCable device (or host) to allow a manufacturer to build a single type of OpenCable device for all of North America. The POD module and its interface (OCI-C2) is described in detail in Chapter 18. At the upper boundary of the POD, two control and signaling channels are presented to the OpenCable device; the data channel and the extended channel.

The data channel provides communications to the POD module for initialization and configuration via a set of defined commands that are carried across the command interface. The data channel also supports a generic impulse pay-per-view (IPPV) interface to allow the OpenCable device to communicate with the conditional access function in the POD module.

The extended channel provides for communications to the headend via the out-of-band channel. The signaling flows include emergency alert system (EAS) messages, service information (SI), and, optionally, Internet Protocol–based communications for applications support.

The center of Figure 16-4 illustrates the protocol stack for NTSC analog channels. The OCI-N interface does not include any definition of scrambled analog channels because the POD module does not support analog de-scrambling. NTSC video channels employ amplitude modulation vestigial sideband (AM-VSB). The video vertical blanking interval (VBI) is used to carry a limited amount of data. Audio is carried by means of a separate subcarrier. (See Chapter 2 of *Modern Cable Television Techology; Video, Voice, and Data Communications,* by Ciciora and others.)

The right side of Figure 16-4 illustrates the protocol stack for digital channels. All in-band digital channels use QAM modulation to impose a digital bit stream onto a 6 MHz RF carrier. Above the QAM layer is the MPEG-2 systems layer, which is used to transfer encrypted digital data to the POD module. The POD module is responsible for providing the conditional access function for digital signals, which varies from one cable system to another. The entitlement management messages (EMMs) are delivered via the out-of-band channel to provide the POD module with the necessary authorization for premium services (see Chapter 18). Above the conditional access layer is a copy protection layer, which is required to protect the digital data as it flows across the OCI-C2 interface. The MPEG-2 systems layer multiplexes compressed audio and video content into a single multi-program transport stream (see Chapter 4). In addition, in-band program and system information protocol (PSIP) might be carried to describe the contents of the multi-program transport stream.

The optional DOCSIS channel is not shown in Figure 16-4 and will be described separately in the DOCSIS section.

This overview provides a summary of the various protocol layers for each channel type. The following sections describe the standards associated with each layer and channel type.

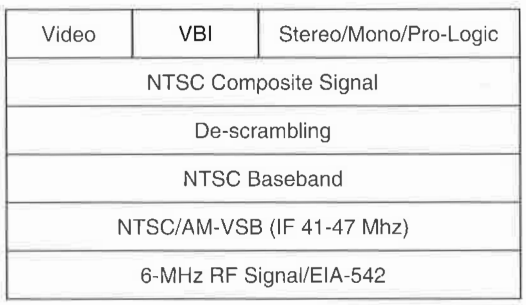
In-Band Channels

In-band channels can be divided according to modulation into analog and digital channels, which are described in the following sections.

Analog

Figure 16-5 illustrates the protocol layers for the analog channels. At the base is the frequency-division multiplexing layer, which is channelized according to the EIA-542 tuning plan into 6 MHz channels.

Figure 16-5 *Analog Protocol Stack*



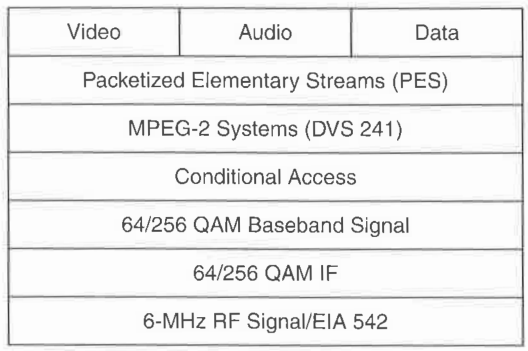
After tuning, an intermediate frequency (IF) signal with a center frequency of 44 MHz is standard. The NTSC baseband signal might be scrambled according to a number of different techniques to prevent signal theft. After demodulation and de-scrambling, an NTSC composite signal is recovered, which includes luminance information at baseband combined with modulated chrominance and audio carriers as defined by SMPTE-170M. The composite signal can be further processed to output other video/audio formats, such as S-Video stereo, mono, and pro-logic audio. VBI data is sent in the NTSC vertical blanking interval (VBI) lines and is then processed by the OpenCable device or television receiver in compliance with FCC 47 CFR part 15.119.

The analog channels deliver broadcast, subscription, and impulse pay-per-view services. The analog channels might be in the clear or scrambled, but the de-scrambling algorithms are closely guarded and proprietary to each cable vendor. The decoder-interface standard EIA 105 was designed to provide a replaceable analog security device but was not implemented by consumer electronics or cable operators. The OCI-N interface defines only in-the-clear analog services.

Digital

The in-band digital channels provide video, audio, and data services. Figure 16-6 shows the protocol stack for digital channels. At the base is the frequency-division multiplexing layer, which is channelized according to the EIA-542 tuning plan into 6 MHz channels. After tuning, the QAM intermediate frequency is recovered and demodulated to a baseband signal that is an MPEG-2 multi-program transport stream as defined by DVS-241.

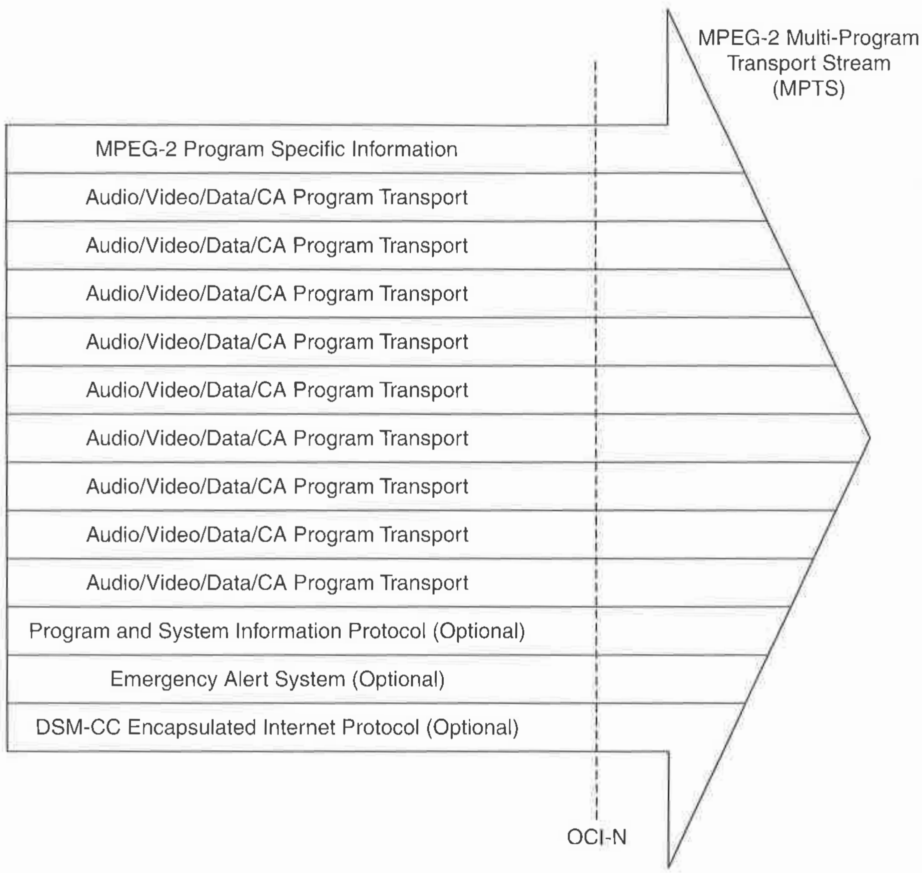
Figure 16-6 *Digital Protocol Stack*



As with analog channels, the digital video channels are secured by conditional access technology that remains the closely guarded and proprietary property of each cable vendor. Unlike analog, a separable security module (the POD module, see Chapter 18) has been adopted by the cable industry. The OCI-C2 interface specifies the interface to the POD module.

Digital channels make extensive use of the MPEG-2 systems layer for multiplexing, as shown in Figure 16-7.

Figure 16-7 *In-Band Digital Channels*



The MPEG-2 systems layer multiplexes a number of different types of information. Figure 16-7 illustrates the different stream types that might be incorporated into a digital video channel:

- MPEG-2 program specific information (PSI)—The role of the PSI tables is to describe the rest of the transport stream (see Chapter 4).
- Audio, video, data, and CA packetized elementary streams (PES)—Each MPEG-2 program consists of several packet identifiers (PIDs) for audio, video, data, and conditional access ECMs. As illustrated, these program transports account for the majority of the bandwidth of the multiplex.

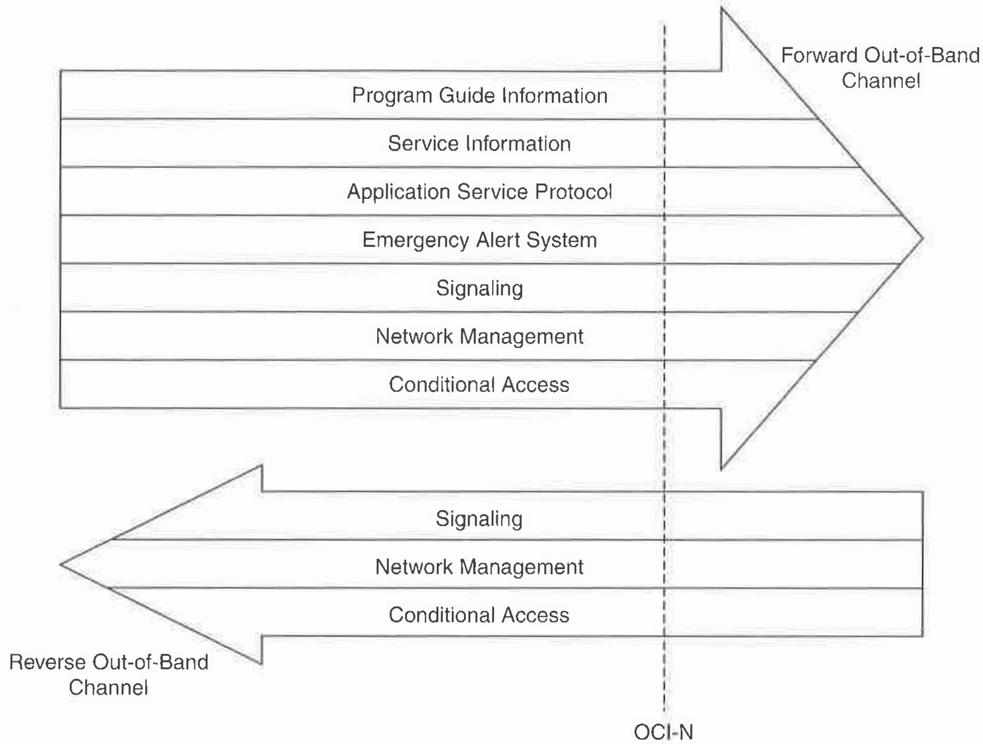
- Program and system information protocol (PSIP)—The PSIP standard (ATSC A/65) might be used to describe the audio and video services within the transport stream. This standard is used for terrestrial broadcast, so a retransmission over cable will include a PSIP description (unless the cable operator explicitly removes it). However, cable-originated channels do not typically include any PSIP description because the out-of-band channel carries equivalent information for all in-band channels.
- Emergency alert system (EAS)—The CEMA/NCTA Joint Engineering Committee has developed a standard for the transmission of EAS messages in the form of MPEG private table sections (DVS-208, EIA 814). This standard allows emergency alert messages to be sent to the OpenCable device to communicate EAS events in a standard format. In-band EAS messages are optional on encrypted in-band channels because the cable operator has the option of sending them on the out-of-band channel (the logic is that to decrypt the channel, the receiver must have an out-of-band receiver). However, in-band EAS messages are mandatory on in-the-clear in-band channels because of the possibility that a cable ready receiver without an out-of-band receiver can tune these channels.
- Internet Protocol(IP)—IP messages can be encapsulated into MPEG-2 private data sections according to the DSM-CC standard (see DSM-CC, Digital Storage Media—Command and Control). IP messages can be used to carry data to support interactive applications, such as Web browsing, which might require more bandwidth than can be supported by the narrow out-of-band channel.

The DSM-CC data carousel provides a standard mechanism for continuously transmitting any type of information over a channel. In practice, a data carousel is typically used to transmit PSIP and EAS messages on in-band digital channels.

Out-of-Band Channels

The forward and reverse out-of-band channels are designed to provide a two-way connectionless signaling path between the OpenCable device and the headend. Figure 16-8 shows the logical message flows supported by the out-of-band channel.

Figure 16-8 *Out-of-Band Channels*



There is considerable controversy about the need for a reverse out-of-band channel, which is required for interactive and on-demand services but not for broadcast services. As a result, the return transmitter is currently defined only in the OpenCable device functional requirements for bidirectional cable systems (see Chapter 14, "OpenCable Device Functional Requirements"). The following sections separate one-way and two-way flows for clarity.

One-Way Flows

It is important to understand one-way operation of the out-of-band channel because this mode of operation can occur for a number of reasons:

- The OpenCable device does not include a reverse transmitter.
- The cable system has not been upgraded to support two-way operation.

- There is a failure in the reverse path due to excessive ingress, attenuation, or a return amplifier failure.

In any of these cases, it is a requirement that the cable system gracefully degrades into one-way operation and continues to support broadcast services. The one-way flows are

- Program guide information—This is continuously broadcast for all channels supported by the cable system. The format is proprietary and often tied to the EPG application in the set-top.
- Service information—This is continuously broadcast for all channels supported by the cable system. The format is specified by DVS-234, which is based on A/56. However, in response to requests from the CE industry, DVS-234 has added several features from PSIP as optional profiles to include support for parental control and a standard program guide data representation.
- Application service protocol—This is continuously broadcast to advertise interactive services available to the OpenCable device. The proposed format is contained in DVS-181, but little progress has been made to adopt it as a standard to date.
- Emergency alert system—During an alert, messages are sent that contain information about the alert condition. The OpenCable device is required to display the alert condition as a graphics overlay. In certain cases, a message might be sent to force-tune the OpenCable device to the appropriate alert channel.
- Conditional access—This consists of addressed messages (EMMs) to individual OpenCable devices and set-tops. The same EMM must be sent repeatedly when a system is in one-way operation because there is no way for the OpenCable device to acknowledge message receipt.

The DSM-CC data carousel provides a standard mechanism for continuously transmitting any type of information over a channel. In practice, a data carousel is used to transmit these information flows on the forward out-of-band channel.

Two-Way Flows

The two-way flows are

- Signaling—There are many possible signaling flows to support interactive and on-demand applications. The TCP/IP protocol suite provides addressing and multiplexing facilities that may be used to support a number of different concurrent signaling flows to different entities in the headend from an OpenCable device.
- Network management—The simple network management protocol (SNMP) may be used to monitor and control the OpenCable device or POD.
- Conditional access—The reporting of purchase information is required for the support of impulse pay-per-view services. A secure protocol is used by the conditional access system, which is not specified by the OCI-N interface.

Forward OOB Channel

Figure 16-9 compares the protocol stacks for the three alternative forward out-of-band channels.

Figure 16-9 *Protocol Stack for Forward Out-of-Band Channel*

SCTE DVS 167	SCTE DVS 178	DOCSIS
Payload	Payload	Payload (DPU)
		IP, ICMP
		LLC/DIX
		Link Security
ATM Cell Format	Data Link Layer	MAC
Reed-Solomon	MAC Sublayer	Transmission Convergence
Interleaving	MPEG-2 Transport	MPEG-2 Transport
SL-ESF Frame Payload Structure	Randomizer	Randomizer
SL-ESF Format	Reed-Solomon	Reed-Solomon
Randomizer	Interleaving	Interleaving
QPSK/Differential Coding	QPSK/Differential Coding	64/256 QAM

Reverse OOB Channel

Figure 16-10 compares the protocol stacks for the three alternative reverse out-of-band channels.

Figure 16-10 *Protocol Stack for Out-of-Band Return Channel*

SCTE DVS 167	SCTE DVS 178	DOCSIS
Payload	Payload	Payload (DPU)
		IP, ICMP
Data Link Layer/AAL-5	Data Link Layer/AAL-5	LLC/DIX
MAC Sublayer	ATM Cell Format	Link Security
ATM Cell Format	MAC Packet Sublayer	MAC Packet Sublayer
Time Slot Structure		Time Slot Structure
Reed-Solomon	Randomizer	FEC
Randomizer	Reed-Solomon	Scrambler
QPSK/Differential Coding	QPSK/Differential Coding	QPSK/16-QAM

Summary

OCI-N is still under development, but progress is being made and OCI-N includes the following standards (which are part of existing cable practice):

- ATSC Digital Television Standard (A/53)—This standard describes the overall system characteristics of the U.S. Advanced Television System.
- RF Interface Specification for Television Receiving Devices and Cable Television Systems (EIA-23)—This standard provides RF performance recommendations for the digital set-top.
- Cable Television Channel Identification Plan (EIA-542)—This standard specifies the frequencies of all cable channels. (See Chapter 8 of *Modern Cable Television Technology; Video, Voice, and Data Communications,* by Ciciora and others.)
- Digital Transmission Standard for Cable Televisions (DVS-031)—This standard specifies the modulation (64-QAM or 256-QAM), forward error correction, and framing of the digital payload (see Chapter 4).
- Digital Video Service Multiplex (DVS-093)—This standard references the MPEG-2 systems layer (see Chapter 4).
- Service Information for Digital Television (DVS-234)—This standard specifies the out-of-band format and is based on A/56.

Retransmission of terrestrial digital broadcast channels adds a new protocol for tuning and guide information:

- Program and System Information Protocol for Terrestrial Broadcast and Cable (DVS-097)—This standard specifies that the in-band format is based on A/65. A/65 is the terrestrial broadcast standard for system information.

References

Book

Ciciora, Walter, James Farmer, and David Large. *Modern Cable Television Technology; Video, Voice, and Data Communications*. San Francisco, CA: Morgan Kaufmann Publishers, Inc., 1999.

Standards

CableLabs. "OpenCable Network Interface Specification." Cable Television Laboratories, Inc.

EIA-23. "RF Interface Specification for Television Receiving Devices and Cable Television Systems." October 1998.

ISO-IEC 13818-6. EIA Engineering Department. "Digital Storage Media—Command and Control (DSM-CC)."

SCTE DVS-241 "Draft: Digital Video Service Multiplex and Transport System Standard for Cable Television." August 6, 1999.

Internet Resources

The SCTE DVS FTP site for DVS documents is maintained by CableLabs

http://www.cablelabs.com.

CHAPTER 17

OCI-C1: The Consumer Interface

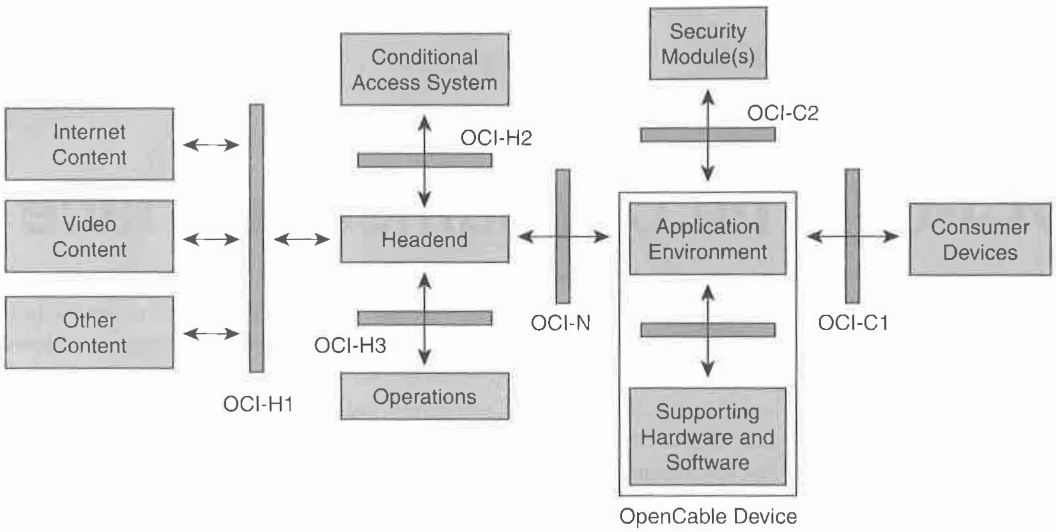
The OCI-C1 interface connects the OpenCable device to the consumer devices in the home. The OCI-C1 interface is of paramount importance for cable operators because it allows them to deploy a digital set-top, which provides the service delivery gateway between the cable network and the consumer device. Conversely, the OCI-C1 interface is less important when a cable ready digital television is envisioned because the set-top functions are integrated into the television. In this case, the consumer interface becomes the territory of the consumer electronics manufacturers.

Figure 17-1 illustrates that the intelligence is to the left of the OCI-C1 interface, within the applications environment. To the right of the OCI-C1 interface, the functions are predominately associated with the display of the service rather than the presentation of it. In other words, the user interface and service management functions are done prior to the OCI-C1 interface in the OpenCable device.

This chapter is organized as follows:

- Goals—The OCI-C1 interface is intended to provide a digital content delivery mechanism from the digital set-top to a digital television with support for content protection. It must also support high definition services and user interface functions.
- Issues—OCI-C1 issues include providing for high-quality transfer of video and audio from the set-top to the consumer display device, the challenges of effective copy protection, and carriage of the high bit rates of digital television signals.
- OCI-C1 Family—The OCI-C1 interface describes a family of analog and digital interfaces between the digital set-top and the consumer display device. The analog interfaces (RF channel 3/4, composite, S-video, and component video) are summarized. The digital interface defined by OCI-C1 (the home digital network interface) is described in detail with descriptions of video, audio, and graphics transfers and the digital transmission content protection mechanism.

Figure 17-1 *OpenCable Reference Diagram*



Goals

The goals of the OCI-C1 interface are

- To support a digital interface from a digital set-top to the television receiver—Until recently, the analog NTSC interface from the set-top to the television receiver provided the only way to display television services. With the advent of digital cable services, the analog link reduces the quality of the signal from the set-top and becomes a bottleneck for new services.
- To provide content protection—Traditionally, the limited quality of the analog NTSC signal and limited analog duplication capabilities makes theft of the signal from an analog set-top uninteresting to the serious pirate. In addition, the Macrovision copy protection techniques for NTSC signals and VHS videocassette recorders achieve the desired result of "keep the honest people honest" despite the fact that they can be easily circumvented.

Today, the combination of digital services, multimedia PCs and the Internet are changing the ground rules of content protection. Signal quality is improved almost to the quality of the master copy, multimedia PCs provide multiple generation digital copying without quality loss, and the Internet provides an inexpensive and rapid distribution mechanism for digital content. For these reasons, digital content protection is based on the same principles of digital cryptography as digital conditional access systems (see Chapter 6, "The Digital Set-Top Converter" and the section Content Protection later in this chapter).

- To support high definition services—An interface is required to carry high definition signals (at 720-line progressive or 1080-line interlace vertical resolutions) from the set-top to the display device. Analog standards exist (see the section OCI-C1 Family later in this chapter), but there is no effective copy protection mechanism. For this reason, the content owners are insisting on the use of digital interfaces that can support encryption.
- To support the cable user interface with a single remote control in the cable environment—As the display device (the television in most cases) becomes more sophisticated, there is more potential for features to clash in the set-top and the television. Examples from the analog world, such as watch-and-record and picture-in-picture (see Chapter 3, "The Analog Set-Top Converter"), transfer to the digital world. In addition, new interactive features (see Chapter 8, "Interactive Services"), implemented in both the set-top and the television receiver, might cause more confusion. In the OCI-C1 model, the set-top provides the user interface and remote control, and the television receiver provides only display functions.

Issues

There are many issues regarding the consumer interface that is associated with the transition to digital television and with advanced services, such as interactive and on-demand services. In general, the more advanced the service, the more local (or client) involvement in the composition and presentation of the user experience. For example, digital broadcast requires only the well-understood MPEG-2 decoding function, whereas an interactive service requires additional graphics, user input, and computational functions.

The following issues are important in the consumer interface:

- To maintain quality of a digital signal, it should be transferred from the set-top to the display device in digital form if possible.
- Associated with the digital transfer of video from the set-top to the display is the issue of content protection. The Motion Picture Association of America (MPAA) has decided that this is a beach to die on. The prospect of unlimited digital copies with no degradation combined with mass electronic communication over the Internet is frightening to any copyright owner. Moreover, the recent Digital Millenium

Copyright Act has made it necessary to physically encrypt digital bit streams to provide the legal basis for content protection. Unfortunately, there are at least five content protection schemes that are currently being promoted by various companies or groups of companies—which one do we pick?

- The required bit rate of *uncompressed* digital video is enormous (especially at higher resolutions) see Table 17-1. Until recently, most digital interconnections were designed for *compressed* digital transfer (for example, IEEE 1394). Unfortunately, the compressed digital video cannot be modified, preventing the addition of graphics overlays for a user interface. Uncompressed digital links are under development (for example, VESA's Plug & Display).

Table 17-1 *Resolution and Frame Rate Versus Bit Rate*

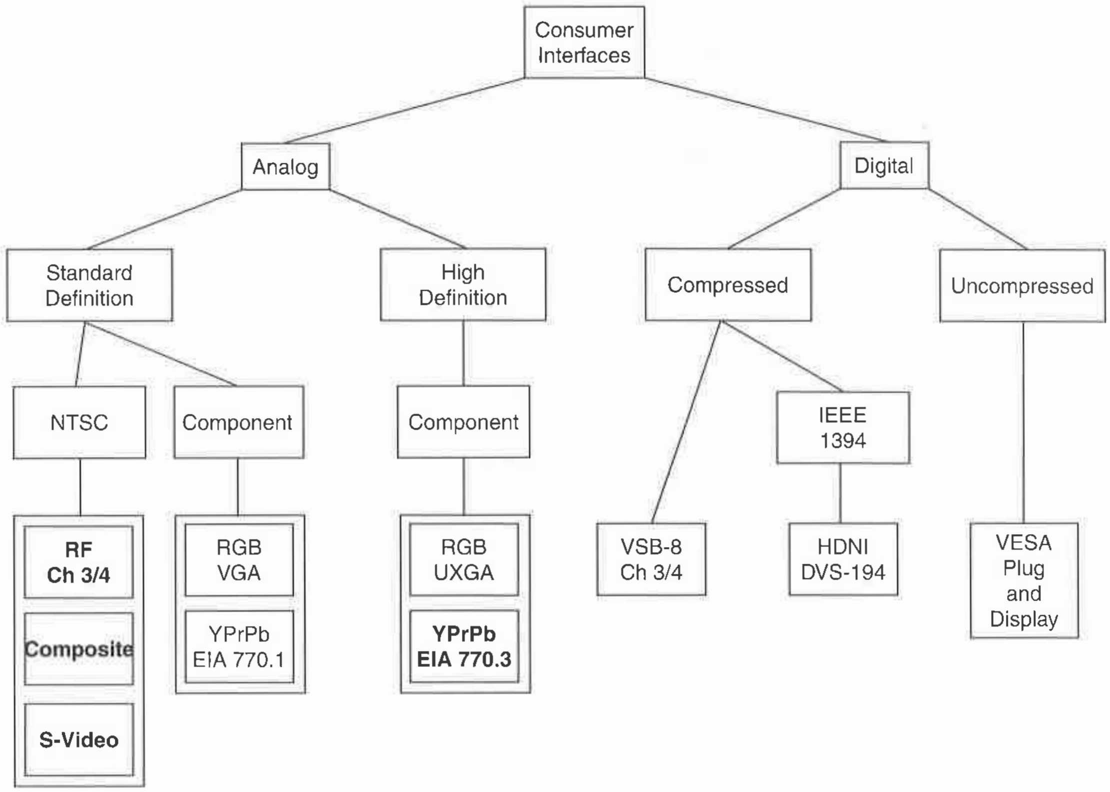
Video Resolution	Compressed Bit Rate	Uncompressed Bit Rate
Standard (30 fps) 480 x 720	3–8 Mbps	124 Mbps
High (60 fps) 720 x 1280	15 Mbps	664 Mbps
High (24 fps) (1080 x 1920)	12 Mbps	597 Mbps
High (30 fps) (1080 x 1920)	18.8 Mbps	746 Mbps
High (60 fps) (1080 x 1920)	Not yet established	1493 Mbps

The home digital network interface (HDNI) uses IEEE 1394 with extensions designed to overcome the limitations of compressed video transfer by separately sending graphics information and establishing that the digital receiver is responsible for compositing the video and graphics. This approach, which comes with its own set of advantages and disadvantages, is explained in some detail in this chapter.

OCI-C1 Family

Although OCI-C1 defines new interfaces required for digital services (both standard and high definition), OCI-C1 is an umbrella definition that includes the current practice for connecting set-tops to consumer electronics equipment. There are many potential interface standards to choose from, as illustrated by Figure 17-2:

Figure 17-2 *Consumer Interface Family Tree*



- NTSC interfaces—Although limited to standard definition signals, NTSC still provides the basis for 99% of today's OCI-C1 connections. The RF channel 3/4 variant is most common and provides a single 75 ohm coaxial connection for video and audio. The channel 3/4 connection is particularly useful because it allows bypass operation of the set-top (see Chapter 6). Composite (or baseband) NTSC video requires separate audio (usually left and right) and solves the problem of delivering a stereo audio signal from a set-top to a separate amplifier. Finally, S-video separates the luminance and chrominance components of the NTSC signal to increase horizontal resolution and to avoid certain NTSC artifacts associated with luma-chroma separation. (See *Video Demystified: A handbook for the digital engineer,* Second Edition, by Keith Jack, Chapter 4.)

- Analog interfaces—Limited because of their lack of copy protection, analog interfaces extend from standard definition to high definition signals. The most important standards are EIA 770.1 and EIA 770.2 (for standard definition 480-line interlaced and 480-line progressively scanned signals) and EIA 770.3 (for high definition 1080-line interlaced and 720-line progressively scanned signals). In addition, RGB (red-green-blue) interfaces for computer monitors are sometimes adapted for use as a video interface: VGA (640 × 480) approximating standard definition signals and UXGA (1600 × 1200 pixels) approximating high definition—both are progressively scanned.
- Digital interfaces—Digital interfaces can be divided into compressed and uncompressed interfaces. Each presents its own set of issues (see the section Issues later in this chapter). The main advantage of digital interfaces is that effective copy protection can be applied (based on cryptography), while maintaining a very high-quality signal. In addition, a digital interface can also support signaling protocols, which can be used to control the flow of information across the interface.
- There are two proposals for carrying an MPEG-2 multi-program transport stream containing compressed video and audio information. The first is based on the IEEE 1394 physical interface and is called home digital network interface (HDNI). The second is based on a channel 3/4 VSB-8 modulated MPEG-2 multi-program transport stream—the digital equivalent of the NTSC channel 3/4 interface.
- The VESA (Video Electronic Standards Association) Plug & Display is an uncompressed digital video link designed for flat panel displays [VESA].

OCI-C1 embraces the subset of interfaces that are commonly used today. The OCI-C1 definition includes the following interfaces (shown in bold text in Figure 17-2):

- NTSC RF channel 3/4—The NTSC signal is modulated onto RF channel 3 or 4 with the audio signal, which might be BTSC-encoded.
- Composite—Composite (or baseband) video uses a single RCA connector to carry the NTSC video signal.
- S-video—S-video provides the highest-quality alternative for NTSC-encoded signals and uses a 4-pin mini-DIN connector.
- Component video—High definition component video provides an interim method for transferring video from a set-top to an HDTV or monitor.
- Home digital network interface (HDNI)—Specified by DVS-194, HDNI is designed to provide the digital equivalent of the analog channel 3/4 interface.

Analog NTSC

Analog video connections that use the NTSC standard have provided the only way of interconnecting set-tops with the television receiver until now. The NTSC standard is the basis for several interfaces:

- NTSC RF channel 3/4—This interface provides a single 75 ohm coaxial connection for video and audio and is the most common variant. The channel 3/4 connection is particularly useful because it allows bypass operation of the set-top (see Chapter 6).
- Composite (or baseband) video—This interface allows separate audio (usually left and right) and solves the problem of delivering a stereo signal from a set-top to a separate amplifier.
- S-video—This interface separates the luminance and chrominance components of the NTSC signal to increase horizontal resolution and avoid certain NTSC artifacts associated with luma-chroma separation. (See Chapter 4 of *Video Demystified: A handbook for the digital engineer,* Second Edition, by Keith Jack.)

Component Video

High definition analog component video provides an interim method for transferring video from a set-top to an HDTV or monitor. Unfortunately, the EIA 770.3 standard (for high definition 1080-line interlaced and 720-line progressively scanned signals) provides, as yet, no content protection mechanism approved by the MPAA. Nevertheless, EIA 770.3 is the only available high definition output for the small numbers of currently deployed high definition capable set-tops, such as the Explorer 2000-HD from Scientific Atlanta.

EIA 770.3 is also commonly used to provide the connection from a digital receiver to the monitor in an HDTV receiver. Many consumer electronics manufacturers have elected to build their HDTV receivers in two components—a digital receiver that includes tuning and MPEG decoder functions, and a high definition monitor. This allows the digital receiver to be upgraded separately and preserves the lifetime of the high definition monitor, which currently represents the most costly items: cathode ray tubes, mirrors, lenses, and power supply.

Home Digital Network Interface

Home digital network interface (HDNI) uses a digital interface to replace the analog link. The digital interface is a high-speed serial bus called IEEE 1394.

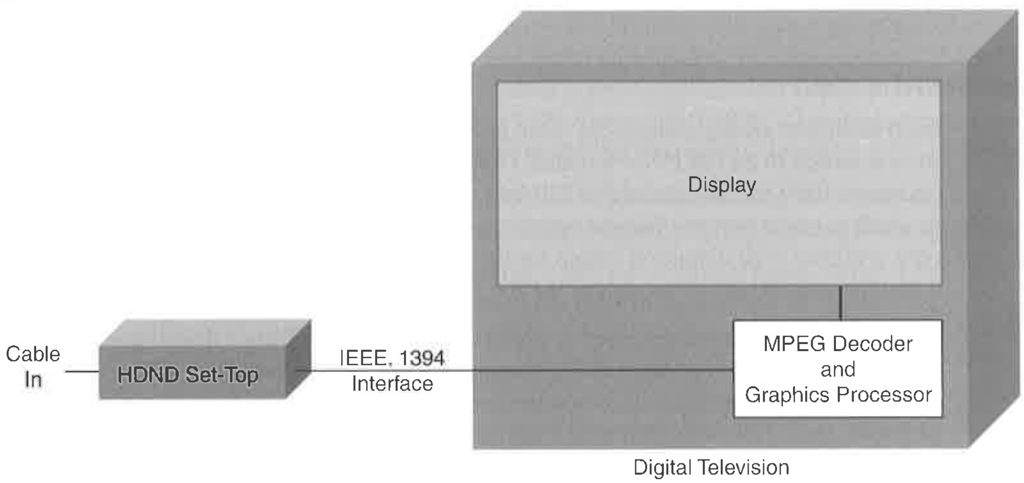
1394 Media

Initially developed by Apple Computer as FireWire for plug-and-play networking for multimedia, IEEE 1394 has become the preferred solution for digital interconnect of consumer electronics devices. The IEEE 1394 connectors are hot-pluggable, and IEEE 1394 equipment (or *nodes*) are designed to autoconfigure into a network when they are daisy-chained together with IEEE 1394 links.

IEEE 1394 defines a family of bit rates of approximately 100, 200, 400, and 800 Mbps over serial or fiber-optic (1394b) connections. The IEEE 1394 network supports guaranteed bandwidth connections for transport of isochronous data (such as audio and video). Nevertheless, IEEE 1394 has insufficient bandwidth for uncompressed, high definition video (refer to Table 17-1) and is designed to carry compressed video and audio streams.

Figure 17-3 shows a digital set-top connected to a digital television (DTV) via an IEEE 1394 interface. This arrangement allows transfer of the compressed MPEG-2 transport stream without modification. This has the advantage of maintaining the signal quality and allows the DTV to provide the tightly coupled decode and display functions. The problem with this arrangement is that graphics cannot be added to the compressed signal before it leaves the set-top, providing no mechanism for user interface display functions.

Figure 17-3 *The IEEE 1394 Interface*

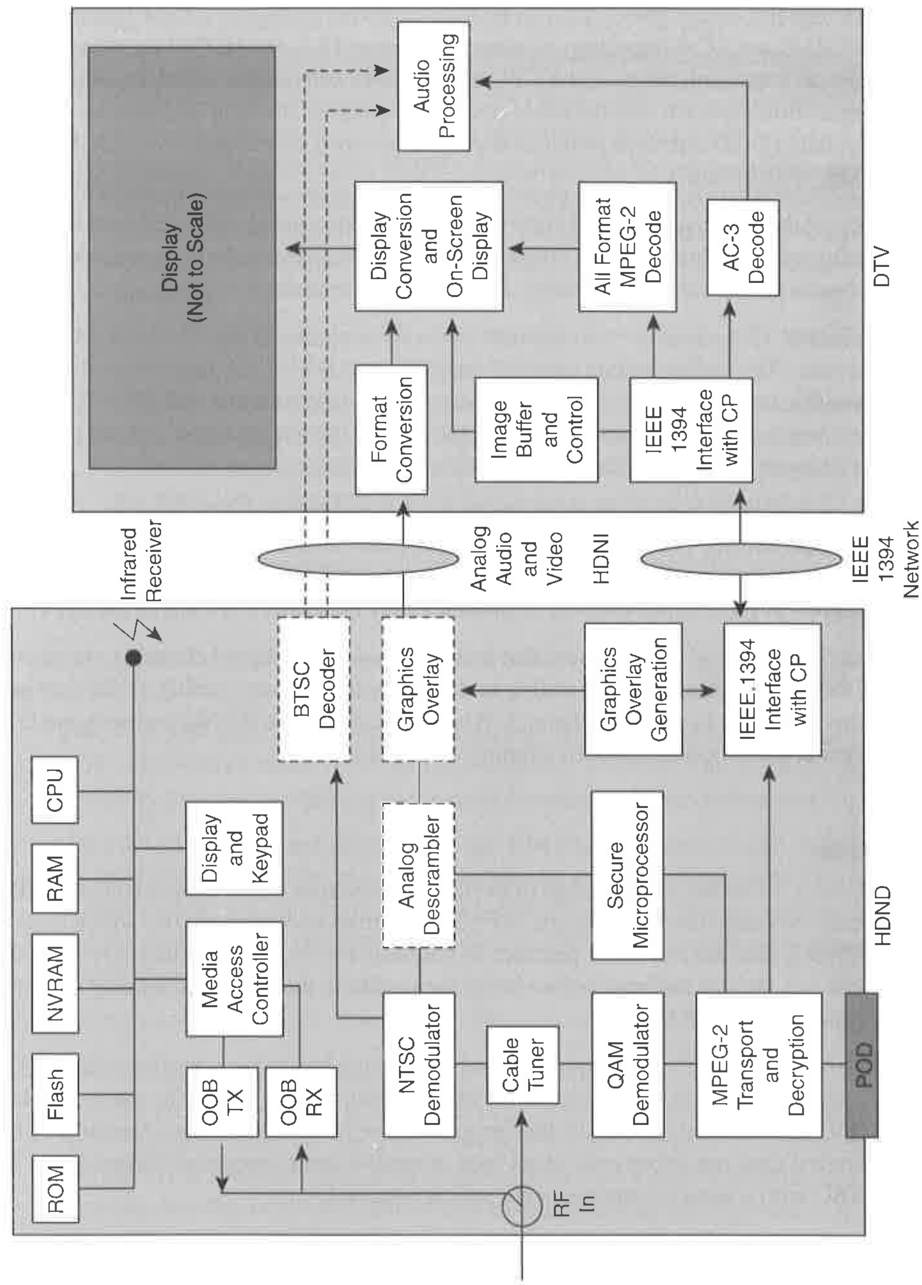


HDNI extends the IEEE 1394 syntax to allow separate transfer of graphics to the DTV. The DTV is responsible for compositing the graphics with the decoded video and presenting them on the television display.

In addition, HDNI specifies a content protection mechanism for the compressed digital signal to prevent unauthorized copying of copyrighted material.

Figure 17-4 illustrates the HDNI concept. A home digital network device (HDND), which is a modified digital set-top, provides the cable network interface and conditional access functions. The HDND is connected to a digital television (DTV) via an IEEE 1394 network and, optionally, by an analog audio and video link. The DTV provides audio, video, and user interface display functions.

Figure 17-4 *HDNI Reference Diagram*



Home Digital Network Device

The home digital network device (HDND) can be compared to the digital set-top described in Chapter 6 (see Figure 6-1). The HDND performs all digital set-top functions except MPEG-2 and AC-3 decoding. As shown in Figure 17-4, the HDND includes two-way, out-of-band communications and a CPU and memory subsystem, which provides an application platform that the cable operator manages. The HDND could be leased or sold at retail; a POD interface provides separable security (see Chapter 18, "OCI-C2: The Security Interface").

The HDND receives infrared signals from a remote control. All cable user interface functions are controlled by a single remote control; these include tuning, electronic program guide, cable preferences, IPPV, or VOD ordering.

In Figure 17-4, there are two separate paths through the HDND for analog and digital services. The analog path is optional (according to DVS 194), but if the cable network provides analog services, it provides the only way to get them to the DTV. Also optional in the analog path is a means to overlay graphics on the analog signal, which provides a mechanism to provide cable user interface functions.

The digital path is mandatory and includes demodulation and decryption of the MPEG-2 transport stream. The IEEE 1394 interface applies content protection (CP) to the signal and encapsulates it in an isochronous channel on the IEEE 1394 bus. The digital path also supports asynchronous transfer of graphics over the IEEE 1394 bus to the DTV.

In a typical hybrid cable system that includes analog and digital channels, the active output of the HDND changes from analog to digital during channel surfing as the user switches from an analog to a digital channel. When this occurs, the HDND instructs the DTV to select the appropriate input by sending a control message.

Digital Television

Figure 17-4 shows the functions of the digital television when connected to the HDNI. The IEEE 1394 interface receives the MPEG-2 program transport stream, which is fed to an MPEG-2 decoder and AC-3 decoder. In addition, bit-mapped graphics arrive via the IEEE 1394 link and are buffered before being forwarded to the on-screen display circuitry of the digital television (DTV).

Optionally, the DTV also supports baseband analog inputs for audio and video. The NTSC video might require format conversion from 480-line interlace to the native display of the DTV, which is likely to be 720-line progressive or 1080-line interlace format. The DVS 194 standard does not specify the exact type of analog input, but either composite or S-video NTSC with a separate analog stereo pair is assumed.

The analog video path also provides another optional alternative for the user interface to bit-mapped graphics transfer over the IEEE 1394 link. In this case, the DTV provides the capability of overlaying the analog video over the digital video.

Video/Audio Payload

The video and audio payload is transferred over the IEEE 1394 link as an isochronous payload with a guaranteed bit rate allocated on the bus. The payload is in MPEG-2 transport stream format, but several variations exist depending on the implementation of the HDND:

- Single program transport stream—This approach is recommended by the cable operators because it fits the tuning and control model envisioned for OCI-C1. When a program is tuned by the HDND, the audio and video is decrypted and assembled into a single program transport stream and forwarded to the DTV. There is additional implementation cost because the new transport stream needs to be re-timestamped to adjust for re-multiplexing from a multi-program transport stream received over the cable.
- Multi-program transport stream—This approach is favored by the broadcasters and consumer electronics manufacturers and recommends that the entire multiple program transport stream is forwarded over the IEEE 1394 interface (a maximum payload of 38.8 Mbps in a 256-QAM environment). The problem with this approach is the split navigation paradigm; the DTV has to select which program to display from the multiplex and requires PSIP information to provide the user with guide information for the multiplex. This leads to a *dueling remote control* scenario where the user must juggle the set-top and DTV remote controls continuously to obtain the desired service.

Graphics

The DVS-194 specification includes a variety of bit-mapped graphics formats from 4- or 8-bit color lookup tables to 16-bit uncompressed graphics. The HDND and DTV use a discovery process to negotiate the highest common graphics format that they both support.

Graphics capabilities are divided into two EIA DTV profiles. Profile A supports only a 4-bit color lookup table for on-screen display and a single, 16-bit pixel format. Profile B supports all the graphics formats in DVS-194. There is some concern from cable operators that the user interface provided by profile A DTVs will be limited compared to existing analog capabilities.

Hypertext Markup Language

A future profile (profile 2) is discussed in DVS-194. The main purpose of profile 2 is to reduce the data traffic on the IEEE 1394 bus. Because Hypertext Markup Language (HTML) is at a much higher level of abstraction than a graphics bitmap (profile 1), it typically requires much less data to describe the same graphics overlay.

Content Protection

The combination of digital services, multimedia PCs, and the Internet pose a serious threat to any owner of copyright material. Picture quality is improved almost to the quality of the master copy, multimedia PCs provide multiple generation digital copying without quality loss, and the Internet provides an inexpensive and rapid distribution mechanism for digital copies. For these reasons, the movie studios adopted a consistent position that they will not release digital content until adequate content protection mechanisms exist. As such, the launch of the digital versatile disk (DVD) was delayed by more than a year while content protection was developed.

The Copy Protection Technical Working Group (CPTWG) is responsible for developing content protection technology. The CPTWG meets about six times a year, usually in Burbank, California, and is sponsored by the member companies of the Motion Picture Association of America (MPAA). The CPTWG is a completely open forum but does not work as a due-process standardization body.

Content protection is obviously important for stored media (for example, DVD) but is equally important for the transmission of digital media. Digital transmission content protection (DTCP) addresses the need to prevent unauthorized copying of entertainment content. DTCP is developed by the Digital Transmission Working Group (DTWG), which is part of CPTWG.

5C Content Protection Overview

The content protection specified by HDNI is 5C digital transmission content protection Volume 1, which defines

> a cryptographic protocol for protecting audio/video entertainment content from unauthorized copying, intercepting, and tampering as it traverses digital transmission mechanisms such as a high-performance serial bus that conforms to the IEEE 1394-1995 standard.

The name 5C refers to the five companies that jointly authored and agreed to use the specification: Hitachi, Intel, Matsushita Electric Industrial (MEI—better known in America as Panasonic), Sony, and Toshiba. The 5C content protection specification represents a hard-won compromise developed by DTWG. The 5C group was formed in February 1998 to break an impasse that had developed between two alternative proposals in DTWG. After much work, the version 1.0 specification was issued in February 1999.

To implement 5C content protection (5C CP), a manufacturer is required to obtain a license from the Digital Transmission Licensing Administrator (see Web page at http://www.dtla.com). A license is required primarily to enforce the conditions under which the intellectual property contained in the 5C CP might be used. These conditions are the set of rules under which copies are allowed and include the types of output that are allowed. The intellectual property hook is used because it is often easier to enforce patent infringement than it is to enforce copyright infringement. Therefore, the goal of any content protection mechanism is to ensure that copies cannot be made without using a chosen, patented technology. If a manufacturer builds a device that makes illegal copies (known as a *circumvention device*), that manufacturer can be sued for patent infringement.

The Content Protection Chain

5C content protection is link-based and forms only one link in the copy protection chain. In a cable television environment this chain has several links:

- The satellite link from the content provider to the headend is protected using a proprietary conditional access system (for example, GI's Digicipher II or SA's PowerVU, see Chapter 7, "Digital Broadcast Case Studies").
- The cable system from the headend to the set-top (HDND) is protected using a proprietary conditional access system (for example, GI's Digicipher II or SA's PowerKEY, see Chapter 6).
- The IEEE 1394 link from the set-top to the digital television is protected by 5C content protection.

5C Content Protection Mechanisms

5C content protection uses a number of techniques to prevent unauthorized copying, which are described using a layered model:

- Copy control information (CCI)—The content owner tags the content with the copying restrictions placed on it using the CCI. The CCI is carried by the encryption mode indicator (EMI) in the sy field of the 1394 isochronous packet header and is also embedded in the MPEG content (to prevent tampering). There are four possible states for CCI: *copy-free*, *no-more-copies*, *copy-one-generation*, and *copy-never*. Table 17-2 shows how these CCI states are expected to be used in a cable environment.

Table 17-2 *Copy Control Information*

CCI State	EMI Value	Content Type
Copy-free	00	Broadcast services
No-more-copies	01	Not applicable
Copy-one-generation	10	Pay services, PPV or VOD
Copy-never	11	PPV or VOD

- Device authentication and key exchange—This step allows the source device (the HDND) to authenticate the sink device (the DTV). There are two levels of authentication: restricted and full. Full authentication is required if copy-never material is to be transferred, so both the HDND and DTV must support full authentication to carry all types of material. Full authentication uses the public key–based elliptic curve digital signature algorithm (EC-DSA) for signing and verification and the elliptic curve Diffie-Hellman (EC-DH) key exchange algorithm to generate a shared authentication key. The elliptic curve intellectual property was contributed by

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Toshiba and is a critical part of the 5C system. Some manufacturers have expressed concern that others might contest the ownership of the elliptic curve intellectual property.

Device authentication allows both devices (in this case, the HDND and the DTV) to verify that the other has a device certificate that is a valid public/private key pair issued by the DTLA.

A shared authentication key is then generated using an EC-DH exchange. The source device uses the authentication key to encrypt the content encryption key.

- Content encryption—This part of the 5C scheme protects the content itself using digital encryption. The selected algorithm is a 56-bit block cipher called M6, which was contributed by Hitachi. Export approval for M6 has been granted by MITI (the Japanese Government department for security).

  The source device selects a random key (which is periodically changed) and uses it to encrypt the MPEG-2 transport stream with the M6 algorithm. It also sends a message to the sink (or destination) device containing the random key encrypted using the shared authentication key.

  The sink device decrypts the message using the shared authentication key to recover the random key. It then decrypts the MPEG-2 transport stream with the random key.

- Device renewability—The final part of 5C content protection is a mechanism that allows the DTLA to revoke a device certificate. The DTLA might periodically issue system renewability messages (SRM), which are digitally signed with the DTLA EC-DSA private key (this allows all 5C-compliant devices to verify the authenticity of the SRM message using the EC-DSA public key). The SRM contains a list of device certificates that are no longer valid (for example, they might have been cloned by a pirate manufacturer to build circumvention devices).

  SRMs may be placed on recorded media or encapsulated in streaming content. They are designed to propagate through the population of 5C-compliant devices rather like a virus. Each 5C-compliant device is responsible for building a list of invalid device certificates and checking it during the authentication process. A 5C-compliant device will refuse to send (or receive) content to (or from) a revoked device.

This brief description illustrates the implementation complexity of the 5C content protection system, which has been demanded by the movie studios. It is not surprising that not all consumer electronics companies support the 5C initiative. Some commonly cited issues are

- Secrets in the box—This refers to the fact that each 5C-compliant device holds a secure secret (a private key). This arguably increases the manufacturing cost of the device.

- Intel administers DTLA—Some CE companies have expressed concern that Intel, one of the world's largest chip suppliers, holds the keys to the 5C licensing process.
- End-to-end security is superior—Thomson Consumer Electronics and Zenith have proposed an alternative content protection mechanism called XCA. In this proposal, content providers encrypt their content at the source, and it remains encrypted until it reaches the display device. A smart card in each display device would be used to enable access to protected content.
- Revocation of devices—When a 5C-compliant device is revoked, it is no longer able to exchange protected content. For example, a revoked DTV would not be able to display premium content from the set-top, doubtless causing a very negative reaction from the customer.

Summary

This chapter describes the OCI-C1 interface between the OpenCable device (typically a digital set-top) and the consumer display device (typically a television). OCI-C1 is actually a family of interfaces that embraces current analog NTSC interfaces and a proposed digital interface called the host digital network interface (HDNI).

The goals of OCI-C1 include support of standard and high definition services, transfer of the digital signal quality to the consumer device, and support for improved content protection.

The HDNI specification is based on the IEEE 1394 standard and supports compressed digital transfer of the MPEG-2 transport stream from the digital set-top to a digital television. The digital television performs MPEG-2 and Dolby AC-3 decoding functions. Graphics overlays for user interface are sent separately over the IEEE 1394 link, and the digital television is responsible for compositing the graphics overlay with video.

The HDNI specification includes provision for digital transmission content protection (DTCP). DTCP uses digital cryptography to prevent unauthorized copying of the digital video and audio content.

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http://www.1394ta.org.

VESA "Plug & Display"

http://www.vesa.org

CHAPTER 18

OCI-C2: The Security Interface

The OCI-C2 interface provides the interface to a *point-of-deployment* (POD) module for digital signals provided over the cable system. The POD module is a Type II PC Card (commonly known as a PCMCIA module) supplied by the cable operator, which provides two important functions:

- Separation of security—The FCC Report and Order (issued on June 11, 1998) mandates the separation of a cable system's security from other functions in a navigation device available at retail by July 2000. Moreover, cable operators will not be allowed to deploy set-tops with embedded security after January 1, 2005. The POD module is designed to satisfy the FCC requirements for separable security.
- Out-of-band communications—Some variation in existing practice in digital cable systems is in the choice of out-of-band (OOB) protocol. The POD module terminates the lower layers of the OOB protocol and adapts a navigation device to the OOB scheme for that cable system. The POD module supports OOB communications according to DVS 167 or DVS 178 (see Chapter 5, "Adding Digital Television Services to Cable Systems").

A third aspect of the OCI-C2 interface is that it transfers programming content across a digital interface. The Motion Picture Association of America (MPAA) requires that the OCI-C2 interface support a content protection system to prevent illegal copying.

This chapter is organized as follows:

- Reference diagram—The OCI-C2 interface is placed in context of the OpenCable reference architecture, and the terms *host* and *POD module* are defined.
- Drivers—The drivers for the OCI-C2 interface are discussed, which include government regulation, retail set-top availability, cable ready digital television, and high definition television.
- Retail issues—The OCI-C2 interface solves some of the portability issues, the choice of conditional access system, and out-of-band communications channel, but does not address user interface and new service introduction issues.

- Opportunities—The separation of conditional access system functions provides opportunities for integration of set-top functions into a cable ready digital television (CR-DTV) and might speed introduction of new technology into the consumer's home. For the cable operator, opportunities are reduced capital expenditure and new ways of acquiring customers.
- Summary of approaches—The different approaches for conditional access system renewal and replacement are summarized to explain the choice of NRSS-B as the basis for the POD module.
- System architecture—The POD system architecture provides a single replaceable module that provides flexibility to adapt the host to all variants of the conditional access system and out-of-band communications channel types.
- POD module—OCI-C2 (SCTE DVS-131) specifies only the POD module interface. This section describes the internal structure and operation of a typical POD module design.
- Copy protection—The OCI-C2 specification includes a content protection mechanism that uses digital cryptography to prevent unauthorized copying of copy-protected material. This section describes the operation of POD copy protection in some detail.
- Applications—Three applications of the OCI-C2 interface are discussed: a digital set-top, a digital set-top with a DOCSIS cable modem, and a cable ready digital television (CR-DTV).

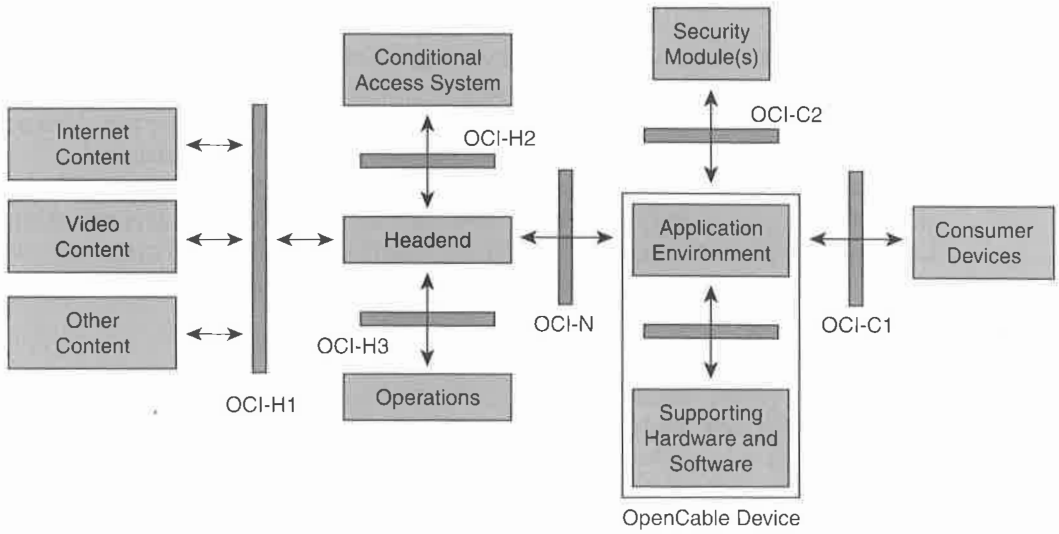
Reference Diagram

Figure 18-1 is the OpenCable reference diagram. The OCI-C2 interface is defined between the OpenCable device and the security (POD) module.

SCTE DVS 131 Revision 7 defines the OCI-C2 interface. DVS-131 uses the following terms for convenience:

- Host—The *host* is responsible for all functions except conditional access. There are many different kinds of host devices with a wide range of functions and capabilities; examples are a digital set-top, a cable ready digital television, or a cable ready VCR. The OpenCable device functional requirements provide a set of performance and functional specifications for an OpenCable-compliant host device.
- POD module—The *POD module* is a replaceable component that is provided by the cable operator. The POD module provides all the security functions required by the cable conditional access system.

Figure 18-1 *OpenCable Reference Diagram*



Drivers

There are a number of drivers for the OCI-C2 interface. These can be divided into

- Regulatory
- Retail
- Cable ready digital television
- High definition television

Regulatory

On June 24, 1998, the Commission released its Report and Order in this proceeding implementing Section 304 of the Telecommunications Act of 1996. Section 304 calls upon the Commission to adopt rules to ensure the commercial availability of navigation devices, while not jeopardizing the signal security of an affected multichannel video programming distributor (MVPD). As part of that R&O, the Commission determined that one means of implementing these twin goals was to separate security (that is conditional access) functions from nonsecurity functions and to require that only the nonsecurity functions be made commercially available in equipment provided by entities unaffiliated with the

MVPD. The security functions would reside in a separate security module to be obtained from the MVPD.

In its decision, the Commission repeatedly references the ongoing effort of CableLabs to develop specifications for both a digital security module and a digital security module interface. That OpenCable effort is focused on cable's *digital* set-top converters. After such specifications are developed and the interface is adopted as an industry standard, manufacturers can produce digital navigation devices (such as digital set-tops) with the standardized digital security module interface and make such equipment available at retail. Cable operators would then supply a compatible digital security module to the customer.

Retail

There has been a long-standing love-hate relationship between the cable industry and manufacturers of cable ready receivers. For many in the cable industry, retail cable devices represent a serious loss of control that threatens their business. For others, retail cable devices are seen as a way to reduce capital costs and to move more quickly to advanced services. It should come as no surprise that retail is an emotive subject as well as a complicated one.

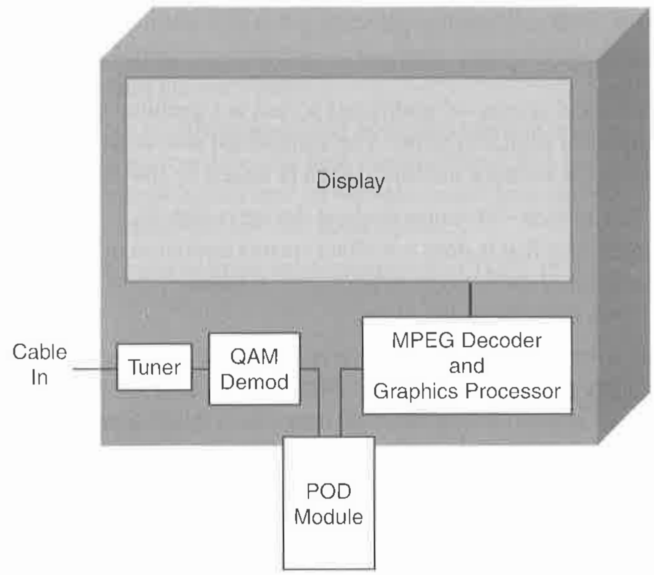
In the analog world, cable ready televisions and video cassette recorders have gained favor with subscribers as manufacturers adopted innovations (such as the remote control) from set-top manufacturers. As cable ready television performance increased (allowing the tuning of all cable channels and providing better adjacent channel rejection), the customer's need for a set-top was reduced to de-scrambling premium channels. In addition, new features, such as picture-in-picture and VCR-plus do not work well with a set-top and cause compatibility issues (see Chapter 3, "The Analog Set-Top Converter"). More recently, advanced analog set-tops have added two major new features—the electronic program guide and impulse pay-per-view, which have increased customer acceptance of set-tops.

The fundamental problem with retail availability of analog set-tops is one of portability. For an advanced analog set-top to work in a cable system it must be exactly the correct make and model and contain the correct revision of software. The analog decoder interface attempted to address this with something called an *extended feature box*. The idea was that a separate box containing extra functions and features, such as software applications, would be plugged into the EIA 105 bus.

Cable Ready Digital Television

The POD module interface specification is designed to facilitate cable ready operation of a digital television when a POD module is inserted. Figure 18-2 shows a simplified diagram of a cable ready digital television (CR-DTV). The DTV's tuner and QAM demodulator feed a baseband digital signal to the POD module, which is responsible for conditional access functions. The output of the POD module feeds the receiver's MPEG-2 decoder and graphics processor that, in turn, drives the display.

Figure 18-2 *Cable Ready Digital Television*



High Definition Television

The OCI-C2 interface supports standard and high definition MPEG-2 packetized elementary streams (in fact, the POD module is unaware of the difference between these stream types). Therefore, an integrated high-definition digital cable ready receiver with a POD module provides an excellent solution for premium high definition television (HDTV) services.

Retail Cable Issues

The fundamental difficulty with a cable ready retail device is the differences between cable systems. Although the 1996 telecommunication's act does not require *portability* from one system to another, it is necessary in practice to avoid leaving the customer with a cable ready device that worked in one part of the country only to become inoperative when moved to a new location.

Portability has become a critical issue because cable's biggest competitor, DBS, does not suffer from this problem. The satellite footprint is national and so, even though each operator is proprietary, there is an implicit portability to DBS services. For this reason, DBS operators were exempted from the 1998 Report and Order (although cable operators continue to contest this decision).

There is considerably more to portability than the choice of conditional access technology. As cable operators start to offer more advanced services, these differences tend to become more and more pronounced. Electronic program guides provide a good example; although simple in concept, they are provided by a small number of companies that claim intellectual property rights over the look and feel of each feature of the guide.

Portability requires technical and/or business solutions in the following areas:

- Conditional access—Conditional access is a problem that has an elegant technical solution for digital systems. The conditional access circuitry can be separated into a replaceable security module, which is leased by the cable operator.
- RF termination—Because the host device is directly connected to the cable system, it is imperative that is does not affect correct operation of the system. Cable systems are broadband, shared-media systems, so all devices must perform to specification to maintain integrity of the plant.
- User interface—The host device provides the user interface. There are two alternatives to provide the user interface for cable services: Either the user interface software is provided by the cable operator or it is independently developed by the host manufacturer. In the first case, the cable operator can provide a consistent and comprehensive user interface but faces the technical challenge of supporting all host varieties. In the second case, each manufacturer independently develops a user interface that provides only the lowest common denominator services without any consistent *look-and-feel*.
- New services—Providing new services is constrained in the same way as the user interface because new services require new application software; either the application software is provided by the cable operator or it is independently developed by the host manufacturer. Moreover, if new hardware features are required by a new service, it can be offered only by hosts that support them—a frustrating situation for customer and cable operator alike.

At the time of writing, CableLabs has issued a request for proposals for OpenCable Software. This software *middleware* addresses user interface and new services issues by providing a portability layer for software applications. The middleware is intended to "allow individual cable operators to deploy custom services and applications on all compliant host devices connected to their networks."

Retail Opportunities

Retail provides some significant opportunities if the technical issues can be resolved:

- Integration with other consumer electronic devices in the home—The best example of this is the cable ready digital television. Not only are cost savings possible by sharing a common chassis and power supply but also integration allows seamless implementation of features such as picture-in-picture.

- New technology—Retail presents a way to introduce new technologies into the host device. Examples are convergence with PC technology, such as local content storage using a hard-drive, or support for video conferencing using a digital camera.
- Less capital expense—Because the customer shares some or all of the cost of the host device, the retail model can significantly reduce the cable operator's capital investment. Moreover, customers that desire extended hardware features can pay for them, providing greater choice.
- New customer acquisition—Cable operators can use retail to acquire new cable customers in partnership with host manufacturers and retailers. For example, new services can be demonstrated on the salesroom floor and rebates on hardware can provide an incentive to service subscription.

These threats and opportunities are summarized in Table 18-1.

Table 18-1 *Retail Summary*

Issue	Threat	Opportunity
New services	How to introduce without loss of control	Sharing of risk
Economic	Loss of guaranteed rate of return	Lower capital outlay
Convergence	Threat to existing business	New business opportunities
Integration with other CE devices	Loss of control—more service calls	Happier customer, access to latest technology

Summary of Approaches

Several approaches exist for separation of security. Most advanced digital set-tops use *smart cards* (ISO-7816), which allow replacement of the secure microprocessor component of the conditional access system (see Chapter 6, "The Digital Set-Top Converter"). But the smart card does not allow complete replacement of the security system because the actual decryption of the signal still resides in the digital set-top.

The Joint Engineering Committee (JEC) of NCTA and CEMA released a specification for a National Renewable Security System (NRSS) to address the issue of conditional access and security functions. The approach is to encapsulate these functions in a replaceable module and to standardize the module interface. In this way, the security system can be upgraded or replaced over time without impacting the host.

Unfortunately, there are two versions of NRSS called Part A and Part B. Part A is a super-smart card, which uses the ISO-7816 connector to carry the entire transport stream through the card. Part B is functionally equivalent to Part A but adopts the Type II PC Card format defined by the Personal Computer Memory Card International Association (PCMCIA).

NRSS Part B is based on the DVB common interface (CI) module, which is required by many European countries (CENELEC EN 50221). The North American cable industry has adopted the Part B specification for several reasons:

- The interface of Part B is more robust and flexible than Part A. The Part B connector has 68 pins and the module is shielded.
- The Part B module is thicker than the Part A card and supports a metallic casing that provides better heat dissipation.

Although the Part B module has these technical advantages over Part A, it is likely to be more expensive. To mitigate this, the Part B module can accept a smart card, allowing security upgrades without replacement of the entire module.

System Architecture

The POD module adapts a *generic* cable ready device to any digital cable system. This is possible largely because of standardization of the OCI-N interface (see Chapter 16, "OCI-N: The Network Interface"). Although OCI-N facilitates a common interface into the device, it cannot account for the choice of OOB signaling and CA system, which vary from system to system. The POD solves this challenge by separating all these variations into a single, replaceable module.

This is possible, in practice, for the following reasons:

- Digital deployment was at an early stage during the specification of OCI-C2. Specifically, only two digital cable system architectures were deployed in North America: General Instrument's DigiCable system, developed in partnership with TCI (now AT&T BIS), and Scientific Atlanta's Digital Broadband Delivery System (DBDS), developed to Time Warner Cable's Pegasus requirements. (See Chapter 7, "Digital Broadcast Case Studies," for an overview and comparison of the two systems.)
- The Harmony agreement (see Chapter 16) established a set of standards for modulation, transport, and MPEG-2 encoding based on the DigiCable system and adopted by the DBDS during its development phase. (Note that the POD module does not rely on the Harmony core encryption because it completely replaces all security functions).
- Many standards already exist for digital television systems due to the work of the Advanced Television Systems Committee (ATSC) on high definition television. These standards include MPEG-2 video compression, MPEG-2 systems layer, and Dolby AC-3 audio (see Chapter 4, "Digital Technologies"). Moreover, the layered approach in MPEG-2 systems allows independence between the transport and application layers in digital television systems. This property is essential to the development of a cost-effective, replaceable security module.

Nevertheless, significant differences remain between the two systems and any system architecture must accommodate innovation by suppliers to promote competition. The hardware differences are accommodated by what OpenCable terms a POD decision. This decision can be made in two ways:

- In a leased set-top environment, the cable operator makes the POD decision when the set-top is ordered. Obviously this is a decision that cannot be reversed, but cable operators are comfortable with managing their set-top inventory (as they do today for analog set-tops).
- In a retail environment, the POD decision must be delayed until the customer chooses a cable television supplier. At that time, the customer might have already purchased the set-top or cable ready television, so a replaceable module is the only viable solution.

The POD module allows the choice of conditional access system and out-of-band communications to be made at the time of customer subscription to the cable service.

Conditional Access System

The POD module provides all the conditional access functions for the host device. These functions include the authorization of services as well as the decryption of the audio/video streams. This complete separation of conditional access functions allows a completely open-ended choice of conditional access system.

Within the cable system it is very expensive to replace the conditional access system, because it is embedded into many headend components and tightly coupled to operational functions (see the section OCI-H2 in Chapter 15, "OpenCable Headend Interfaces"). Therefore, the POD module provides the flexibility to adapt any host to the conditional access system chosen by the cable operator.

Out-of-Band Communications

The out-of-band communications options for cable are described in Chapter 5. There are currently three options:

- DVS-178—Developed and owned by General Instrument, this option uses a 2.048 Mbps forward channel and a 256 Kbps return channel. Modulation is QPSK.
- DVS-167—Developed and standardized by DAVIC, this option specifies a 1.544 or 3.088 Mbps forward data channel (FDC) and a 256 Kbps, 1,544 Mbps, or 3.088 Mbps reverse data channel (RDC). The DVS-131 specification supports only one variant of DAVIC 1.2 operating with a 1.544 Mbps FDC and a 1.544 Mbps RDC. Modulation is QPSK.

- DOCSIS cable modem—Developed and standardized by CableLabs, this option specifies a 27 or 38 Mbps FDC using 64-QAM or 256-QAM modulation. The RDC supports a range of bit-rates from 320 Kbps to 10.024 Mbps and uses QPSK or QAM-16 modulation [DOCSIS]. Because DOCSIS is an agreed standard, it may be built into any retail device at the option of the manufacturer. Currently, no cable operator is using DOCSIS for out-of-band communications, but some have publicly stated their plans to do so. The POD module supports DOCSIS as a host modem (see the section DOCSIS Operation, later in this chapter).

Because DVS-178 and DVS-167 use the same type of modulation, it is possible to build a unified QPSK transceiver that supports both standards. This approach has a number of advantages:

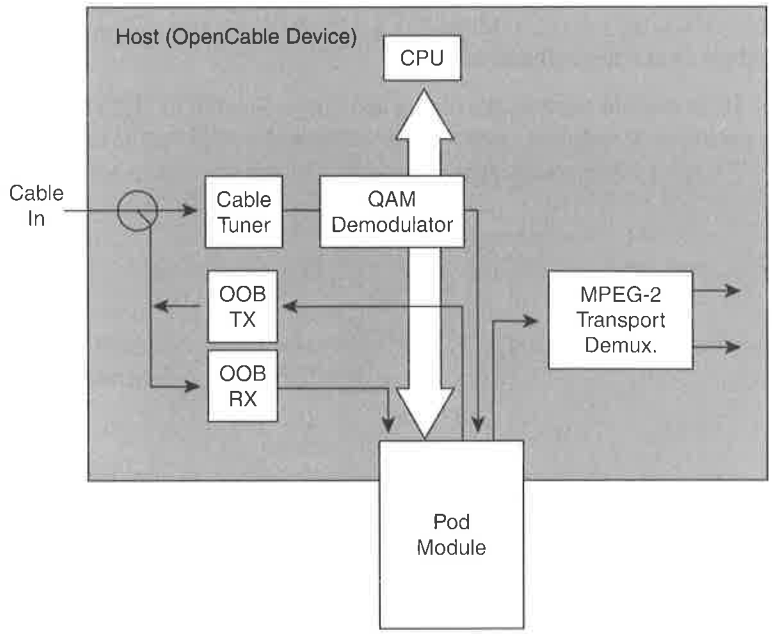
- All digital set-tops and cable ready digital televisions can include a standard RF transceiver at low cost and complexity for the support of out-of-band communications.
- The data-link and media access control protocol components are completely implemented by the POD module. This allows further development of these protocols. More importantly, the cable operator remains in control of the return channel operation, which is critical because a single *babbling* transmitter can disrupt an entire fiber node until it can be located and disabled.
- The POD terminates and processes conditional access messages with no host intervention. This reduces the threat of theft-of-service attacks.

Two-Way Operation

The POD is designed to support two-way operation, as shown in Figure 18-3.

The QPSK receiver circuit in the host tunes and demodulates the out-of-band forward data channel (FDC) under control of the POD module. The receiver circuit adapts to the 1.544 Mbps (DVS-167) or 2.048 Mbps (DVS-178) FDC bit rate, and delivers a serial bit stream and clock to the POD module. The POD module controls the tuning of the QPSK receiver circuit by means of commands delivered over the command interface. The tuning range is between 70 and 130 MHz.

Figure 18-3 *POD Two-Way Operation*



The serial data received from the out-of-band receiver carries entitlement management messages (EMMs) from the conditional access system to the POD module. These messages are not documented by the DVS-131 specification because

- There is always a one-to-one match between the conditional access system and the POD module. For example, a DigiCipher II POD module is required for hosts in cable systems that employ DigiCipher II CA.
- The exact EMM format is one of the details of the conditional access system that is not disclosed to reduce the risk of theft-of-service attacks.

In addition to EMMs, the out-of-band channel carries several other message types, which support various functions in a digital set-top, including navigation, signaling, and management. Because the host device is now responsible for these functions, these messages must be routed back into the host. DVS-131 defines an extended data channel for this purpose, and DVS-216 defines the format of these messages.

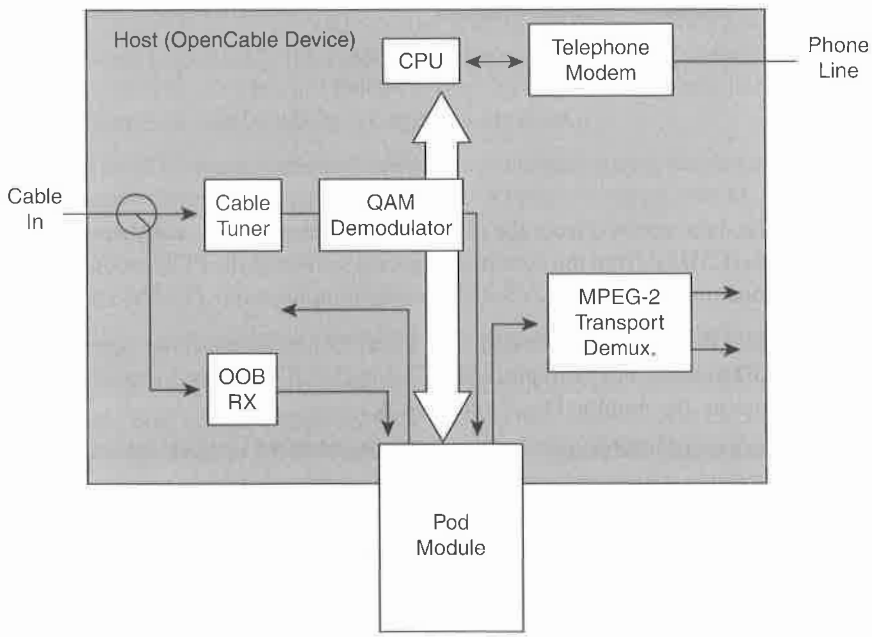
In the reverse path, the POD module generates QPSK symbols and clock and transfers them to the out-of-band transmitter circuit in the host. The transmitter circuit adapts to the 1.544 Mbps (DVS-167) or 0.256 Mbps (DVS-178) RDC bit rate and modulates the QPSK symbols onto a narrowband carrier.

The POD module controls the tuning and output level of the QPSK transmitter circuit by means of commands delivered over the command interface. The tuning range is between 8 and 26.5 MHz. The output level is variable in 1 dB steps from +26 dBmV to +55 dBmV.

One-Way Operation

The POD is designed to support one-way operation using an optional telephone modem, as shown in Figure 18-4. The QPSK transmitter in the host is not used (and is omitted from the diagram). The receiver circuit operates in the same manner as described in a two-way operation.

Figure 18-4 *POD One-Way Operation*



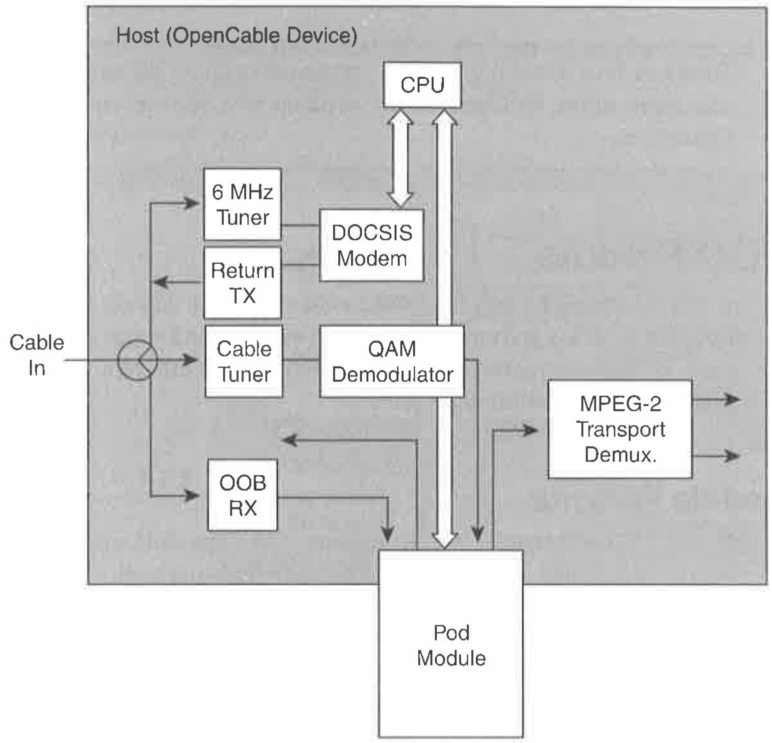
A standard telephone modem can be incorporated into the host to support impulse pay-per-view services in one-way networks. In this case, the POD module accesses the telephone modem via the extended channel interface.

The host signals an available *low-speed communication resource* to the POD module. The POD module establishes a dial-up connection with the cable headend and sends messages to the telephone modem via the data channel interface.

DOCSIS Operation

The POD module may be designed to support two-way operation using a host-resident DOCSIS cable modem, as shown in Figure 18-5.

Figure 18-5 *POD DOCSIS Operation*



The DOCSIS cable modem is capable of completely replacing the QPSK out-of-band FDC and RDC channels but, in practice, it complements and enhances the OOB channel:

- If the cable system uses a DOCSIS-based out-of-band from day one, the host's OOB receiver and OOB transmitter are not used in that system. In this case, the host forwards conditional access messages received by the DOCSIS modem to the POD via the extended data channel (as described in DVS-216). The host terminates all other messages.
- If the cable system adds a DOCSIS channel to support additional capabilities, such as interactive or data services, the host uses the OOB receiver to receive *legacy* conditional access messages.

- Retaining the host's OOB transmitter is more problematic because it is difficult to combine its output with the DOCSIS return transmitter and achieve the required maximum transmit power levels. To ease migration to DOCSIS, the POD module may use the DOCSIS cable modem as a resource to send messages to the cable system instead of the OOB transmitter.

NOTE To ensure host portability across systems using DVS-167 or DVS-178 for out-of-band data communications, *all* OpenCable-compliant host devices require an OOB receiver and transmitter.

The POD Module

DVS-131 describes only the POD module interface and not the module itself. Each cable operator specifies and procures the POD modules and leases them to the customer. As such, there will be several variants of POD module with different capabilities according to different cable operator requirements.

POD Module Variants

It seems likely that at least three variants of POD module will be deployed according to the conditional access and out-of-band technology being deployed by North American cable operators:

- Digicipher II CA and DVS-178 OOB—This variant of POD module, developed by General Instrument (GI), supports DigiCipher-II conditional access. This POD module variant supports GI's DigiCable system, which uses GI's out-of-band specification (SCTE DVS-178).
- PowerKEY CA and DVS-167 OOB—This variant of POD module is developed by Scientific Atlanta, which owns the intellectual property for PowerKEY CA. This POD module variant supports Scientific Atlanta's Digital Broadband Delivery System (DBDS), which uses DAVIC 1.2 out-of-band (SCTE DVS-167).
- MediaGuard CA and DVS-167 OOB—At the time of writing, it seems likely that this variant of POD module will be developed by SCM Microsystems under license from SECA (Canal+). This POD module variant will support MediaOne's digital system, which uses DAVIC 1.2 out-of-band (SCTE DVS-167).

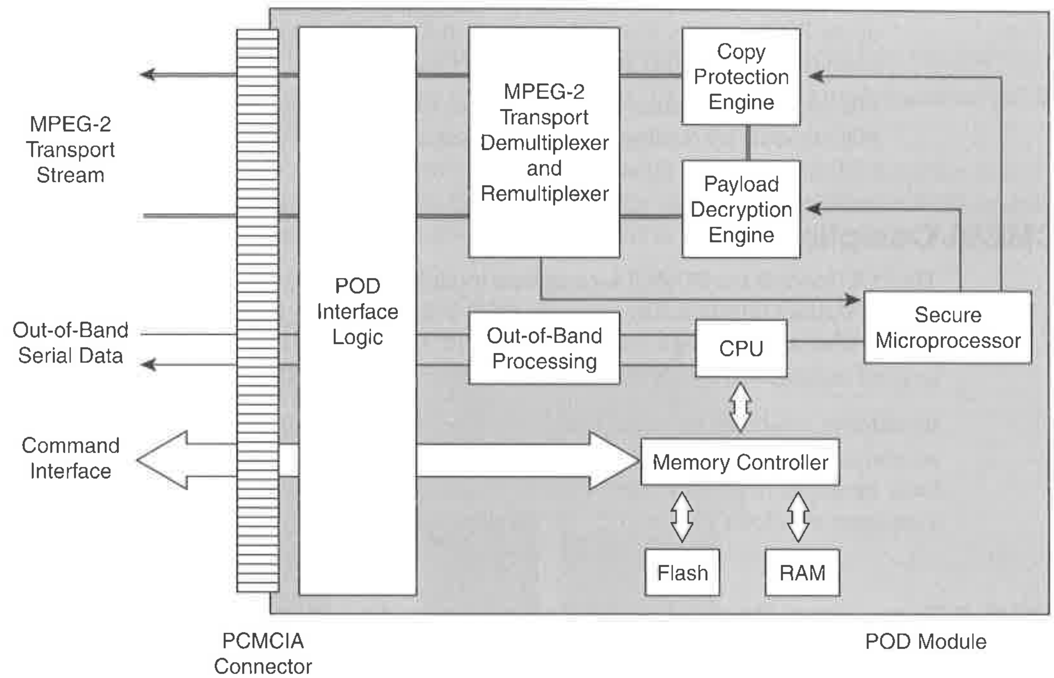
See Chapter 7 for a description of the DigiCable and DBDS systems.

As cable systems continue to evolve, it is quite likely that new POD variants will be required. If a cable operator selects DOCSIS for out-of-band communications, the POD module can be cost-reduced by removing support for DVS-178 or DVS-167. However, this places the additional cost burden of a DOCSIS cable modem on the host device. Moreover, a cable system that selects DOCSIS as the *only* OOB communications mechanism will work only with host devices that include a DOCSIS cable modem.

POD Module Architecture

The design of the point-of-deployment module varies from one implementation to another. Figure 18-6 shows an example of a typical POD design.

Figure 18-6 *POD Module Block Diagram*



Although the POD module separates security functions into a replaceable module, system operation is identical to the integrated set-top described in Chapter 6:

- The MPEG-2 multi-program transport stream enters the POD module via the PCMCIA connector and is de-multiplexed into its component program elementary streams. The selected PIDs are filtered and sent to the payload decryption engine. In addition, the entitlement control messages are sent to the secure microprocessor where they are decrypted and fed to the payload decryption engine.

- After the payload is decrypted, it is fed into the copy protection engine, which encrypts protected content. In the example shown, the same secure microprocessor that supports CA functions generates the encryption keys for content encryption.
- The final payload is re-multiplexed into an MPEG-2 multi-program transport stream and leaves the POD module via the PCMCIA connector.
- The out-of-band data enters the POD module via the PCMCIA connector and arrives at the out-of-band processing circuit. This block contains data link and media access control functions and provides the out-of-band communications processing for the POD.
- Messages from the out-of-band processing circuit arrive at the CPU, which is the heart of the POD module. The CPU controls and coordinates all POD functions by executing applications stored in FLASH memory.
- The command interface allows messages to be exchanged between the host and the POD module by reading and writing locations in RAM.

PCMCIA Compliance

The POD module is a PCMCIA-compliant module that is registered as the OpenCable POD module custom interface. On reset, the POD behaves as a 16-bit memory-only interface. After a host device recognizes the POD, the PCMCIA signals are reassigned to carry the in-band channel and the out-of-band channels across the POD module interface.

In addition, while the first card-enable pin (CE1) is used to support the *data channel*, the second card-enable pin (CE2) is used to support the *extended channel*. This allows out-of-band messages to be exchanged over the extended channel independently from control messages, which are exchanged over the data channel.

MPEG-2 Transport Stream Interface

The MPEG-2 multi-program transport stream is transferred across the DVS-131 interface as a byte-parallel stream. There is a separate 8-bit parallel input to the POD module and a separate 8-bit parallel output, together with control signals and a byte clock. The POD module introduces a constant delay to the transport stream so that MPEG-2 timestamps do not require adjustment by the host. The maximum transport stream data rate supported is 58 Mbps.

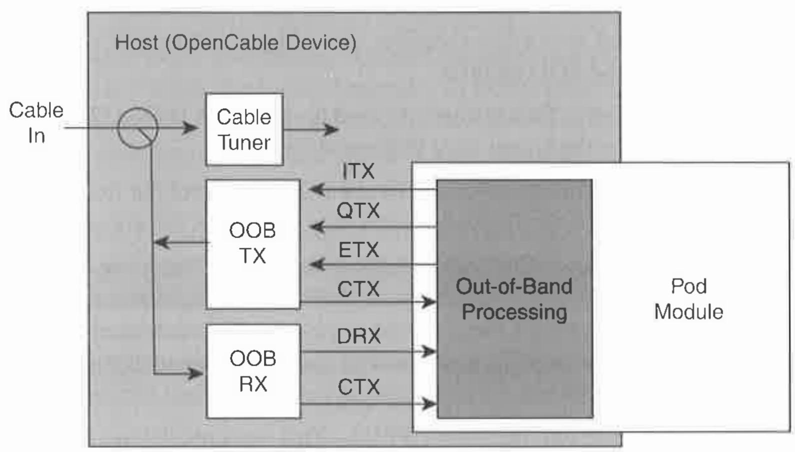
Out-of-Band Interface

The out-of-band interface is the main distinguishing feature of the POD module interface over other replaceable security modules. It is required for the cable systems in North America because there is no single standard for out-of-band communications in digital cable systems. The out-of-band interface is designed to support both DVS-167 and DVS-178 standards using a single, unified RF front end. All cable ready devices incorporating the unified front end will be portable across all North American cable systems. The unified RF front end is designed to be simple to minimize cost, which is estimated at less than two dollars (including the diplex filter).

The out-of-band interface uses six dedicated pins to provide a serial connection from the out-of-band receiver and transmitter (in the host) to the out-of-band processing circuitry (in the POD module). Figure 18-7 shows the pin assignments:

- Two pins (DRX and CRX) pass the receive data and clock from the out-of-band receiver to the POD module.
- Two pins (ITX, QTX) are used to send transmit symbols to the host transmitter.
- The transmitter provides a symbol clock (CTX) to the POD module, which sets the transmit rate.
- The POD module controls an explicit transmit enable signal (ETX) to the host transmitter. This ensures that the transmitter cannot operate unless a POD module is inserted, and that the timing of transmit bursts in under the control of the POD module.

Figure 18-7 *Out-of-Band Interface*



CPU Interface

The CPU interface supports command and signaling traffic between the host and the POD module via an 8-bit bidirectional data bus together with address and control signals.

The SCTE DVS-064 CPU interface defines a data channel that is designed to allow the exchange of control messages between the host and the POD module. This data channel is called the *command interface* in DVS-064. The DVS-131 CPU interface is augmented with a second channel, called the *extended channel*.

Data Channel

The DVS-131 data channel supports the DVS-064 command interface. The data channel uses four registers to control the exchange of variable length messages between the host and the POD. DVS-131 also adds two interrupt enable bits that cause the POD to interrupt the host when it has new data available or when it is free to accept data. The data channel is activated by Card Enable #1 (CE1#).

The DVS-064 command interface syntax defines a set of application level messages that define the application programming interface (API) to the POD module. DVS-131 extends the DVS-064 API in a number of areas:

- Low-speed communication—This resource is modified to describe the out-of-band communications resources provided by the host. This allows the host to describe any combination of out-of-band receiver, out-of-band transmitter, or DOCSIS modem resources to the POD module.
- Copy protection—This resource is used to define the DVS-213 content protection mechanism for the OpenCable POD module.
- Host control—This resource allows the POD to control the frequency of the out-of-band receiver and the frequency and transmit level of the out-of-band transmitter.
- Extended channel—This resource allows signaling flows to be established across the extended channel. For example, a new flow request might be used to establish the flow of on-demand signaling messages from the out-of-band channel, via the POD module, to the host on-demand application. The use of the extended channel is described in detail in DVS-216.
- Generic impulse pay-per-view (IPPV)—This resource defines a general purpose IPPV API for use between a host navigation application and the security manager (in the POD module).
- Specific application support—This resource allows a private syntax to be used between the host and the POD module. It allows the use of a specific POD driver, which would be downloaded to the host, to communicate via the POD module using a private set of objects. For example, a host might support an IPPV application that is tightly coupled to the POD module to provide a specific IPPV implementation.

Extended Channel

The DVS-131 extended channel is a second physical channel that operates identically to the data channel. The extended channel uses four registers to control the exchange of variable length messages between the host and the POD and defines two interrupt enable bits that cause the POD to interrupt the host when it has new data available or when it is free to accept data on the extended channel. The extended channel is activated by Card Enable #2 (CE2#).

The extended channel allows the POD module to act as a communications resource for the host. The out-of-band channel message flows can be directed to host applications to allow two-way, real-time communications between the host application and the cable system.

Content Protection

The content community (primarily the movie studios represented by the MPAA) requires that the POD module interface support a sophisticated content protection system that encrypts the MPEG-2 payload. The content protection system authenticates the host device and allows revocation of service to fraudulent hosts.

Why Is Content Protection Required?

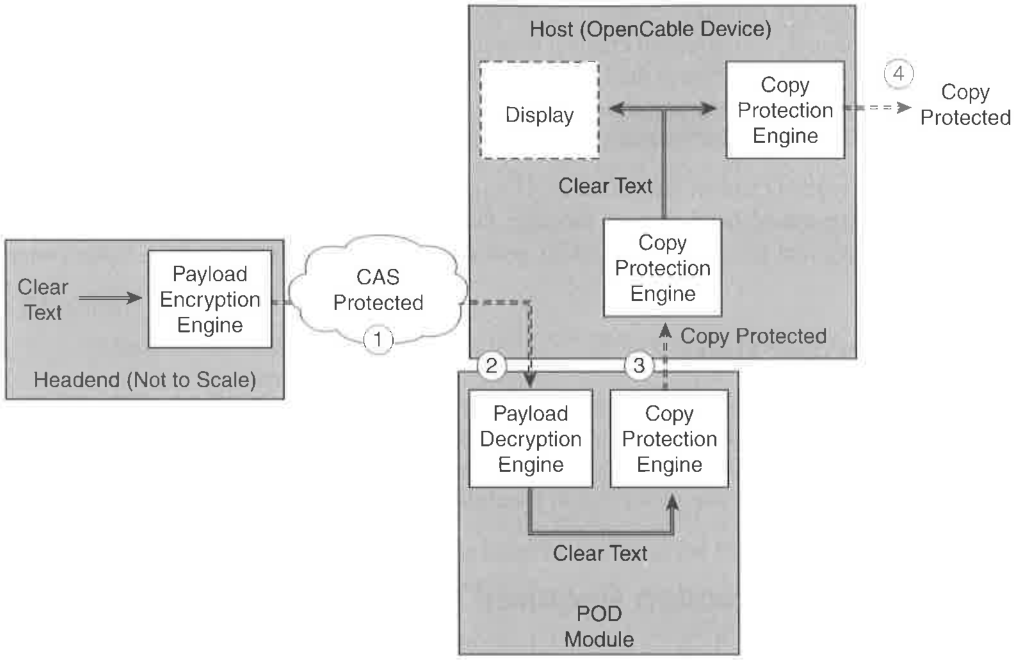
The combination of digital services, multimedia PCs, and the Internet pose a serious threat to any owner of copyright material. Digital picture quality is improved almost to the quality of the master copy. Multimedia PCs provide unlimited generation digital copying without quality loss. Finally, the Internet provides an inexpensive and rapid distribution mechanism for digital copies. For these reasons, the movie studios have adopted a consistent position that they will not release digital content until adequate content protection mechanisms exist.

The Motion Picture Association of America (MPAA) consider the POD interface to be a potential source of digital media because the POD module could be inserted into the PCMCIA slot of a standard personal computer. With appropriate software, the PC could be made to emulate a host, making it possible to record a clear MPEG-2 multi-program transport stream. Some form of content protection is required to prevent unauthorized copying of the digital transport payload flowing across the POD module interface.

The Content Protection System

The POD module interface is one link in the content distribution chain from the content provider to the consumer. Figure 18-8 illustrates the path of the MPEG-2 payload from the headend via the cable network to the host. (Note that in the case of a cable ready digital television, there is one less interface to worry about because the display is integrated into the host.)

Figure 18-8 *Payload Protection*



The content protection system prevents unauthorized copying of the MPEG payload when it is exposed at any interface in the content distribution chain (the numbers in the following list refer to the numbers on the figure):

- At 1 (OCI-N), the conditional access system (CAS) protects the payload from unauthorized viewing and copying.
- At 2 (OCI-C2), the conditional access system (CAS) protects the payload from unauthorized viewing and copying.
- At 3 (OCI-C2), the POD copy protection mechanism protects the payload from unauthorized copying. (At this point, the conditional access system has done its job of allowing only authorized POD modules to decrypt the payload.)
- At 4, the OCI-C2 copy protection mechanism protects the payload from unauthorized copying. Macrovision copy protection is used for analog NTSC connections. For an IEEE-1394 digital link, 5C digital transmission content protection is employed (see the section The Content Protection System in Chapter 17, "OCI-C1: The Consumer Interface").

In all exposed interfaces (OCI-N, OCI-C2, and OCI-C1), the digital payload is encrypted to prevent unauthorized copying (represented in Figure 18-8 by a dashed line).

The payload is present in *clear text* form (that is, unencrypted) *within* devices. (Clear text is represented in Figure 18-8 by a solid line.) There are three instances of clear text payload:

- Within the headend—At this location, access is securely controlled to authorized technicians.
- Within the POD module—The clear text is present only within the POD ASIC (Application Specific Integrated Circuit), making it very difficult to tap.
- Within the host—The clear text is physically protected by the case of the host. Only the serious pirate will open the case, invalidating the warranty, to make illegal copies of the payload.

Content Protection System Integrity

The content protection system is only as strong as the weakest link in the content distribution chain. Therefore, each link consists of licensed technology, and the conditions of the license dictate the copy protection methods that are employed on the *next* link in the chain. The POD module copy protection license enforces the following requirements:

- The host must monitor and respect the copy control information (CCI) associated with the content. If the host contains a recording device, it cannot be used to record *copy-never* material. (Please refer to Chapter 17 for more information on CCI.)
- The host must employ Macrovision copy protection for analog NTSC outputs.
- The host must employ 5C digital transmission content protection for IEEE-1394 outputs.

Over time, the MPAA might add additional requirements to the POD copy protection license agreement.

POD Interface Copy Protection

POD copy protection is described in detail by SCTE DVS-213. The copy protection system is very similar in operation to a conditional access system and uses some of the 5C digital transmission content protection (DTCP) technology developed for IEEE 1394. POD module interface copy protection includes several steps:

- Host authentication—The POD module authenticates the host before it releases any payload over the OCI-C2 interface. Each host contains a 5C restricted authentication device certificate that is digitally signed by the Digital Transmission License Authority (DTLA). The POD verifies that the host certificate is valid before it binds with the host. (The POD module uses the public key of the DTLA to authenticate the host certificate using public-private key cryptography.)
- Host certificate reporting—The POD module sends the host's device certificate to the headend when it binds with a host where it is stored in a database.

- Modified Diffie-Hellman key exchange—The POD module and the host exchange random numbers to generate a shared secret key. This key is refreshed periodically to reduce vulnerability to brute-force key search attacks. (A brute-force attack tries every possible key until the correct key is found.)
- Payload encryption—The POD module encrypts the MPEG-2 payload using a standard 56-bit DES algorithm. The POD module uses a session key (derived from the shared key generated by the Diffie-Hellman exchange) to encrypt the payload.
- Authentication of copy control information (CCI)—The CCI is sent to the POD, protected by the conditional access system. The POD module sends a CCI message, in the clear, to the host across the data channel. CCI authentication is achieved by using information contained in the CCI message to compute the derived session key. Any attempt at tampering with the CCI message causes the host to compute an invalid session key, preventing it from decrypting the protected content.

These steps ensure that is very difficult for the customer to make illegal copies of the payload. Nevertheless, a serious pirate could modify (or even manufacture) *fraudulent hosts*, which are hosts that are specifically designed to circumvent the copy protection system. Experience with conditional access system piracy shows that fraudulent devices are usually cloned from a single valid host. Therefore, a mechanism is implemented to *revoke* a cloned 5C restricted authentication device certificate.

Host Revocation

If a pirate modifies or manufactures hosts to produce fraudulent clones, it is usually possible to discover identity of the cloned 5C restricted authentication device certificate. This can be done in two ways:

- The POD module reports a 5C restricted authentication device certificate to the headend when it binds with a host. All valid hosts have unique certificates, so if any duplicate certificates are reported this indicates a cloned device.
- The fraudulent host can be recovered from the field.

When a cloned 5C restricted authentication device certificate has been discovered, the content providers have two ways to prevent further piracy:

- Deny service to affected channels—for example, premium movie channels.
- Deny service to affected events (or programs)—for example, pay-per-view or video-on-demand events.

This approach is called *service revocation* because it disables services using the conditional access system instead of revoking the host itself. Service revocation represents a compromise between the content providers and the consumer electronics manufacturers. In contrast, *device revocation* prevents the host from viewing any protected content. CE manufacturers are very concerned about device revocation—effectively, the screen goes dark and they have an irate customer whose digital television suddenly no longer works with any protected content. Service revocation is less draconian but still prevents piracy of premium content at the discretion of the service provider and allows the service provider to make a judgement call on which services (or events) to deny to a fraudulent host.

Applications

Now that the operation of the POD module has been described, it is possible to describe how the POD module can be used in a retail environment. There are several different classes of retail OpenCable device:

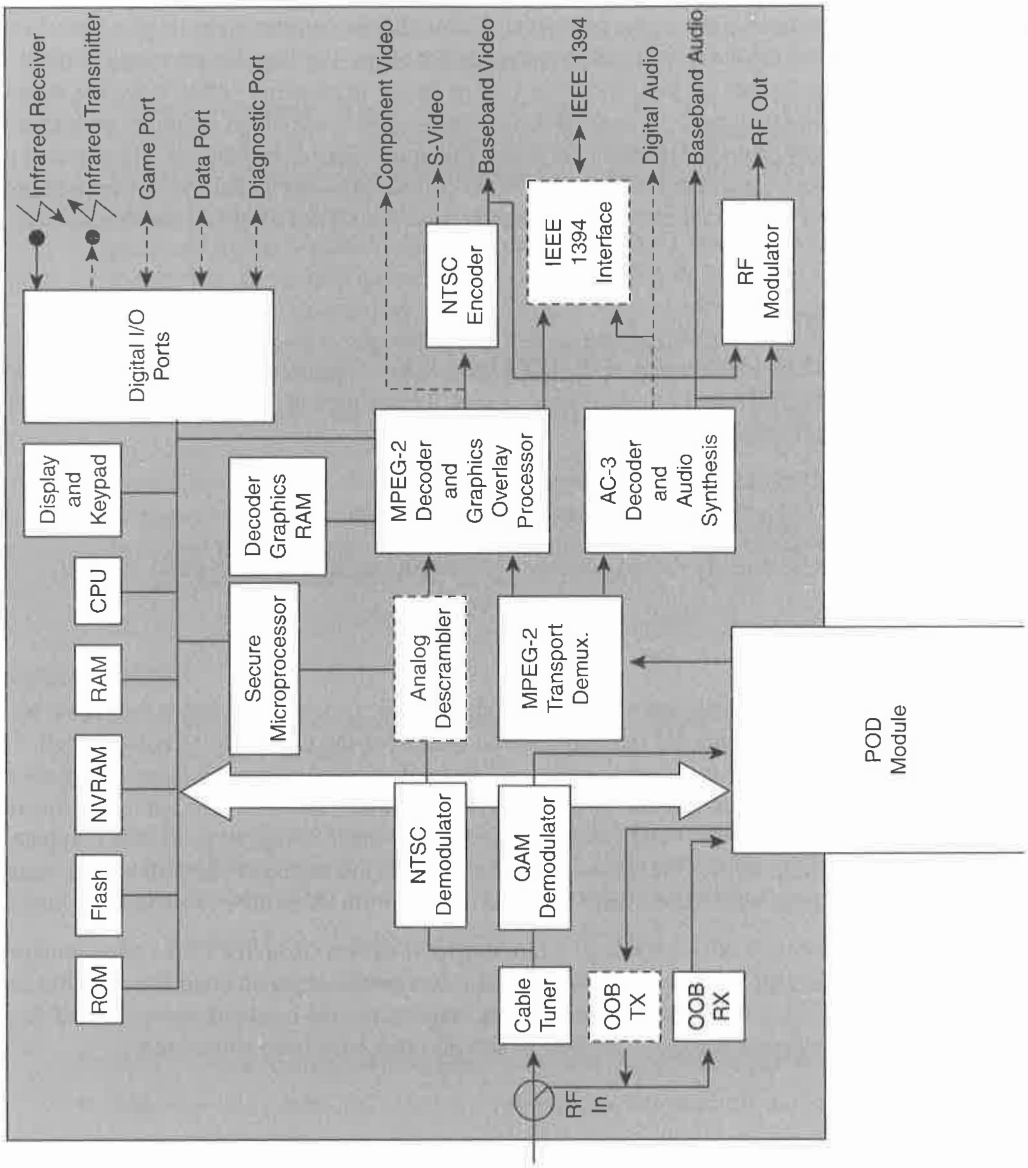
- Digital set-top
- Digital set-top with DOCSIS cable modem
- Cable ready digital television (optionally with a DOCSIS cable modem)

Digital Set-Top

Figure 18-9 shows how the POD module can be incorporated into a digital set-top (see Chapter 6, Figure 6-1) to implement a digital set-top that could be sold at retail. The POD module makes the conditional access and out-of-band communications functions *portable* by placing them in a customer-replaceable module. The customer purchases the digital set-top and leases the POD module from the local cable company (the cable company retains ownership of the POD module). Upon moving, the customer can still use the same digital set-top but must lease a different POD module from his or her new cable television supplier.

The entire MPEG-2 multi-program transport stream (from the QAM demodulator) is fed into the POD module. The POD module is responsible for all conditional access functions: authorizing services in response to messages from the headend controller and decrypting the encrypted MPEG-2 payload of services that have been authorized.

Figure 18-9 *Digital Set-Top*



In addition, the POD module terminates the out-of-band channel. The block labeled OOB RX (out-of-band receiver) demodulates the QPSK signal and forwards it to the POD module. Two different OOB communication methods (DVS 167 and DVS 178, see Chapter 5) are currently used in digital cable systems. The appropriate type of POD module is supplied by the customer's cable operator.

The out-of-band transmitter circuit is optional (labeled OOB TX in the diagram). It is not required for subscription services, but an out-of-band transmitter is required for interactive services (see Chapter 8, "Interactive Services") and on-demand services (see Chapter 10, "On-Demand Services").

The analog de-scrambler is problematic because there is, as yet, no adopted standard for a replaceable module. It is unlikely that a retail digital set-top will contain any analog de-scrambling circuitry.

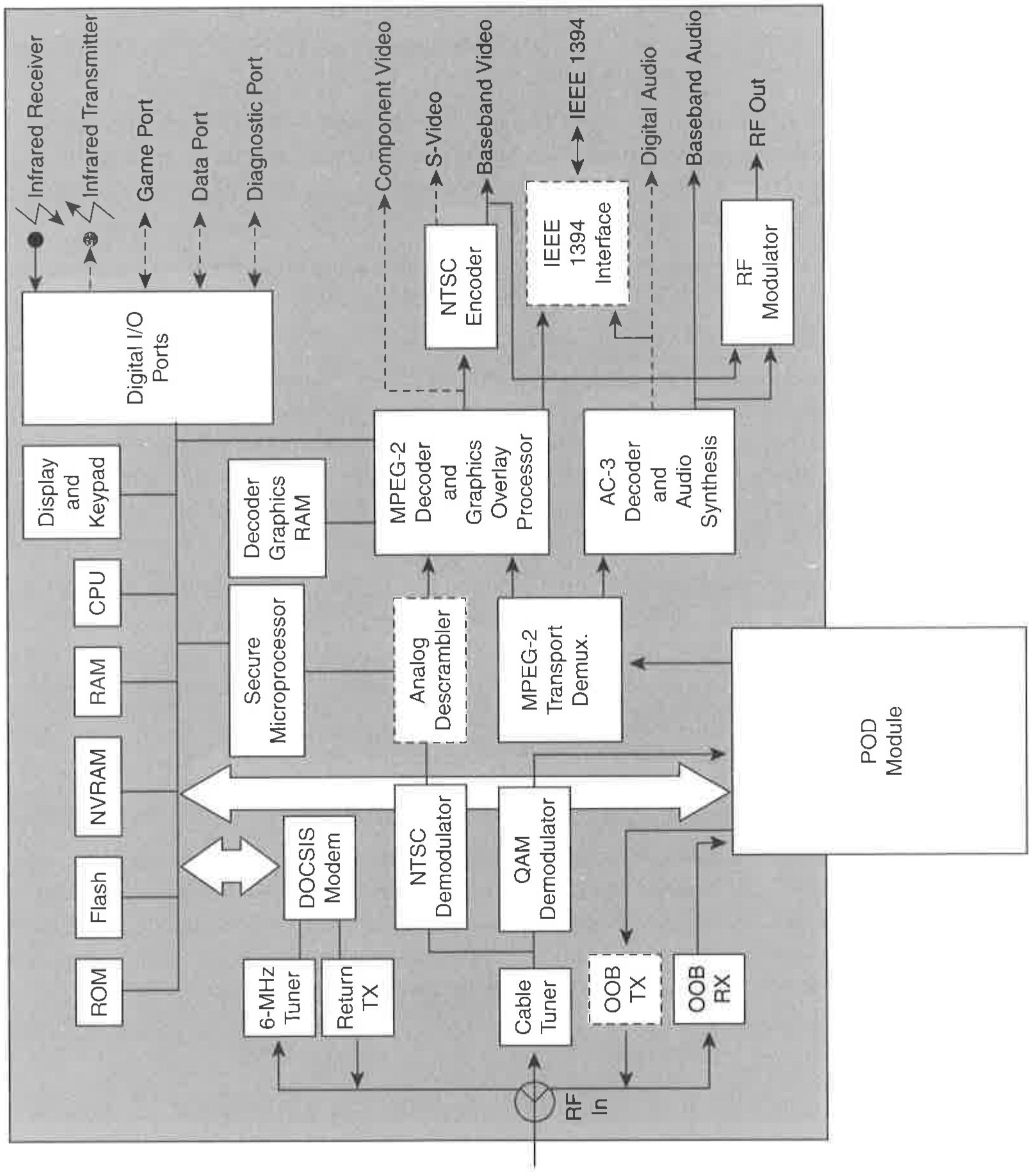
Some cable operators (notably Time Warner Cable) have decided to simulcast all analog scrambled channels in digital form so that analog de-scrambling circuitry is not required in a digital set-top. This approach requires additional investment at the headend and consumes more cable spectrum, but it reduces set-top cost and provides a migration path away from analog scrambling. There is also some early indication from the FCC that this approach satifies the Report and Order requirement for a separate analog de-scrambling module.

The retail set-top provides competition in the digital set-top marketplace by allowing the customer a choice of features and price. For example, additional features, such as a second tuner or a hard disk, could be added to the digital set-top. Another feature, which has generated a lot of interest, extends the communications capabilities of the digital set-top by adding a DOCSIS cable modem.

Digital Set-Top with DOCSIS Cable Modem

Figure 18-10 is an example of the implementation of a digital set-top with an integrated DOCSIS cable modem. Operation is identical to a standard (that is, non-DOCSIS) set-top except that the out-of-band channel is replaced by the DOCSIS channel. Nevertheless, the out-of-band receiver might still be required to receive conditional access messages for backward compatibility with existing cable systems.

Figure 18-10 *Digital Set-Top with DOCSIS Cable Modem*



The DOCSIS cable modem provides a high-speed communications resource that can support interactive applications (particularly Internet applications). To support the DOCSIS modem, the cable operator must provide the same network infrastructure as for a standalone DOCSIS cable modem, and this infrastructure can be shared between the population of standalone cable modems and digital set-tops.

General Instrument has announced a digital set-top with equivalent functionality to Figure 18-10 called the DCT-5000. Scientific Atlanta has also announced a DOCSIS-based digital set-top called the Explorer 6000.

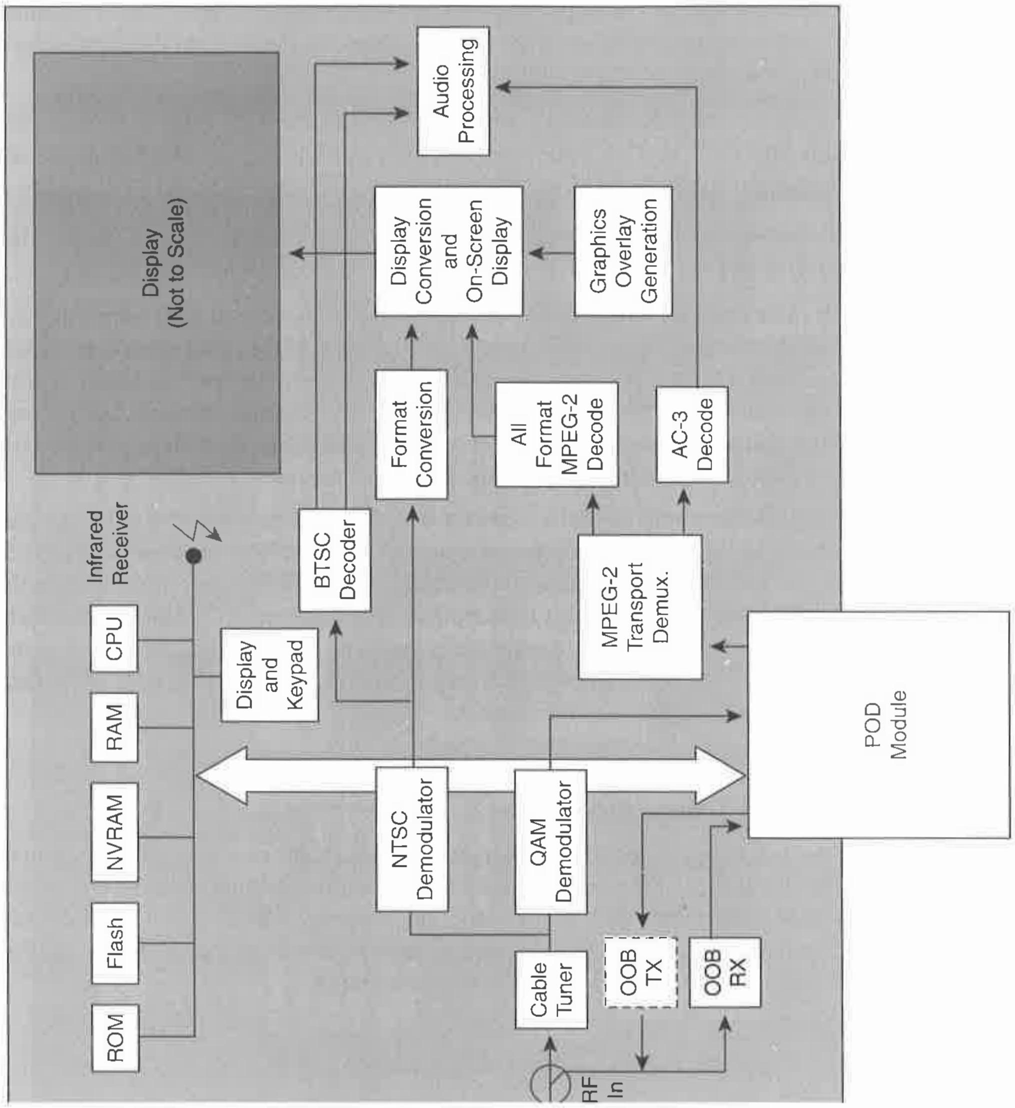
The digital set-top with an integrated DOCSIS modem raises some interesting issues for the cable operator and the customer:

- The cable operator would like to recover the costs associated with supporting a DOCSIS channel. These costs include provisioning of the cable modem termination s ystem (CMTS) in every hub, and building a high-speed network backbone. The cable modem business is based on a subscription service of approximately $40 per month. Will a customer who purchases a set-top with a DOCSIS modem be prepared to pay this kind of monthly premium for the additional services?
- The customer would naturally expect a wide range of new services to be associated with the addition of a DOCSIS cable modem in the set-top. However, the DOCSIS cable modem does not provide the services, only the communications link. In the personal computer model this is acceptable because every PC comes with a Web browser, and a wide range of software is available for download from the Internet. Maybe the DOCSIS-enabled digital set-top will become more like a PC to provide the new services that the customer expects.

Cable Ready Digital Television

Figure 18-11 is an example of the implementation of a cable ready digital television (CR-DTV). The integration of digital set-top and television functions allows reduction of overall cost (because components such as the power supply, tuner, MPEG-2 and AC-3 decoders, and CPU subsystem are shared). This can be seen by comparing figure 18-11 with Figure 17-4 (in Chapter 17), which provides the same functions.

Figure 18-11 *Cable Ready Digital Television*



The CR-DTV has generated tremendous interest in the cable industry, in the consumer electronics industry, and at the FCC. There are some compelling advantages to cable ready devices:

- The cost of an integrated device can be considerably less than two separate devices. In fact, Moore's Law naturally pushes all consumer electronics manufacturers to higher levels of integration just to stay competitive.
- The cable operators currently provide only basic services to about 50 percent of their customers. If these customers could purchase impulse pay-per-view services without the need for a set-top, the cable operator could realize significant additional revenue.
- Many customers dislike the additional complexity introduced by set-tops. Although customers like the additional features that set-tops provide (such as electronic program guides, expanded choice of services, digital quality, and impulse pay-per-view ordering), many customers would prefer an integrated device with the same features.

Nevertheless, one of the requirements that the cable industry views as important when considering the definition of a CR-DTV is an IEEE 1394 interface so that a digital set-top can be added later to upgrade the service to a customer. Moreover, it is difficult to agree on standards for the CR-DTV. Not only does a CR-DTV have to meet a gamut of electrical specifications but it must also provide a set of services. The Joint Engineering Committee's Digital Standards Sub-Committee has been wrestling with the definition of a cable ready receiver for some time (see Chapter 13, "OpenCable Architectural Model"). This process is highly political (as well as highly technical) because there are many different interests represented.

From a cable operator's (and customer's) point of view, the CR-DTV should be able to provide all the services that are currently supported by a digital set-top. *Comprehensive cable ready* operation includes support of the following services:

- Emergency alert system (EAS)
- Navigation
- Impulse pay-per-view (IPPV)
- On-demand services
- General messaging
- Interactive services

Emergency Alert System

The FCC has mandated that cable systems support the emergency alert system (EAS), as described in Chapter 12, "Why OpenCable?" The EAS overrides *analog* channels by IF switching at the headend, but this method does not work well for digital channels:

- Overriding digital channels at the headend is difficult and expensive. For analog channels a simple IF switch is sufficient, but for digital channels this does not work because each 6 MHz QAM channel carries a multiplex of *compressed* digital programs. (To overlay text or graphics into a digital program, you have to decode it, overlay, and then reencode.)
- Some services provided in a digital system are not provided by a digital program. For example, if the customer is checking stock quotes by means of an interactive service, there is no program to override.

For these reasons, EAS is implemented using digital messaging, and the cable ready device must be able to correctly act on EAS messages. In response to an emergency alert system message, the host displays a text message, plays an audio message, or force-tunes to another channel. EAS messages are delivered to the host by means of the out-of-band and/or the in-band (QAM) channel. DVS-208 and EIA-814 (a single standard developed under the auspices of the JEC DSSC) define the format of the EAS messages. A cable ready device, with an OOB receiver, ignores in-band EAS messages in favor of out-of-band messages.

In-band carriage uses MPEG-2 private sections to insert EAS messages in the same PID used to carry in-band Service Information. Out-of-band carriage uses a data carousel (or similar) mechanism that is defined by the cable operator. The POD module forwards EAS messages across the extended channel using MPEG-2 private section syntax, as defined by SCTE DVS-216.

Navigation

Navigation includes channel numbering and electronic program guide information. Channel numbering identifies the display channel number, which is not directly related to the frequency of the channel in a digital system (channel numbering is contained in the aptly named *virtual channel table*). Cable systems use channel numbers that consist of one number, whereas the ATSC A/65 standard defines a two-part channel naming and numbering scheme for terrestrial digital broadcast.

An electronic program guide (EPG) allows the user to navigate to available services, including basic channels, premium channels, impulse pay-per-view, interactive services, and on-demand services. Program guide data can be delivered to the navigation application by means of the in-band channel and/or the out-of-band channel:

- Program and System Information Protocol (PSIP, ATSC standard A/65) describes the program numbering and the program events carried in a digital multiplex. This standard is used by digital terrestrial broadcasters and is sent in-band. In-band PSIP information typically describes only the digital multiplex in which it is sent, and this forces a single-tuner host device to periodically scan through all channels to accumulate program guide information in memory.
- The out-of-band channel is also used to deliver Service Information (SI). The format of out-of-band SI is defined by DVS-234. DVS-234 includes a number of profiles that may be used to send additional information, such as two-part channel numbering, rating information, and program guide information.
- Cable operators use proprietary guide data formats to support specific EPG implementations. The program guide data is sent in the out-of-band channel and describes the entire range of services offered by the cable system. Sending the program guide data on the out-of-band channel conserves system bandwidth because the guide data is sent only once. The EPG is always up to date because the set-top continuously receives data via the out-of-band channel.

The POD forwards SI received on the out-of-band channel to a cable ready host over the extended channel. The POD encapsulates SI into MPEG-2 private sections for transfer across the extended channel (as defined by DVS-216). This method is designed to simplify the cable ready device design by putting the SI into the same format as in-band SI.

Impulse Pay-per-View

A cable ready digital television might support the purchase of impulse pay-per-view (IPPV) events. IPPV processing is split into two parts as follows:

- All security-related and billing functions are in the POD module.
- All user interface functions are in the host.

The IPPV API is specified by *Generic IPPV Support* in section 6.10 of DVS-131 and covers common functions related to IPPV purchase, IPPV cancel, and IPPV purchase review.

On-Demand Services

On-demand services can be modeled as an IPPV event where the program stream is dedicated to an individual subscriber. The on-demand application executes in the host and supports all the user interface functions. The generic IPPV support API can be used for VOD event purchases.

The additional streaming media control functions (that is, pause, play, fast-forward, and rewind) can be supported using DSM-CC user-to-user messages, for example. The extended channel provides the communication path for on-demand signaling (see DVS-216). After an on-demand session control is established via the session creation interface, signaling messages can be exchanged transparently between the host and the cable system.

General Messaging

General messaging supports the display of HTML 3.2–formatted text messages by the host device in response to a request from the POD module.

Interactive Services

Interactive services are supported by applications executing on the cable ready receiver—for example, an e-mail or game application. To advertise interactive services, a mechanism is required to deliver information about applications to the host, and the application service protocol (ASP) (DVS-181) is used for this purpose. Typically, interactive services are not associated with a streaming media service, so information about them is delivered via the out-of-band channel. The ASP is passed to the host via the extended channel.

The extended channel also provides the communication path for interactive service signaling. After an interactive service session is established via the session creation interface, messages can be exchanged transparently between the host and the cable system.

Issues for Cable Ready Devices

To support the services described in the preceding sections, a cable ready device must contain the appropriate software applications. There are several possible ways to provide applications:

- Each manufacturer of a cable ready device could independently develop applications. This works only for services that are fixed and standardized—for example, support of EAS messages.
- The service developers could license applications to the manufacturer of cable ready devices. This does not work very well, because each cable operator uses different licensed applications to support electronic program guides, impulse pay-per-view, on-demand services, and interactive services. To be portable, a cable ready device would have to license *all* variants of *each* application.
- The cable operator could download applications to the cable ready device to support the offered services. The drawback to this approach is that each application would have to be ported to and certified against every different model of cable ready device.

The most promising solution to the software application problem is to establish a common middleware for all OpenCable devices. Each application would have to be ported and certified against the middleware only once. In addition, each manufacturer would have to port the middleware to the OpenCable device only once.

Summary

This chapter discussed the requirements for a replaceable security module. The POD module satisfies two requirements—separation of the conditional access system and adaptation to the out-of-band communications system used to carry conditional access system messages. The POD module interface (OCI-C2) includes an MPEG-2 multi-program transport interface, an out-of-band interface, and a CPU interface. The operation of each interface is defined by DVS-131, DVS-213, and DVS-216.

The POD module can operate in one-way, two-way, and DOCSIS-based networks, and the potential advantages of using the DOCSIS cable modem standard for out-of-band communications are discussed. DVS-216 allows the POD module to provide a two-way communications resource to the host via the out-of-band channel.

The MPAA requires that the POD module interface support a sophisticated content protection system (DVS-213) that encrypts the payload to prevent unauthorized copying. The content protection system authenticates the host device and allows revocation of service to fraudulent hosts.

The POD module interface enables the development of OpenCable devices that can be made available through retail distribution channels. Nevertheless, significant issues have to be solved to make cable ready digital television a reality. These issues include the ratification of a number of standard protocols to support Emergency Alert System messaging (DVS-208, EIA-814) and navigation (DVS-234). In addition, electronic program guides, impulse pay-per-view, on-demand services, and interactive services require software applications in the OpenCable device.

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DVS-213 Revision 2. "Copy Protection for POD Module Interface." SCTE DVS. June 1, 1999.

DVS-216 Revision 3. "Proposal for MPEG Sections in POD API." SCTE DVS. August 6, 1999.

DVS-217 Revision 1. "Point-of-Deployment (POD) Module Power Requirements." SCTE DVS. April 15, 1999.

DVS-221 Revision 1. "Point-of-Deployment (POD) Module Low Level Initialization (Informative)." SCTE DVS. April 15, 1999.

DVS-222 Revision 1. "Point-of-Deployment (POD) Module Attribute and Configuration Registers." SCTE DVS. April 15, 1999.

DVS-223 Revision 1. "Standby Power Management Control for the Point-of-Deployment (POD) Module." SCTE DVS. March 8, 1999.

Internet Resources

Personal Computer Memory Card International Association (PCMCIA)

http://www.pcmcia.org

SCTE DVS documents

http://www.cablelabs.com

DOCSIS specifications at the DOCSIS Web site

http://www.cablemodem.com

EPA ENERGY STAR Program

http://www.epa.gov/appdstar/home_electronics/

GLOSSARY

A

AAL. ATM adaptation layer, used to adapt variable length packets to fixed-length ATM cells.

analog broadcast service. One or more events transmitted via an analog transmission channel.

analog channel. An AM-VSB waveform with a bandwidth of 6 MHz used for transporting an NTSC signal from the headend to the customer's home.

ANSI. American National Standards Institute.

API. Application programming interface. The software interface to system services or software libraries.

application server. Application servers provide application services. Although some of these services will be time-critical in nature, they do not have the high-bandwidth requirement of media servers. Application servers provide services such as database services, network management services, and transactional and electronic commerce services.

artifact. Any video or audio degradation of a signal due to digital processing, particularly compression.

ASI. Asynchronous serial interface. A DVB standard for the transfer of MPEG-2 transport streams.

aspect ratio. The ratio of width to height of a picture. Standard definition television uses a 4:3 aspect ratio. High definition television uses a 16:9 aspect ratio.

ATM. Asynchronous Transfer Mode. A switching and transport protocol for efficient transmission of both constant-rate and bursty information in broadband digital networks. The ATM digital stream consists of fixed-length packets called *cells*; each one has a 5-byte header and a 48-byte information payload.

ATSC. Advanced Television System Committee.

author. A person who creates applications for digital set-top converters.

B

baseband. An unmodulated signal. Baseband video refers to a video signal before it is modulated onto an RF carrier.

BER. Bit error rate. The number of erroneous bits divided by the total number of bits over a stipulated period of time. Usually expressed as a number and a power of 10, per second.

B-frames. Bidirectional frames. MPEG-2 frames that use both future and past frames as a reference. This technique is termed *bidirectional prediction*. B-frames provide the most compression. B-frames do not propagate coding errors because they are never used as a reference.

BFS. Broadcast file system. A data carousel system by which application data can be stored on an application server and transmitted frequently to the set-top converters for application use.

block. An 8-by-8 array of pel values or DCT coefficients representing luminance or chrominance information.

broadcast. A service that is delivered to all customers. Each customer may select a particular broadcast channel out of many.

broadcast application. An application running on the set-top converter that is loaded through in-band information, inserted either at the headend or by a content provider farther upstream.

BTSC. Broadband Television Standard Committee.

C

CA. Conditional access.

CableLabs. Cable Television Laboratories. The research consortium of the cable television operating companies and originator of the DOCSIS and OpenCable specifications.

cascade. A set of series-connected components (usually amplifiers).

CATV. Community antenna television.

CBR. Constant bit rate. Transmission of data at a fixed data rate. Most frequently used in conjunction with CBR encoding of MPEG-2 video.

CEMA. Consumer Electronics Manufacturers Association.

chroma. Chrominance. The color information in a television signal.

closed captioning. A system used to transmit captioning information in the Analog VBI or MPEG-2 video user data to hard-of-hearing viewers. Since extended to support V-chip rating data.

CMOS. Complementary metal-oxide silicon.

CMTS. Cable modem termination system (for cable modems).

commercial insertion. A mechanism to insert commercials in *ad. avails* in broadcast programming. In the digital domain, digital program insertion performs this function.

conditional access and encryption. A system that provides selective access to programming to individual customers in exchange for payment.

content protection. A mechanism to protect the unathorized copying of video and audio programming.

CPTWG. Copy Protection Technical Working Group.

CPU. Central processing unit.

CRC. Cyclic redundancy check; used to detect errors in digital messages.

CSMA/CD. Carrier sense multiple access/collision detection. The shared media access control mechanism used by Ethernet.

customer. A customer who has subscribed to cable service.

D

DAVIC. Digital Audio Video Interactive Council. An international consortium working on the development of standards for interactive television.

DBDS. Digital Broadband Delivery System. Scientific Atlanta's implementation of the Pegasus architecture.

dBmV. Decibels with respect to 1 millivolt in a 75 ohm system.

DCG. Data channel gateway. The point at which a traditional IP-based network is interfaced to the HFC network.

DHCP. Dynamic Host Configuration Protocol. An Internet standard for assigning IP addresses dynamically to IP hosts.

DHEI. Digital headend extension interface. A proprietary GI MPEG-2 transport interface used by the GI Integrated Receiver Transcoder (IRT).

DigiCipher-II. GI's proprietary conditional access and encryption system for digital video.

digital broadcast service. One or more events transmitted via a digital channel.

digital channel. A QAM signal with a bandwidth of 6 MHz used for transporting an MPEG-2 transport stream from a headend to a digital set-top converter. A digital transmission channel is capable of supporting a data rate of 26.9703 Mbps (after FEC) when modulated using 64-QAM, or 38.8107 Mbps (after FEC) when modulated using 256-QAM.

digital stream. The digital equivalent of an analog television channel. A digital stream contains compressed audio and video information to provide a single program. A digital stream will typically contain a single video and multiple audio components with subtitles and other related information.

discrete cosine transform. A mathematical transform that can be perfectly undone and which is useful in image compression.

distribution hub. A signal distribution point for part of a cable system.

DOCSIS. Data-Over-Cable Service Interface Specification for retail cable modems.

Dolby AC-3. The audio encoding format adopted by the ATSC for its advanced television audio encoding. Also known as Dolby Digital.

DPI. Digital program insertion. The technique of splicing one digital stream into another to perform commercial insertion.

DSM-CC. Digital storage management-command and control. Part 6 of the MPEG-2 standard.

DTS. Decoding timestamp. A field that might be present in a PES packet header that indicates the time that an access unit is decoded in the system target decoder.

DVB. Digital Video Broadcast. A European standard for digital television.

DVS. Digital Video Subcommittee. An ANSI-sponsored standardization committee of the SCTE.

E

electrically-eraseable programmable read-only memory. EEPROM. EEROM that can be electrically erased and reprogrammed.

elementary stream (ES). A generic term for one of the coded video, coded audio, or other coded bit streams. One elementary stream is carried in a sequence of PES packets with one and only one stream_id.

entitlement control message (ECM). Entitlement control messages are private conditional access information that specifies control words and possibly other stream-specific, scrambling, and/or control parameters.

entitlement management message (EMM). Entitlement management messages are private conditional access information that specifies the authorization level or the services of specific set-top converters.

entropy coding. Variable-length lossless coding of the digital representation of a signal to reduce redundancy.

EPG. Electronic program guide. An application that displays television program information, including program name, start time, and duration.

event. A unit of programming, such as a movie, an episode of a television show, a newscast, or a sports game. An event can also be a series of consecutive units of programming.

F

FAT channel. Forward applications transport channel. A data channel carried from the headend to the set-top converter in a QAM modulated channel. MPEG-2 transport is used to multiplex video, audio, and data into the FAT channel.

FCC. Federal Communications Commission.

FCS. Frame check sequence.

FDC. Forward data channel. A data channel carried from the headend to the set-top converter in a modulated channel at a typical rate of 1.5 to 8 Mbps.

FDM. Frequency-division multiplexing. A method of transmitting two or more signals by dividing the available transmission frequency into narrow bands and using each as a separate channel.

FEC. Forward error correction. A technique for regenerating lost data transmissions or error messages.

fiber node. The point at which the optical signal is converted into an electrical signal in an HFC network.

field. For an interlaced video signal, a field is the assembly of alternate lines of a frame. Therefore, an interlaced frame is composed of two fields, a top field and a bottom field.

forward path. A physical connection from a distribution hub to a digital set-top converter. A forward path can support multiple analog channels, digital channels, and forward data channels.

frame. A frame contains lines of spatial information of a video signal. For progressive video, these lines contain samples starting from one time instant and continuing through successive lines to the bottom of the frame. For interlaced video, a frame consists of two fields, a top field and a bottom field. One of these fields will commence one field later than the other.

G

green application. An application that is designed to conserve system or network resources.

GUI. Graphical user interface. A point-and-click style of interaction with the computer user, rather than a strictly character-based display.

H

Harmony DES. The DES-based encryption algorithm agreed upon through the CableLabs Harmony effort.

HDTV. High definition television. Has a resolution of approximately twice that of conventional television in both the horizontal and vertical dimensions and a picture aspect ratio of 16:9. ITU-R Recommendation 1125 further defines *HDTV quality* as the delivery of a television picture that is subjectively identical with the interlaced HDTV studio standard.

headend. The control center of a cable television system, where incoming signals are amplified, converted, processed, and combined into a common cable, along with any origination cable-casting, for transmission to customers.

HFC plant. Hybrid fiber coaxial plant. A cable network featuring optical fiber from a headend location to a fiber node, and coaxial cable from the node to individual homes.

high level. A range of allowed picture parameters defined by the MPEG-2 video coding specification that corresponds to high definition television.

HTML. A presentation language for the display of multiple media contents, typically used on the Internet.

HTTP. Hypertext Transport Protocol. The transport layer for HTML documents over IP.

Huffman coding. A type of source coding that uses codes of different lengths to represent symbols that have unequal likelihood of occurrence.

I

ICG. Interactive cable gateway. The conversion point from the core network to the HFC transport network. Core connections are terminated and MPEG-2 transport streams are reconstructed.

IEC. International Electrotechnical Commission.

I-frames. Intra-coded frames. MPEG-2 frames that are coded using information present only in the frame itself and not depending on information from other frames. I-frames provide a mechanism for random access into the compressed video data. I-frames employ transform coding of the pel blocks and provide only moderate compression.

IP. Internet Protocol. The network layer (layer 3) of the OSI Internet Protocol, providing connectionless datagram service.

IPPV. Impulse pay-per-view. A movie rental service, such as pay-per-view, but which allows the customer to purchase the right to view the movie or event through an onscreen interface.

ISO. International Standards Organization.

ITU. International Telecommunication Union.

ITV. Interactive television. All forms of interactive television applications, in which the customer can make choices in viewing. This might involve real-time transactions between the customer and the headend.

J

JEC. Joint Engineering Committee of EIA and NCTA.

K

Kbps. Kilobits per second.

KHz. Kilohertz. 10^3 of a hertz, frequency unit.

L

LAN. Local-area network.

layer. One of the levels in the data hierarchy of the MPEG-2 video and system specification.

level. A range of allowed picture parameters and combinations of picture parameters in MPEG-2.

linear optical transmission. A technique that modulates the intensity of the optical signal (from a laser), which is used in HFC systems.

local interactivity. A class of client-only applications that are downloaded to the set-top converter and interact only locally with the customer. These generate no headend impact but place considerable limitations on the application. However, this form of interactivity might become common before the wide-scale deployment of full-service networks, because it is simpler to engineer and requires only a one-way path to the set-top terminal.

luma. Luminance. The brightness of a television picture.

M

macro-block. In MPEG-2 compression, a macro-block consists of four blocks of luminance, one Cr block, and one Cb block.

main level. A range of allowed picture parameters defined by the MPEG-2 video coding specification with maximum resolution equivalent to ITU-R Recommendation 601.

main profile. A subset of the syntax of the MPEG-2 video coding specification that is expected to be supported over a large range of applications.

media asset. A movie, video clip, music clip, or any other piece of content or programming (usually when stored on a media server).

media server. Servers responsible for the delivery of time-critical media assets to client devices through the core and HFC network.

meta-data. Data that describes a media asset, such as its type, location, or duration.

modulation. The process of imposing information on an RF carrier by varying the amplitude, frequency, or phase of the carrier to allow signals to be frequency-division multiplexed in a broadband network.

motion vector. A pair of numbers that represent the vertical and horizontal displacement of a region of a reference picture for prediction.

MP@ML. Main profile at main level.

MP@HL. Main profile at high level

MPEG. Motion Picture Experts Group. An international standards-setting group, working to develop standards for compressed full-motion video, still image, audio, and other associated information.

MPEG-2. An ISO standard for the compression of video and audio assets. It supports field- and frame-based coding, which is critical for 60 field-per-second interlaced video formats. It also supports a range of resolutions and aspect ratios, and bilateral interpolation (that is, B-frames).

MPEG-2 Systems. An ISO-IEC international standard for the transport of compressed digital media (video and audio).

MSO. Multiple system operator.

N

narrowcast. A service delivered to a subset of customers. An on-demand service is narrowcast to a single customer. Other customers can receive the electrical signal but are prevented from viewing it by the conditional access system.

NATBS. Joint EIA/CVCC Recommended Practice for Teletext: North American Basic Teletext Specification (NABTS) (ANSI/EIA-516-88) (May, 1988).

navigation device. The FCC term for a set-top converter.

NCTA. National Cable Television Association.

NMS. Network management system. A system that provides fault and alarm management, configuration management, and equipment management.

NRSS-B. IS 679 Part B National Renewable Security System.

NTSC. National Television Systems Committee. The developers of a color television system that has been adopted as a national standard.

NVRAM. Nonvolatile random access memory. RAM that maintains its contents when the power is turned off.

O

OC-3. SONET Optical Carrier at 155.52 Mbps.

OOB channel. Out-of-band channel. The combination of the forward and reverse out-of-band communications channels. The OOB channel provides an IP-based communication channel between the network and the digital set-top converter.

OpenCable device. An OpenCable-compliant digital set-top converter or cable ready digital television, allowing reception of existing cable television channels and providing the user interface for future, interactive applications.

P

packet. A header followed by a number of contiguous bytes from an elementary data stream. It is a layer in the MPEG-2 system coding syntax.

payload. The bytes that follow the header byte in a packet. For example, the payload of a transport stream packet includes the PES_packet_header and its PES_packet_data_bytes or pointer_field and PSI sections, or private data. A PES_packet_payload, however, consists only of PES_packet_data_bytes. The transport stream packet header and adaptation fields are not payload.

PC. Personal computer. A computer designed for single-user operation. Examples include a Macintosh or an IBM PC-compatible.

PCMCIA. Personal Computer Memory Card International Association.

peak usage. The highest percentage of total interactive customers who are active at any given time. The network must be engineered to support a certain number of interactive sessions simultaneously.

P-frames. Predicted frames. MPEG-2 frames that are coded with respect to the nearest *previous* I- or P-frame. This technique is termed *forward prediction*. P-frames provide more compression than I-frames and serve as a reference for future P-frames or B-frames. P-frames can propagate coding errors when P-frames (or B-frames) are predicted from prior P-frames where the prediction is flawed.

PHY. Physical layers.

PID. Packet identifier. A unique integer value used to associate elementary streams of a program in a single or multi-program transport stream.

PIN. Personal identification number.

POD module. Point-of-deployment module. Used to enable retail availability of navigation devices.

PowerKEY. Scientific Atlanta's proprietary conditional access and encryption system for digital video.

ppm. Parts per million.

PPV. Pay-per-view. A movie rental service that requires the customer to call the cable company in advance of a movie or event, so the set-top converter can be programmed to receive the encrypted stream

presentation timestamp (PTS). A field that might be present in a PES packet header that indicates the time that a presentation unit is presented in the system target decoder.

profile. A defined subset of the syntax specified in the MPEG-2 video coding specification

program. A collection of program elements. Program elements can be elementary streams. Program elements need not have any defined time base; those that do have a common time base are intended for synchronized presentation.

program clock reference (PCR). A timestamp in the transport stream from which MPEG decoder timing is derived.

program specific information (PSI). PSI consists of tabular data that is necessary for the de-multiplexing of transport streams and the successful regeneration of programs.

PSTN. Public switch telephone network.

Q

QAM. Quadrature amplitude modulation. A signaling modulation scheme that greatly increases the amount of information that can be carried within a given bandwidth.

QPSK. Quaternary phase shift keying. A signaling modulation scheme in which the phase of the signal is changed. It is used for transmitting digital signals over an analog medium.

R

resident application. An application running on the set-top converter that stays resident in the set-top memory.

Reverse Data Channel (RDC). A communications channel carried from the set-top converter to the headend in a modulated channel at a typical rate of 1.5 to 3 Mbps.

reverse path. A physical connection from a digital set-top converter or cable modem to a distribution hub. A reverse path can support multiple reverse data channels.

RF. Radio frequency.

RFC. Request for Comments. An IETF standard.

rms. Root mean square.

RPC. Remote procedure call. The capability of client software of invoking a function or procedure call on a remote server machine.

S

SAP. Secondary audio program. A second monophonic audio stream (typically in a second language) delivered on the right channel of a stereo broadcast.

scrambling. The alteration of the characteristics of a video, audio, or coded data stream to prevent unauthorized reception of the information in a clear form. This alteration is a specified process under the control of a conditional access system.

SCTE. Society of Cable Telecommunications Engineers.

SDH. Synchronous digital hierarchy.

SDTV. Standard definition television This term is used to signify a *digital* television system in which the quality is approximately equivalent to that of NTSC. This equivalent quality can be achieved from pictures sourced at the 4:2:2 level of ITU-R Recommendation 601 and subjected to processing as part of the bit rate compression. The results should be such that when judged across a representative sample of program material, subjective equivalence with NTSC is achieved. Also called standard digital television.

shared media access control (MAC). A technique for sharing transmission bandwidth in a shared media.

SMPTE. Society of Motion Picture and Television Engineers.

SNMP. Simple Network Management Protocol. An IETF standard protocol for the remote management of equipment over TCP/IP networks.

solicited application. An application that is downloaded by the network at the request of the client application.

S/PDIF. Sony/Philips Digital Interface. A digital interface for transmission of AC-3 audio in compressed digital form.

splicing. The concatenation performed on the system level or two different elementary streams. It is understood that the resulting stream must conform totally to the Digital Television Standard.

SS7. Signaling system 7.

SSL. Secure sockets layer.

system clock reference (SCR). A timestamp in the program stream from which decoder timing is derived.

T

TCP. Transmission Control Protocol. The transport layer (layer 4) of the OSI Internet Protocol, providing reliable transmission of data.

TDMA. Time division multiple access.

TFTP. Trivial file transfer protocol.

ticker. An application that displays data (such as sports scores) on top of another application or analog channel.

U

UDP. User datagram protocol.

V

VBI. Vertical blanking interval. The unused lines in each field of a television signal, seen as a thick band when the television picture rolls over. Some of these lines can be used for teletext and captioning, or might contain specialized data.

VBR. Variable bit rate. Transmission of data at a variable data rate. Most frequently used in conjunction with VBR encoding of MPEG-2 data.

VOD. Video-on-demand. An application through which the customer can rent a video that can fast forward, rewind, and pause. The video is delivered by a media server.

VSB-8. Vestigial sideband modulation with 8 discrete amplitude levels.

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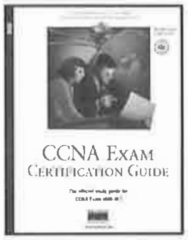

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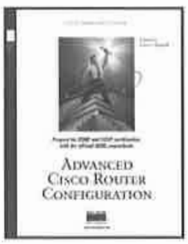

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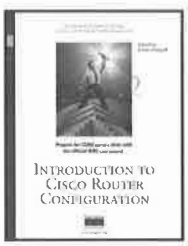

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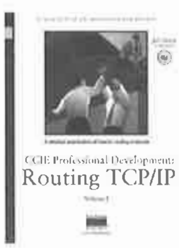

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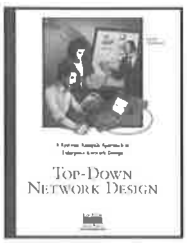

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