♦ Switched Digital Video Access Networks

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Telecommunications service providers are upgrading their network infrastructure to enhance telephony and to enable future video and data services. This discussion focuses on an access network that serves as a platform for transporting telephony and asynchronous transfer mode (ATM) data to the customer premises using fiber-in-the-loop (FITL) technology. The platform provides the building blocks that will enable service providers to furnish a wide variety of offerings, such as interactive and broadcast video, Internet access, and other high-bandwidth data communications. The platform is called the switched digital video (SDV) access network. This paper describes the SDV access network, and it also presents an example of how SDV network elements could be configured with other broadband network elements to provide an interactive video services network.

Introduction

As telecommunications service providers modernize, interest is increasing in upgrading networks to meet not only the near-term need of providing high-quality telephony but also the demand for emerging broadband transport services—for example, interactive video, Internet access, and high-speed data communication.

To address these needs, several new architectures and technologies are proposed, including switched digital video (SDV), hybrid fiber-coax[1,2], asynchronous digital subscriber line (ADSL)[3,4], and broadband ADSL (BDSL)[5].

The SDV access network uses fiber-in-the-loop (FITL) as its key technology, and the service provider can select the extent of deployment. Options are available that facilitate bringing fiber to within a few yards of a house or directly to a hub that serves hundreds of homes. All subscriber and control information is embedded in asynchronous transfer mode (ATM) cells, which are carried in synchronous optical network (SONET)-compatible streams allowing a variety of service options. By using FITL and ATM, the SDV access network can support multiple applications simultaneously. SDV has the flexibility to meet present telephony needs efficiently while enabling future services, including interactive video, Internet access, and digital broadcast video.

The SDV access infrastructure supports both broadband services (such as digital video) and narrowband services (such as telephony). Intrinsic to the SDV system is the ability to switch various information streams (for example, voice, video, and ATM data packets) at the various network elements within the access network. Thus, SDV provides an integrated telephony and broadband services platform. In addition to supporting traditional telephony (narrowband) services, this network also provides the capability of delivering ATM data to the home for interactive SDV services, such as video on demand (VOD) and digital broadcast video. SDV also supports analog broadcast video overlaying.

This paper discusses the SDV access network, its capabilities, functions, and an example of its implementation. The focus of this paper is on the digital video and data-transport platform because telephony and analog broadcasting in the access network are widely discussed and well understood.

Network Overview

The end-to-end topology for the SDV network consists of two levels. Level 1 (L1) consists of telephony and data equipment traditionally associated with the central office (CO) and the SDV transport/access network infrastructure, which is the focus of this paper. Level 2 (L2) includes all ele-

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ments necessary to provide OC-3/OC-12/OC-48 based ATM signals for digital video services from the video information providers (VIP). It also provides channelized National Television Standards Committee signals and analog broadcast services from the VIP. Customer premises equipment, such as the set-top terminal (STT), PC, and the telephone, are also considered to be L2 network equipment.

SDV is a star network that provides an efficient mechanism for ATM transport of baseband signals.[6] The SDV network transmits digital video and telephony signals directly as bits through dedicated ATM transmission paths to a subscriber. The transport system is designed with the following six criteria in mind:

- Large channel capacity to accommodate multiple information providers.
- Format independence to accommodate many signal formats and data rates. For example, formats could range from still frames to high-definition television having varying bit rates.
- Sufficient downstream capacity per subscriber to provide nonblocking service.
- Low-latency reverse channel having sufficient capacity to allow nonblocking real-time navigation for such services as interactive games and work-at-home networks.
- Maintainable network, including operational support system to reduce life-cycle costs.
- Signal security (freedom from signal theft).

Figure 1 illustrates the major elements of the SDV access network. In addition to the transport, switching, and access equipment associated with today's telephony infrastructure, the SDV L1 network includes an L1 gateway complex (L1G), an ATM switch, and a SONET transport network to support the ensemble of digital video services. Delivery of these services will rely on the host digital terminal (HDT), optical network unit (ONU), and power/analog video node. As shown in Figure 1, the L2 network includes the VIP complex consisting of video servers and switches and the STTs at the user end.

L1 SDV access equipment consists of the HDT, ONU, power node and the network interface device (NID). The HDT serves as the integration point for all the narrowband telephony and broadband digital services destined for the end user. One of the functions of the HDT is to format the digital signals from a Class-5 switch and the digital video from the VIPs to the format required by the ONUs. It also performs concentration between the DS0 telephony channels delivered to the ONUs and the feeder trunks connecting to the Class-5 switch. Another function performed by the HDT is to receive the ATM cells over the SONET facilities, select the appropriate ATM cells, and deliver them to the ONUs. ATM signaling streams from the ONUs are aggregated by the HDT and transported to the ATM switch.

The ONU terminates the HDT optical links carrying the telephony and SDV signals and provides the interface between the end customers and the HDT for all SDV services. For example, an ONU can serve up to 16 living units (LUs), and up to 24 narrowband telephony lines are supported by the ONU. The analog and digital signals are combined

Panel 1. Abbreviations, Acronyms, and Terms

ADSL—asynchronous digital subscriber line
ATM—asynchronous transfer mode
BDSL—broadband ADSL
BSS—broadband switching system
CBR—constant bit rate
CO—central office
DBV—digital broadcast video
DSM-CC—Digital Storage Media Command and Control Committee, a standards-setting organization
DSX—digital signals cross-connect
FITL—fiber in the loop
HDT—host digital terminal
L1—Level 1
L1G—Level 1 gateway
L2—Level 2
LDS—local digital switch
LU—living unit
MPEG—Motion Picture Experts Group
NID—network interface device
OC-3—optical carrier level 3
ONU—optical network unit
QPSK—quadrature phase shift keying
RF—radio frequency
SDV—switched digital video
SONET—synchronous optical network
STT—set-top terminal
SVC—switched virtual circuit
UNI—user network interface
VAM—video administration module
VBR—variable bit rate
VIP—video information provider
VOD—video on demand

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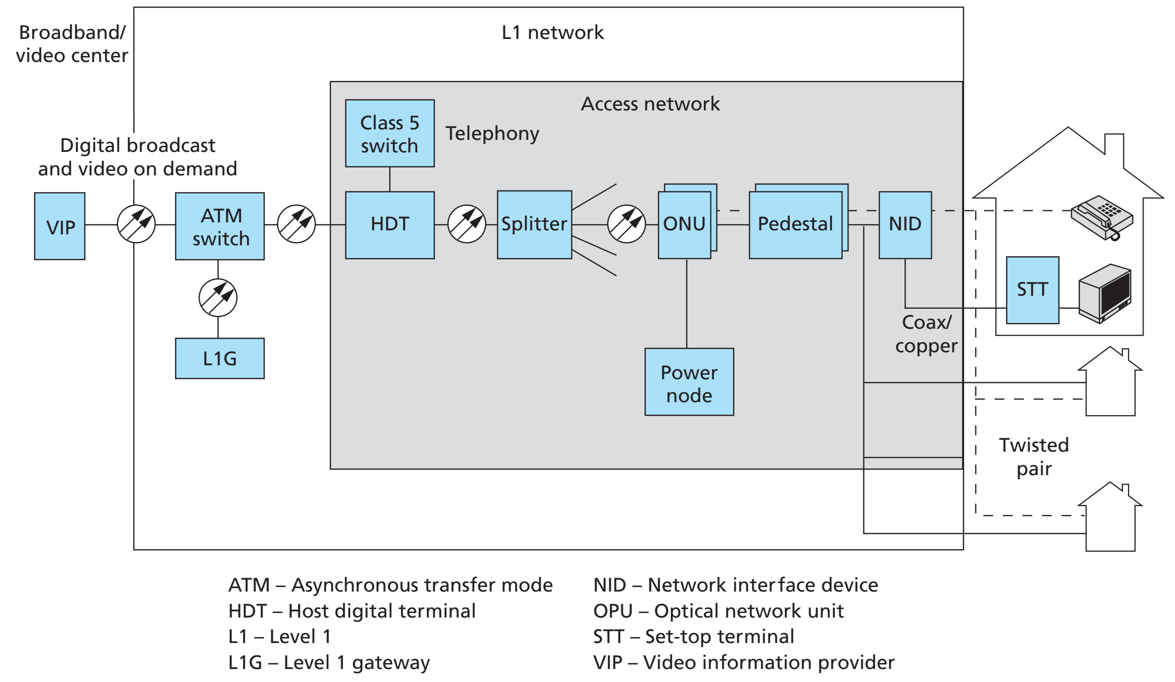

Figure 1.
Network overview that illustrates the major elements of the L1 and L2 parts of the SDV access network.

and transmitted over coax to each LU. The telephony transport streams are demultiplexed in the broadband subsystem and routed to the narrowband subsystem for distribution to the LUs over twisted pairs. Both the coax and twisted pairs are brought to a pedestal for direct connection to an LU.

In some implementations, each drop carries up to 36 Mb/s of digital video payload to the residence. Depending on the network provider, several STTs per LU can be accommodated. The ONU contains active components that require power. Power for the ONU is extracted from the coax cable that runs from the power node to the ONU. The power node provides power for the ONUs and RF-active components over the coaxial cable.

The NID provides an environmentally secure housing for both telephony twisted-pair drops and video/data coaxial drops. The NID is normally located on the side of a living unit. The Class-5 switch provides all narrowband telephony call processing.

Other L1 network elements, such as the ATM switch and L1 gateway switch, control the ATM broadband data. The L1G manages the L1 network to provide a consistent view of the L1 network to the VIPs and the STTs for interactive video services by communicating with the broadband ATM switch, HDTs, STTs, and VIPs. The L1G uses a session-level message set to communicate with the STT and VIP. Through this dialog, the L1G determines what network resources are needed. The L1G then uses network-layer protocol over user network interfaces (UNIs) to the broadband switch and HDT to establish ATM switched virtual circuit (SVC) connections between the STT (at the living unit) and VIP selected by the end user. The L1G serves as the central repository for customer data. Measurements provided by the L1G include session-related counts for billing purposes, as well as network and service usage information.

L1 network elements also perform provisioning, administration, and control of digital broadcast services for subscribers, video information providers, and network providers. It can provision STT information, signaling network addresses in the HDT, and HDT-to-ONU physical path information.

The ATM broadband switch supports SDV capabilities by providing SVCs. The ATM switch interfaces to the L1G, the VIPs, and the HDTs via OC-3 links. The ATM switch, in response to mes-

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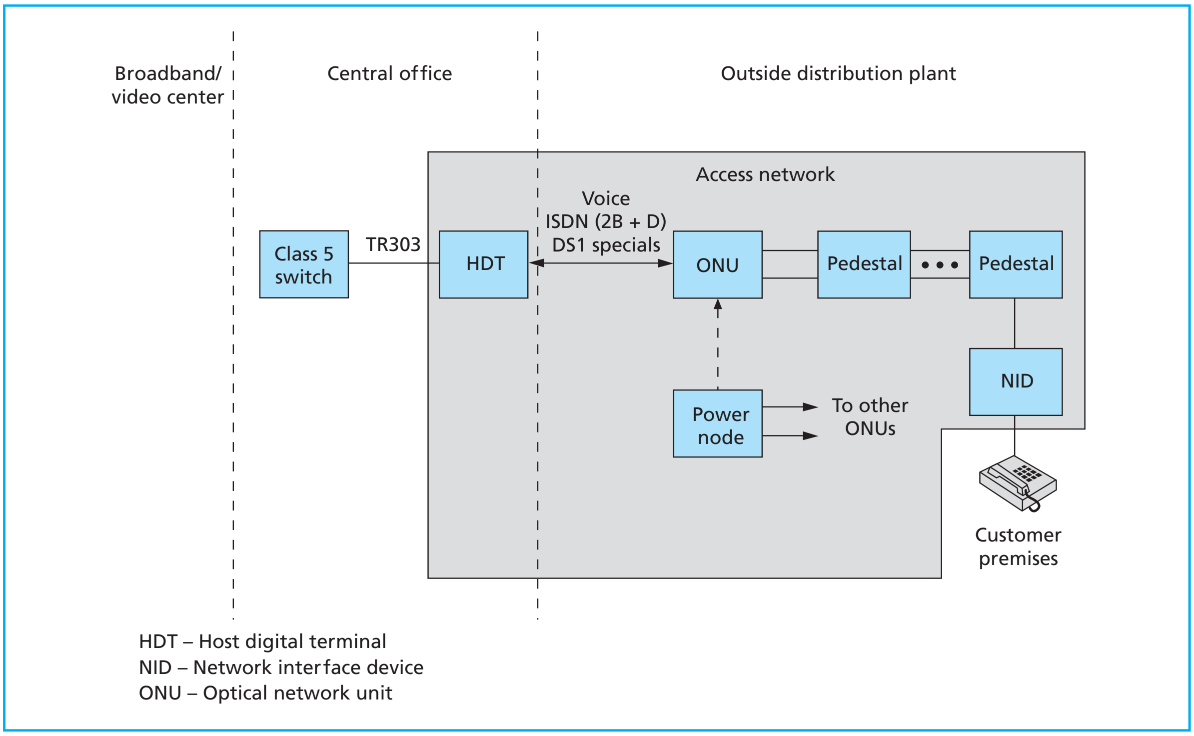

Figure 2.
Major elements of an SDV L1 network for telephony service.

sages from the L1G, provides SVC connections from the VIPs to the appropriate HDT.

L2 components, such as telephone sets, the VIP complex, and STTs are necessary for this network. The VIP complex provides digital video capabilities over SONET/ATM facilities to subscribing customers. The STT is required to terminate ATM links for digital video services at the subscriber premises. All standard telephony equipment required to support POTS, ISDN (2B+D), and DS1 specials is supported.

Services

The next four subsections summarize the interworking of the network elements for the following major service categories:

- Telephony,
- Interactive digital video/data,
- ATM data connectivity, and
- Digital broadcast video (DBV).

Telephony

Figure 2 shows the major elements of an SDV L1 network for telephony service. Telephony is transported over twisted pair from an NID located at a subscriber's premises through a pedestal to an ONU. The ONU contains channel units that terminate the twisted pairs and provide a wide variety of different telephony services. High-speed optical links transport the telephony channels from the ONU to the HDT. The interfaces between the HDT and Class-5 digital switch are composed of digital transmission facilities, which use the Bellcore standard TR303 protocol.

Interactive Video/Data Services

Figure 3 shows the major elements of an SDV L1 access network for interactive video/data. The L2 VIPs will provide digital video signals—encapsulated in ATM cells and transported on SONET facilities—to the L1 network for transmission to the STTs. Figure 1 shows the transport architecture. Two types of transmission paths are required to provide switched interactive video services: one path for setup and control and another for video program transport.

The VIPs provide the video programs over SONET facilities that terminate on the ATM switch. The selected outputs of the switch are transported over an OC-12/48 multiplexer, which is either a point-to-point system or a ring configuration. The interface between the multiplexers and the HDT is configured in the OC-3c format. The HDT func-

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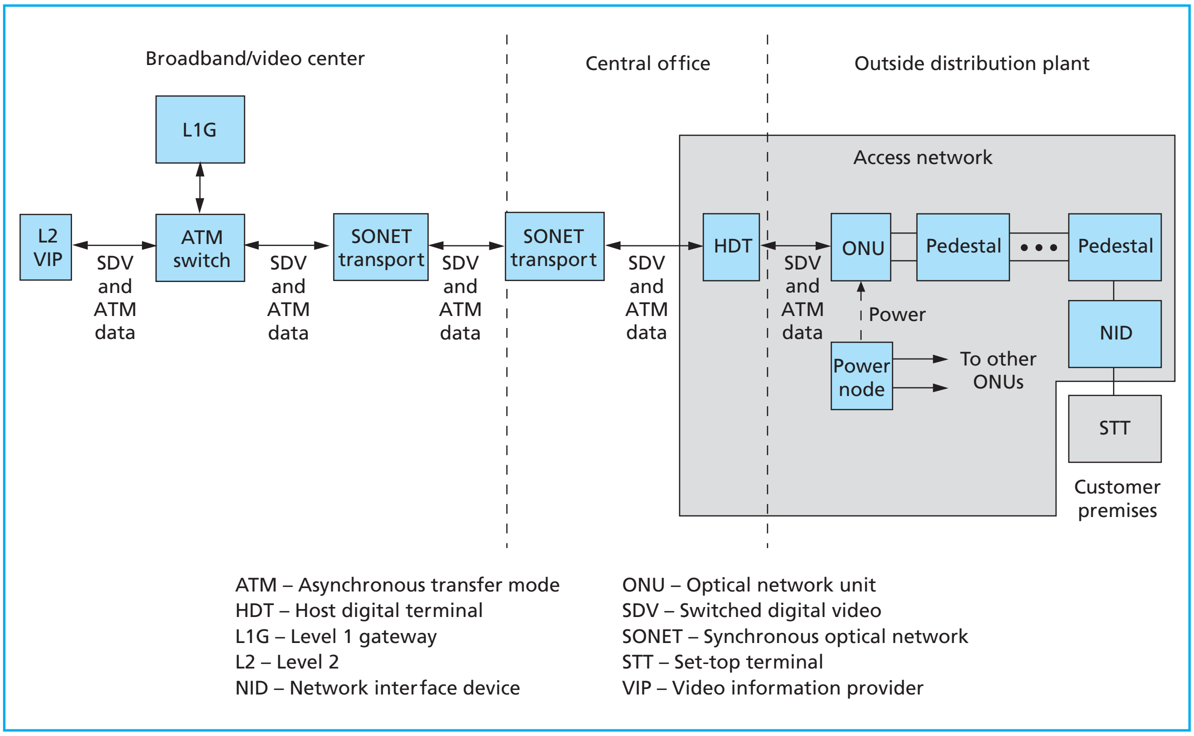

Figure 3.
Major elements of an SDV L1 access network for interactive video and data.

tions as a multiplexer to combine telephony and video/data services. The output of the HDT drives a fiber link that terminates at an appropriate curb-side ONU. The output is then transported from the ONU over coax to the appropriate customer's NID. Multiple living units can be served by a single ONU. The digital video/data on-demand services are transmitted over the coax from the ONU to the LU by a baseband signal in a spectrum below 50 MHz.

ATM Data Connectivity

The SDV architecture's data connectivity is provided by common agreements between the network provider, VIP, and STT vendors. Any data protocol encapsulated within the ATM format is supported because the L1 network will transport format-independent ATM encoded signals. Additional interfaces at the STT may need to be provided at the home for PC connectivity. For data services, the SDV network either will follow the same bidirectional paths as it does for the video command and control information or use different distribution facilities.

Digital Broadcast Video

Figure 4 shows the major elements of the SDV L1 access network for the DBV service. DBV is transported as ATM-formatted programs on SONET facilities from the VIPs to the STTs. All digital broadcast channels will be broadcast to all the HDTs. At the HDTs and the ONU, the digital broadcast signals are routed to the appropriate subscribers based on a combination of network control and end-user requests. An L1 network element called the video administration module (VAM) provisions, administers, and controls all digital broadcast services on the HDT.

The digital broadcast video signals are transported from the VIPs to the CO, where the optical outputs are split and transported to each HDT. The HDT routes the appropriate channel to the intended STT. The signal is optically transmitted from the HDTs to the ONUs, where they are transmitted to the STTs over coaxial cable terminated at an NID. For digital broadcast services in the SDV network, the L1G performs provisioning, administration, and control of digital broadcast services, as well as support for enhanced pay-per-view offerings. The next section describes Lucent Technologies' implementation of an SDV access network.

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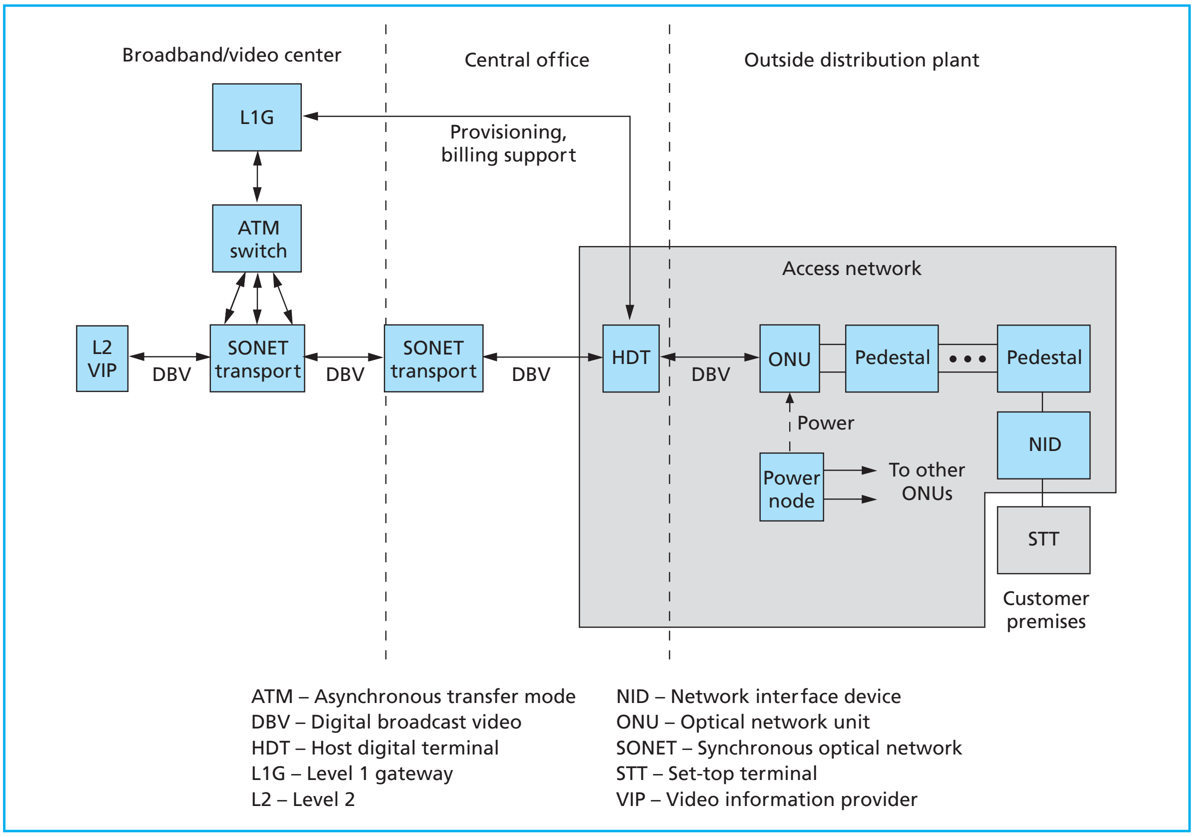

Figure 4.
Major elements of the SDV L1 access network for the digital broadcast video service.

SLC®-2000 System with FLX® SDV Network

The SLC®-2000 access system and the FLX® SDV system constitute Lucent Technologies' implementation of the SDV network. Lucent Technologies, in partnership with BroadBand Technologies (BBT), is working toward deploying its SDV system this year. Lucent Technologies and BBT provide the network elements, and together the companies are responsible for the L1 integration of the network elements. The L1 and L2 network elements necessary to provide the various services are discussed in the following four subsections.

Class 5 Switch

All narrowband telephony call processing in this architecture is provided by the Class 5 switch, which connects to the HDTs via the TR-303 interface. The switch will support all standard telephony equipment required for POTS (DS0-based telephony) or ISDN (2B+D). In addition, other DS0 and sub-DS0 rates, as well as HICAP (DS1 special services), will be supported via appropriate interfaces at the ONU.

Host Digital Terminal

The HDT serves as the integration point for all narrowband telephony and broadband digital services destined for the end user. The main function of the HDT is to adapt the digital TR-303 telephony signals from the 5ESS®-2000 switch (or other local digital switches [LDSs]) and the digital video/data signals from the network to the format required by the ONUs. The HDT also performs concentration of both the telephony DS0 channels delivered to the ONUs and the feeder trunks (for example, on TR-303 time slots) connecting to the LDS. Three other functions performed by the HDT are to receive the MPEG 2 video streams transported in an ATM payload arriving from the broadband/video center over the SONET facilities, select the appropriate channels, and deliver the video streams to the ONUs. SDV signaling streams

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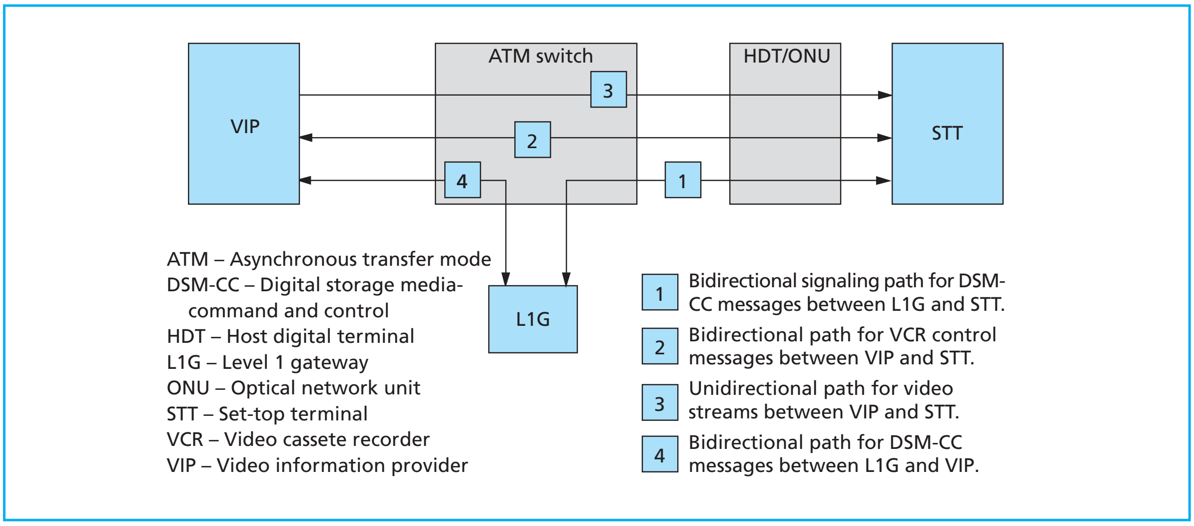

Figure 5.
End-to-end logical connections that exist between the various network elements.

from the ONUs are aggregated by the HDT and relayed to the ATM switch (for example, a broadband switching system [BSS]).

Optical Network Unit

The ONU consists of both narrowband and broadband subsystems. The narrowband subsystem provides channel units for DS0-based narrowband services. It also provides a DSX interface for DS1-based services and powering for both the narrowband and broadband subsystems. The broadband subsystem consists of the FLX node, and the subsystem terminates the HDT optical links carrying the telephony and digital video signals. The broadband subsystem provides the interface between the end customers and the HDT for all digital video services.

In the downstream direction, the broadband subsystem terminates the 1.036-Gb/s optical link from the HDT, converts it to an electrical signal, and separates the telephony and SDV signals from the composite stream. The incoming digital video signals consist of ATM cells carrying MPEG 2 encoded programming. These signals are formatted into 51.84-Mb/s streams that, in turn, are encoded into approximately 25-MHz-wide channels for delivery to a pedestal or splice enclosure via twisted pairs. The pedestal or splice enclosure will consist of a tap/combiner that can be located in either the ONU, pedestal, or splice enclosure.

In the upstream direction, each STT can transmit via QPSK modulation at rates varying between 16 kb/s and 1.024 Mb/s, depending on traffic loading. All upstream information and signaling is carried within the 51.84-Mb/s (line rate) link from the ONU to the HDT.

Other Elements in the SDV Access Network

The BSS application of the GlobeView™-2000 product line is the ATM switch, which supports SDV capabilities in the SDV access networks. The video manager serves as the L1G for the SDV access network.

The VIP provides SDV capabilities via the MPEG 2 format over an ATM network to subscribing customers. The services are transported through the ATM network to the customer premises.

An STT (or a terminal that provides the equivalent of STT functionality) is considered customer premises equipment and is required to terminate digital video services. An STT will be required for digital video services to terminate the ATM link and to convert the ATM payload into a usable format (for example, a video display). Each coax drop carries up to 36 Mb/s of digital video payload to a residence. A maximum of six STTs per home can be accommodated.

PCs, together with supporting hardware (such as the STT interface), will allow for data connectivity between PCs and the SDV network. PCs are used in implementing ATM data-only service.

The video administration module (VAM) enables the implementation of the functions described for digital broadcast video service in the SDV access network.

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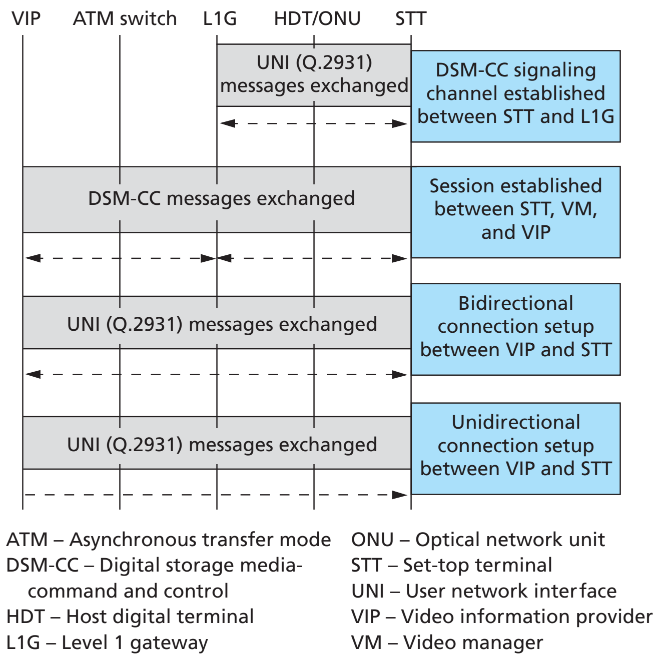

Figure 6.
Sequence of messages that are exchanged in setting up the end-to-end connections and sessions for the video-on-demand service.

Session/Connection Management

This section provides a high-level view of how the SDV access system elements interact with the L1/L2 network components to set up connections and manage sessions.

Interactive services are based on the concept of a *session*. The concept implies a relationship between an STT and a VIP for a period of time during which an end user participates in an interactive activity. Associated with a session are the series of related connections through the network between one or more video servers belonging to the VIP and the end user's STT. A detailed description of session protocols is available.[7]

Interactive services often necessitate creating several connections through the ATM network. As an example, for a movie-on-demand application, a bidirectional connection may be available over which an end user interactively chooses a program to view. A downstream high-bandwidth unidirectional connection may also be available for transport of the actual program content. Connections may have different properties in terms of directionality (unidirectional, bidirectional), symmetry/asymmetry, bandwidth, and quality of service.[8] Figure 5 shows the logical connections that exist between the various network elements.

Sessions between the VIP server complex and STTs are managed by the L1G in the CO. This allows the L1G to take care of multiple connection setups and tear-downs and to recover an entire session in the event of failure. The L1G provides a unified billing record to the VIP (for use of the network). The L1G can also provide an implicit or explicit L1 gateway function to allow subscribers to select from a field of VIPs.

A typical request for a session setup or termination could originate either from a VIP or an STT.[4] A typical resource request could be for an ATM connection between a server and an STT.

Session layer protocol is standardized by a branch of the MPEG standards body known as the Digital Storage Media Command and Control (DSM-CC) Committee. Once a session is established using DSM-CC messages, several methods are available for setting up ATM connections at the discretion of a VIP. Depending on the method used, the protocol can provide a degree of abstraction,

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isolating the STTs and servers from the details of the network.

A session is set up or torn down from either an STT or VIP, and it is established using a combination of DSM-CC messages and user network interface (UNI) (Q.2931) signaling.

For interactive services, both the STTs and VIP server complex must support the DSM-CC session-level message protocol. In addition, both STTs and servers must support broadband UNI signaling interfaces for establishing ATM connections (network layer). Depending on the method chosen for establishing a connection, support may be necessary only for receiving calls on these UNI interfaces. In addition, the STT will need to support the ATM *metasignaling layer* and some modulation/demodulation for extraction of both upstream and downstream data transmitted over the coax.

The network supports both associated and nonassociated[9] UNI signaling between the VIP complex and the network. With associated signaling, the UNI signaling messages (Q.2931) will take place on the same facility over which the ATM connection will be established. Nonassociated signaling allows signaling on one facility for connections on other facilities. Nonassociated signaling can provide for more cost-effective facilities between a VIP and the network. Signaling is bidirectional in nature. Much of the traffic between server and network, however, is unidirectional (for example, video programs). Using nonassociated signaling, it is possible to concentrate bidirectional activity on a minimum set of facilities. Other facilities not carrying UNI signaling can be cost reduced by eliminating the unused upstream transmission path (for example, unidirectional).

Interactive Multimedia Example

This section discusses the typical interactive service known as *video on demand (VOD)*. This is only an example in that a VIP—using the capabilities provided by the L1 network—may design such a service in many ways. The L1 network is assumed to provide a menu application whereby a user is presented with a list of VIPs, and the user has the ability to choose a VIP in real time for establishment of an interactive session. Additionally, it is assumed that an operating system already exists in the STT containing the various signaling protocols.

Figure 6 illustrates the following 11-step sequence of messages, which are exchanged in setting up the end-to-end connections and sessions:

1. A user activates the STT through a power switch on the infrared remote control. This stimulates the STT to send a UNI (Q.2931) SETUP message to the network. This signal is terminated at the HDT shelf that, in turn, sends a SETUP message to the L1G. The L1G responds with a CONNECT message to the HDT. The HDT then sends a CONNECT message to the STT. This sequence causes the HDT to establish a cell route between the STT and the L1G and informs the L1G of the connection. The STT can now communicate directly with the L1G.
2. The L1G now runs an L1 application that provides text for a menu of available VIPs to the STT. The STT displays the menu to the user.
3. The user now selects a VIP. This stimulates a sequence of DSM-CC messages between the STT and L1G and between the L1G and VIP to establish an interactive session. As part of establishing the session, the L1G authenticates the STT and creates an active session record.
4. The VIP now requires an ATM bidirectional connection between itself and the STT for interaction with the user. The VIP now establishes the connection.
5. The VIP next provides the user with a menu of service choices. One choice is *movie on demand*. This interaction is L2 activity, which is transparent to the L1 network.
6. The user selects the movie-on-demand option.
7. The VIP may require application-specific code in the STT for the movie-on-demand choice. The VIP either downloads this code over the existing ATM connection or requests another ATM connection with appropriate characteristics (for example, higher downstream bandwidth) for application downloading. When the network completes the connection, the VIP proceeds to download the application. Note that the L1 network allows a VIP to request new ATM connections (or tear them down) whenever necessary during the interactive session.
8. The VIP provides a program guide (list of available movies) over an existing or new ATM connection as appropriate.
9. The user selects a movie.
10. The VIP requests a downstream ATM connection to the STT to carry the program (movie). The requested bandwidth (for example, 4 Mb/s) matches the movie's encoding rate the customer has chosen. The network then completes the connection.
11. The VIP plays the movie, during which the customer may exercise VCR-like control over one of the upstream connections previously established.

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At the movie's conclusion, the VIP initiates the DSM-CC sequence to end the session. The L1G will tear down any ATM connections relative to the session that have not been explicitly deleted by the VIP. The L1G will also terminate the session record and finalize the session's billing.

Traffic and Performance Considerations

As evidenced by the previously discussed connection sequence, several key parameters exist within the access network that must be optimized to increase the operational efficiency of the access network. Although several studies are being conducted on VOD, the traffic call patterns are only now emerging. This is an important part of the network optimization. Once trends are better understood, peak rates, burst length, and other parameters can be optimized for any multimedia application.[10]

Bandwidth

Multimedia systems impose different bandwidth requirements for divergent applications. The bandwidth to be handled depends on a combination of media and total traffic, and it must be supported by the network.

For the VOD application in the SDV network, end-to-end bandwidth is limited by the ability to transport video streams among the various elements that encompass the network. For instance, the SDV architecture is limited by the ONU's ability to transport digital video signals to the STT, which currently operates at 51.84 Mb/s (36-Mb/s payload) in the downstream direction. In the upstream direction, data carried from the STT to the ONU is limited to 1.024 Mb/s. The SDV architecture assumes a maximum number of six STTs per drop. Thus, the average downstream payload bandwidth per STT is 6 Mb/s. It is expected that for most VOD applications, 6 Mb/s per video stream is sufficient.

Burstiness is a critical traffic characteristic component. It is determined by two parameters: peak and average traffic parameters. Burst length and variance of traffic are also useful parameters. The composite bandwidth required is based on the peak bit rate, peak-to-average bit ratio, variance of the bit rate, and burst length.

Policing and *shaping* of the traffic prior to entering the L1 network by the L2 VIP and STT to ensure compliance with the negotiated traffic descriptors (for example, peak cell rate) help in load balancing and optimal use of the total bandwidth available in the network. In the SDV network, this function is jointly carried out by the VIP resources and the ATM switch.

Blocking

Congestion of traffic flow between the various stages of the network in which multiplexing occurs could cause blocking. Congestion control schemes are essential to optimize the network because buffering delays are critical to the performance of the network. Connection management optimizes the use of network resources, helping to alleviate the problems of congestion.

Traffic studies are being performed to determine if a particular traffic pattern can be handled in the SDV network. These studies will help in understanding the limits on both the number of simultaneous STT sessions that can be handled and virtual channels desired, and hence the total bandwidth preferred.

The performance criteria for the SDV network is important to guarantee a high degree of video transmission quality through the L1 network. For additional information, a brief analysis of performance criteria for a universal multimedia switching architecture is available.[2] The key performance parameters for the transport of cells in the SDV network are cell transfer delay, cell transfer delay variation, cell loss rate, and bit error rate.

Cell transfer delay is the time required for an ATM cell to be transferred to its end-point. The end-to-end delay from the VIP to the STT should be no more than 1 ms. This includes the propagation, network, and equipment delay. The SDV network allows for 1 ms of buffering within the STT. This allowance is based on the assumption that within the L1 network, at any single network element switching stage, the maximum delay that shall be incurred is 250 µs.

Cell transfer delay variation (CTDV), also known as jitter delay, is the variation in a cell interarrival time. The end-to-end jitter should be minimized. In any network, if the same medium is used for constant-bit-rate (CBR) and variable-bit-rate (VBR) traffic, jitter could be introduced due to the burstiness of VBR traffic. Previous studies suggest that if higher priority is given to CBR traffic over VBR traffic, jitter is minimized.

Cell loss rate refers to the probability of losing an ATM cell during transmission. Thus, cell loss rate must be minimized.

Bit error rate refers to the probability of losing bits during transmission, and it should be very low. In the SDV network, SONET bit error rates will exist because the audio and video streams are encapsulated into a SONET frame.

The following three performance parameters are crucial in setting up and tearing down connections:

- Setup and teardown times,

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- Number of requests handled per second, and
- Number of simultaneous users that can be handled.

The frequency of connection setups, tear-downs, and re-directions for sessions depend on the end user's calling patterns, and it can be determined based on the average number of simultaneous users and holding times.

In a typical SDV network application, the average holding time for each session is expected to be 90 minutes (the range being from 60 to 135 minutes). Interarrival time for an SVC setup request is 360 ms. It is anticipated that the average number of SVC connections per session will vary between two to eight setups and tear-downs. The setup times between network elements are expected to range from 2 to 4 seconds.

By developing a detailed end-to-end model of the L1 SDV network, we can better understand traffic congestion points, bit error rates, traffic blocking, and the ability to quantify the delay and jitter encountered at each network stage. By applying the call traffic pattern data, this model can also identify potential sources of performance bottlenecks within the network.

Key Characteristics

Baseband architectures like SDV are well matched to properties of optical fiber communication channels (the communication medium of choice) due to better noise immunity at the frequencies of operation for digital video transmission. In addition, baseband signals tend to use simpler modulation schemes and lower-cost components for the fiber-optic transport system.

SDV benefits from the advantages of ATM because it uses such standards-based ATM transport facilities as high bandwidth, low-latency transport, the ability to encapsulate format-independent protocols at varying data rates, and dynamic bandwidth allocation. The potential bandwidth provided can be of an order of magnitude higher than that for other similar networks.[1] Also, increased signal security (freedom from signal theft) for the network is provided through dedicated ATM transport facilities and the star network topology.

The use of FITL technology not only helps service providers place the fiber much closer to homes but also facilitates more complete automated fault isolation and service provisioning within the network. The total available bandwidth capacity within the SDV access network allows outside plant costs to be distributed over several homes, thus lowering the average capital cost per home.

The deployment of a network having a standards-based platform for resource management gives network providers and VIPs greater flexibility to custom-tailor the network for various applications. In addition, a standard platform allows interoperability among various transport formats, helping to reduce the cost of network equipment.

Summary

FITL and ATM are the key technologies on which the next generation of access services will be based. Furthermore, SDV architecture provides an ATM path from the source (headend/VIP) to the home. Thus, it allows many users to share the network simultaneously while enjoying the full range of existing and future services.

The SDV access network provides an integrated telephony and broadband services platform using FITL technology. In addition to supporting traditional telephony/narrowband and analog broadcast video services, this network also provides the capability of delivering ATM data to the home, including such digital broadcast and interactive video services as video on demand.

In partnership with BBT, Lucent Technologies has developed an SDV access network that supports these important and emerging services. Connections among the various network elements, as well as control, are both accomplished using standard protocols. Tuning the network's traffic and performance parameters is the key to its operational efficiency. A unique characteristic of the SDV access network is its standards-based end-to-end ATM transport feature that provides a vehicle for implementing a wide variety of future broadband services.

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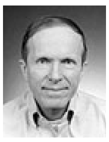

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