Integrated Narrowband/Broadband Access Architecture

By Michele Kerr, Russ Couture, Douglas Ramsayer, and Joe Rich

Southwestern Bell Telephone (SWBT) Technology Planning chose a digital fiber-optic, integrated narrowband/broadband fiber-to-the-curb (FTTC) access architecture for deployment in the Richardson, Texas, video trial. The trial architecture consists of a two-level network: Level 1 and Level 2. The Level-1 network is the infrastructure provided by SWBT. The Level-2 network is that portion which provides the digital video services and the analog broadcast services. This paper describes the network designed for SWBT that will be used to replace and extend the existing telephony transport and access network in Richardson with a state-of-the-art network that will provide telephony and other narrowband services, analog broadcast video services, digital broadcast services, and interactive switched digital video services. Also discussed are some of the new operations, administration, maintenance, and provisioning systems (OAM&P) required in this new environment. The characteristics and challenges of this new network, new technology, and the Richardson video trial are examined in detail.

After considerable research and review of available technologies and architectures from a variety of vendors and expert advice from Technology Resources, Inc. (TRI) and Bell Communications Research (Bellcore), Southwestern Bell Telephone (SWBT) Technology Planning chose a digital fiber-optic, integrated narrowband/broadband fiber-to-the-curb (FTTC) access architecture for deployment in the Richardson, Texas, video trial. Richardson is a suburban community in the northeastern part of the Dallas metropolitan area.

A planned steady evolution of the public switched telephone network to a fully digital network has been the technological strategy at SWBT, and for most of the telecommunications industry, for several decades. The technological strategy for the combined "information-entertainment" industry is also digital evolution. High-definition television (HDTV) and digital video compression development point to this trend.

The end-to-end topology for the SWBT network consists of a two-level network: Level 1 and Level 2, which will provide traditional telephony services and both digital and analog video services. The Level-1 network is defined to be the transport infrastructure provided by SWBT. It consists of telephony and data equipment traditionally associated with switching and transport, an access network infrastructure, and a broadband access network. Level-1 network elements include: switches, loop access nodes, a transport network, and the Level-1 video manager (VM).

The Level-2 network includes those elements necessary to provide synchronous optical network (SONET) optical carrier level standard 3c (OC-3c) based asynchronous transfer mode (ATM) signals for digital video services and to provide channelized NTSC signals for analog broadcast services. These services and this part of the end-to-end topology will be provided by Southwestern Bell Video Services (SBVS). Customer premises equipment (CPE), such as the set-top terminal (STT), are considered to be Level-2 network elements.

Lucent Technologies, Inc. (Lucent) and BroadBand Technologies (BBT) are the developers and suppliers of network components and will perform the end-to-end network integration of the Level-1 network. Lucent is a major provider of telecommunications equipment with an extensive and solid background in the telephone industry. BBT is an innovative developer of switched digital video platforms that integrate video and telephony. Lockheed Martin Communication Systems & Services (Lockheed Martin) and americast® have been selected by SBVS to provide equipment, end-to-end system integration, and applications for the Level-2 video information network.

Architecture

This architecture is a significant metamorphosis from the copper-based network of today. The goal of this network rebuild is to provide an infrastructure that will evolve to meet the growing needs for bidirectional high-bandwidth applications and to realize significant operational savings. The objectives of the technical portion of the Richardson video trial are as follows:

- To test the effectiveness of an integrated service delivery platform.
- To test integrated digital switching functionality based on Bellcore Technical Requirement TR-NWT-000303 (TR-303).
- To test an ATM-based switched digital video delivery system.
- To test the effectiveness of intelligent network elements in reducing operational costs, to develop operations support (OS) solutions for integrated OAM&P.
- To quantify the operating costs associated with an FTTC network.
- To determine the optimum broadband architecture for deployment by SWBT.

Presented at the 137th SMPTE Technical Conference in New Orleans, La. (paper no. 137-48), September 6-9, 1995. An unedited version appears in *Moving Images: Meeting the Challenges*, SMPTE, 1995. Michele Kerr (who read the paper) is with Southwestern Bell Telephone, St. Louis, Mo.; Russ Couture is with AT&T Bell Laboratories, Holmdel, N.J.; Joe Rich is with Lockheed Martin, Sunnyvale, Calif.; and at the time of writing, Douglas Ramsayer was with BroadBand Technologies, Research Triangle Park, N.C.

Glossary of Terms and Acronyms

ANI	ATM network interface
ATM	Asynchronous transfer mode
Baseband	Analog communications bandwidth in the 5 to 1000-MHz range.
BBT	BroadBand Technologies, Inc.
Bellcore	Bell Communications Research, Inc.
Broadband	Digital communications bandwidth above 45 Mbits/sec. Usually implies SONET transport from OC-1 (51.8 Mbits/sec) to OC-192 (9.6 Gbits/sec).
BSS	Broadband switching system
CAP-16	Carrierless amplitude phase, a modulation scheme for transporting digital signals over an analog medium.
CCS	Custom calling services, vertical services provide by local switches, including Call Waiting, Three-Way Calling, and Call Forwarding.
CCO	Call control options, vertical services provided by SS7 and AIN, including Calling Number Identification and Calling Number Blocking.
CEV	Controlled environment vault, a large buried enclosure containing environmental conditioning for the housing of electronic equipment.
DS1	Digital Signal 1, a standard for transport of a 1.544 Mbit/sec signal.
DS3	Digital Signal 3, a standard for transport of a 45 Mbit/sec signal.
DSM-CC	Digital Storage Media Command and Control, a protocol to provide control functions and operations for manage ment of MPEG streams.
EPG	Electronic program guide
FLX®	Fiber loop access products including the FLX® Shelf and FLX® Node. A registered trademark of Broadband Technologies.
FTTC	Fiber-to-the-curb, a network architecture that places fiber within 1000 ft of the customer premises.
HDT	Host digital terminal
HDTV	High-definition television
HE	Head end
IS-3	International carrier level standard 3, a SONET standard for the transmission of an optical signal formatted to carry three DS3s with overhead using multimode fiber.
IS-3c	International carrier level standard 3, a SONET standard for the transmission of an optical signal formatted to carry the equivalent of three DS3s without overhead using multimode fiber.
IST	Integrated services terminal
Lucent	Lucent Technologies, Inc., formerly a part of AT&T, including the former AT&T Network Systems, Western Electric, and Bell Labs
MPEG-1	Motion Picture Experts Group 1
MPEG-2	Motion Picture Experts Group 2
Narrowband	Digital communications bandwidth from 0 to 1.544 Mbits/sec
NID	Network interface device
NVOD	Near-video-on-demand
OC-3	Optical carrier level standard 3, a SONET standard for the transmission of an optical signal formatted to carry three DS3s with overhead using single-mode fiber.
OC-3c	Optical carrier level standard 3c, a SONET standard for the transmission an optical signal formatted to carry the equivalent of three DS3s without overhead using single-mode fiber.
OC-12	Optical carrier level standard 12, a SONET standard for the transmission of an optical signal formatted to carry the equivalent of 12 DS3s with overhead.
ONU	Optical network unit
O/S	Operating system
PAN	Power and analog node
POTS	Plain old telephone service, refers to traditional voice grade telephone service, not including data or private line technologies.
QPSK	Quaternary phase shift keying, a modulation scheme for transporting digital signals over an analog medium.
RF	Radio frequency, refers to the electromagnetic transmission spectrum from 300 kHz to 30 GHz.
SLC®	Subscriber loop carrier products including SLC® Series 5 and SLC®-2000. A registered trademark of Lucent Technologies, Inc.
SONET	Synchronous Optical Network, a standard for digital, optical, and electrical transport of all communications signals, including POTS, data, etc.
STB	Set-top box, also referred to as set-top terminal (STT)
STS1	Synchronous transport signal level 1, a standard for the SONET electrical transport of a DS3.
SBVS	Southwestern Bell Video Services, wholly owned video delivery subsidiary of SBC, Inc.; operates in Richardson, Tex.
SWBT	Southwestern Bell Telephone, wholly owned local exchange telephone subsidiary of SBC, Inc.; operates in Arkansas, Kansas, Missouri, Oklahoma, and Texas.
T1	Transmission signal 1, a standard for the electrical transmission of a 1.544 Mbit/sec signal.
TRI	Technology Resources, Inc., wholly owned technology research subsidiary of SBC, Inc.
TR-303	TR-NWT-000303, a Bellcore technical requirement standard for the integration of digital loop carrier equipment with a digital switch.
UNI	User-to-network interface
VAM	Video administration module
VF	Voice frequency, refers to the 300 to 3000-Hz range of standard telephone transmission.
VM	Video manager, a Level-1 Gateway
VOD	Video-on-demand
VTR	Video transmitter and receiver, a circuit card used in the FLX® Node of an ONU.
Wideband	Digital communications bandwidth between 1.544 and 45 Mbits/sec

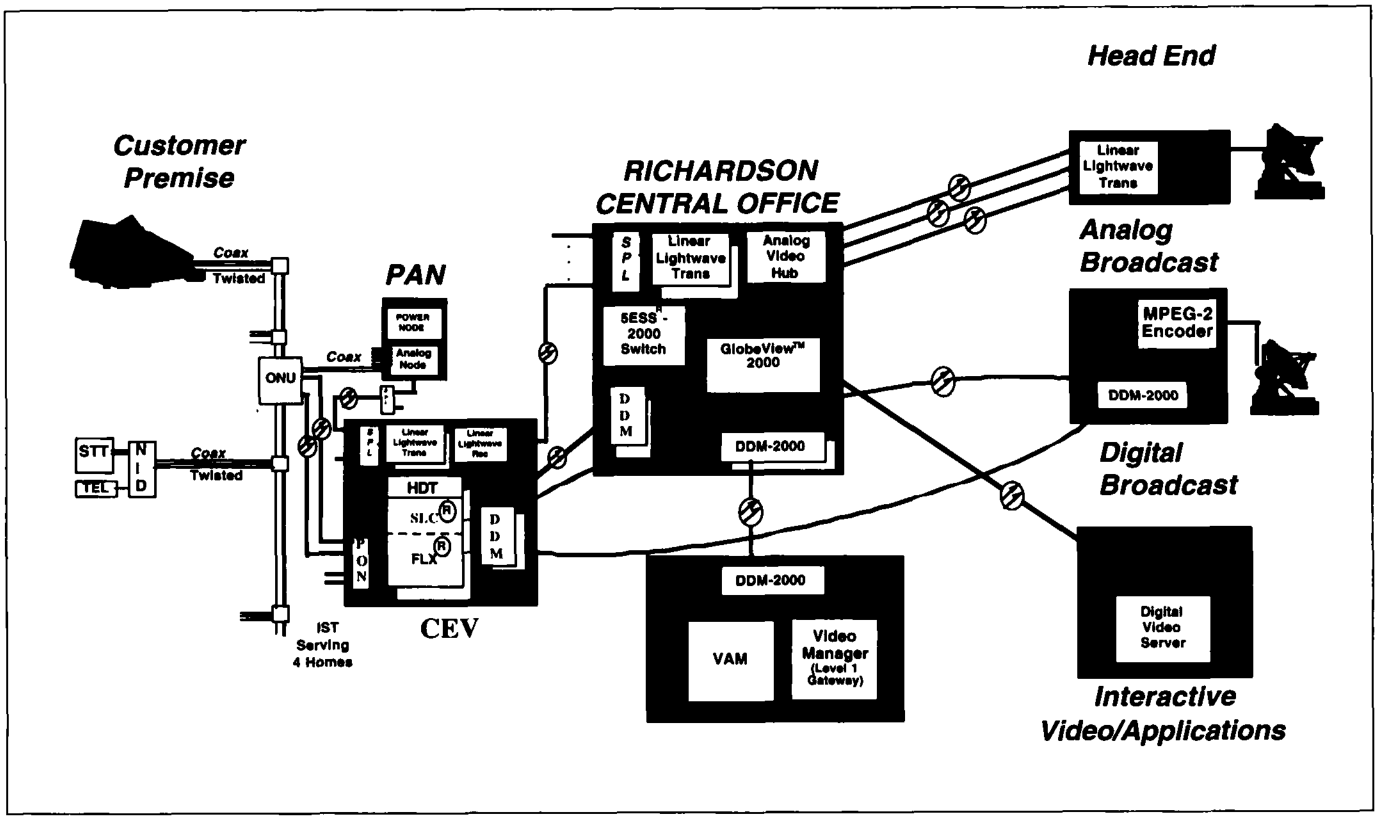

Figure 1. Integrated narrowband/broadband access architecture.

From a marketing and regulatory standpoint, the trial is expected to provide information concerning market potential, tariffing and pricing options, regulatory impacts, and the ability of SWBT to attract customers, both end users and client-programmers.

Level-1 Architecture

The architecture, shown in Fig. 1, consists of four functional networks to transport the set of offered services. The four networks, one for narrowband telephony and three for broadband and baseband video, are:

- Narrowband service
- Telephone services
- Broadband service
- Analog broadcast video
- Digital broadcast video
- Switched digital video and interactive applications

These networks are integrated in the SLC®-2000 Access System with FLX® SDV host digital terminal (HDT) as their signals are transported from a central office (CO) to the customer premises. Overall system economy is achieved by combining network functions to achieve a cost-effective network. For example, three of the networks — telephone, broadcast digital video, and interactive digital — share the access equipment between the customer premises and the CO. Similarly, the analog video network performs power distribution to the field equipment.

The Level-1 network will consist of several elements, including the SLC-2000 Access System with FLX Switched Digital Video HDT, the Optical Network Unit with FLX® Node (ONU), GlobeView™-2000 Broadband Switching System (BSS) ATM switch, the Video Manager (VM), the Video Administration Module (VAM), the 5ESS®-2000 Switch (5ESS®), the DDM-2000 SONET multiplexing equipment, and Linear LightWave Systems™ (Fig. 1).

Other commercially available equipment will be used where needed. This network consists of fiber connecting the HDT to the ONU and coax cable and multiple twisted pairs providing the connectivity from the ONU to the end user residence. The configuration of the network to support video services will require installation of both existing equipment/technologies (e.g., analog CATV equipment, SONET networks) and new/evolving technologies (e.g., ATM, VM). Several components of this network (e.g., HDT, ONU) are being developed to merge the digital video and telephony/narrowband signals for delivery to the end user.

Level-2 Architecture

The Richardson trial Level-2 architecture is shown in Fig. 2. This top-level architecture diagram shows the major product areas identified through the requirements process. Within the head end, several elements interface to an internal network. Through this network the various elements can exchange information as required and also connect to the level-network or the set-top box.

Content development is hosted on a standalone workstation that can be located either within the head end or at a remote site. Using this workstation an operator can edit media and add special effects to prepare it for presentation on the network. The primary intent for the workstation is to

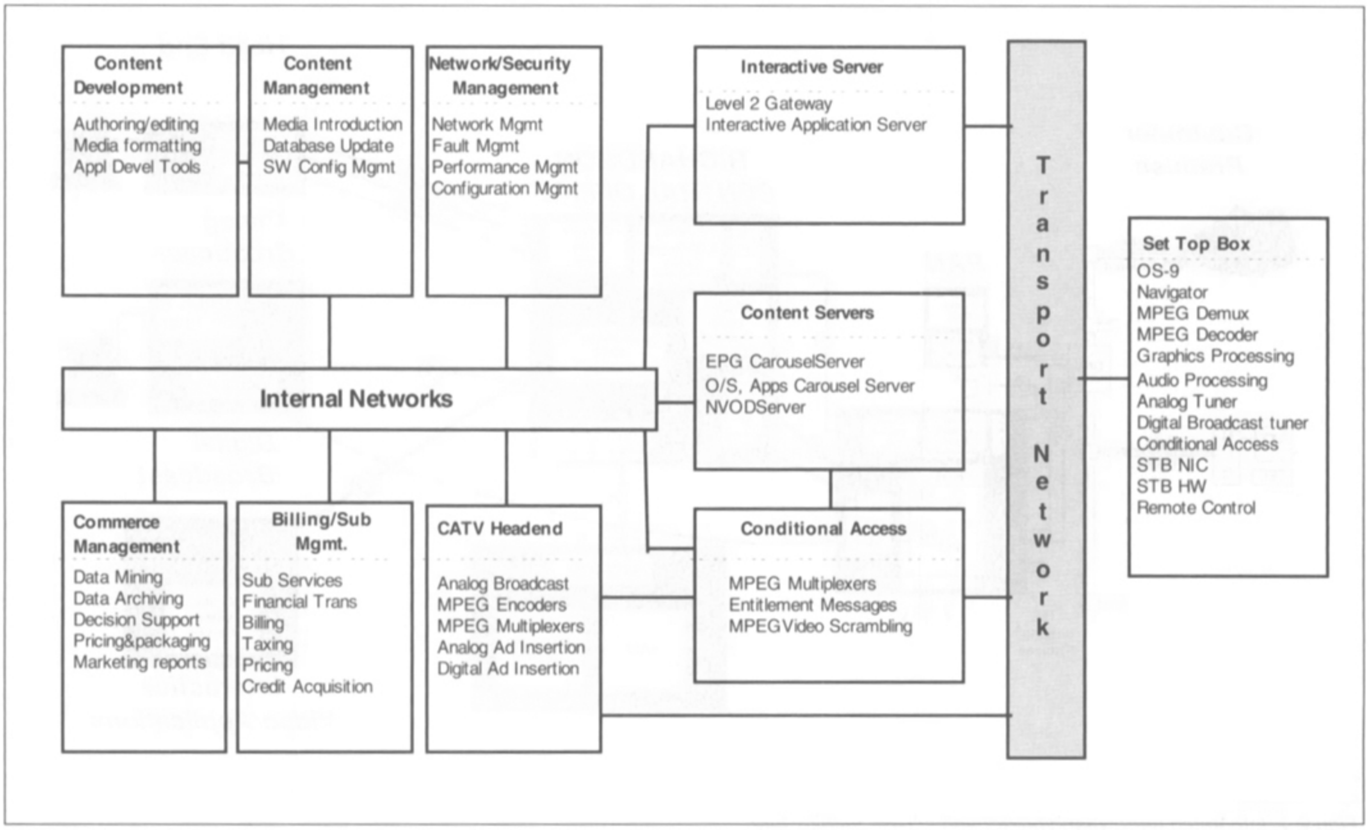

Figure 2. Richardson Level-2 architecture.

provide access for local media suppliers, such as school sports programs or local advertisers. Content development also includes an encoder to allow introducing media that has not yet been encoded to the network.

Content management provides the tools to manage all aspects of media within the system. This involves media introduction and removal, applications data updates, authorizations, and application and software upgrades.

Network and security management performs fault detection and isolation and performance monitoring functions. It uses a commercial network management system and runs on a SUN workstation.

Commerce management provides an on-line pricing engine that allows complex pricing, packaging, and discount schemes to be defined. There is also software for extracting data for off-line analysis and reporting. These two software components provide capability for developing various marketing approaches and determining how well each performs.

The billing and subscriber management product is based upon an off-the-shelf product. The selected vendor has demonstrated its experience in the cable industry to provide a product that is integrated with the americast applications to provide real-time billing for interactive services.

The cable TV (CATV) head end receives off-air and satellite broadcasts. It rebroadcasts a set of these channels in the clear over a fiber-optic/coax distribution system through the SWBT network. Another set of premium channels are real-time MPEG-2 encoded and are broadcast using digital distribution through the SWBT network. The CATV head end will also perform ad insertion.

The interactive server consists of a Level-2 gateway and an interactive applications server. The Level-2 gateway terminates the DSM-CC and UNI 3.1 signaling protocols used by the STBs to establish sessions and circuits with the Level-2 head end. The interactive applications server hosts interactive applications, such as home shopping, that STBs can access once a session has been established with the Level-2 gateway.

The content servers are video servers and data carousels capable of storing and streaming MPEG-2 encoded content. As part of the americast platform, these servers provide near-video-on-demand (NVOD) digital broadcast service, host the EPG (also a digital broadcast channel), and serve up the O/S downloads and applications like the channel navigator for the STBs.

Conditional access is provided by a collection of equipment provided as part of the americast platform. Encoders are used to scramble MPEG-2 transport streams, and entitlement messages are added using remultiplexers. Separate entitlement control keys are passed over the transport network by the carousels and used by the STBs to access and decode the digital broadcast signals.

The set-top box provides a platform for interactive applications, allowing the consumer to make selections from multiple services, programs, or movies. The set-top boxes perform either analog TV tuning or MPEG-2 decoding of the video broadcasts from the head end.

Services

A sample of the telephone services to be provided over this network includes:

- Plain old telephone service (POTS)
- ISDN — basic rate interface
- Custom calling services (CCS) and call control options (CCO)
- Switched and nonswitched special circuits
- 1.544 Mbits/sec (T1)

A sample of the video services to be provided over this network includes:

- Digital broadcast
- Analog broadcast
- Switched interactive digital video
- Interactive applications

End-to-end integration of the Level-1 network, as well as integration of the Level-1 and Level-2 networks, is a unique challenge for all the parties involved. The wide range of experience and expertise drawn from all the participants in this project continually improves and evolves the architecture and systems design. The following sections document the efforts of Lucent, BBT, and Lockheed Martin in the development of this trial.

System Overview

The digital video broadcast and interactive application services are transported from the HE to the STTs in ATM-formatted packets within OC-3c facilities. At the HDT these signals are combined with the telephony narrowband signals and optically transmitted to the ONU. At the ONU, this optical signal is terminated and the telephony signals are converted to VF signals and transmitted over twisted-wire pairs to subscribers. The digital broadband signals are combined with the analog television signal and transmitted to subscribers over a conventional coaxial cable. Upstream data is carried by the interactive digital system over the coaxial cable.

Analog broadcast video signals are transported over an overlay analog lightwave network from the HE to the power and analog node (PAN), where it is converted to a standard National Television Standards Committee (NTSC) radio frequency (RF) signal and transported to the ONUs over coaxial cable that is also carrying the power to the ONUs. There is no upstream return path for the analog services.

Elements of the SDV System

An examination of the individual elements of the network will help in understanding the network architecture. The network elements are shown in Fig. 3. Starting at the customer location and going towards the CO, a collection of equipment described with three-letter acronyms is encountered, as follows:

- NID: Network interface device, is on the side of a home and is the end of the Level-1 network.
- IST: Intermediate service terminal, is a field connection point.
- ONU: Optical networking unit, separates the telephone and video services onto their appropriate media to deliver signals to the home.
- PAN: Power and analog node, supplies power to the ONUs and carries the analog video signal.
- HDT: Host digital terminal, combines the telephone signal (in a digital format) and the digital video signals to transport them together.

Each of these elements is discussed in more detail in the following sections.

The NID is a passive device located on the outside of the customer's house that terminates the broadband coaxial cable and the narrowband telephony twisted-pair cables. Attenuators to adjust the level of the analog signal for different distances from the ONU are located in the NID. The system can support up to six STTs per home; however, the network has been optimized to support four. The IST is a buried connection box, nominally located at the corner of four homes, that provides a convenient connection point for preparing the telephone twisted copper pairs and the video coaxial cable to drop into each home.

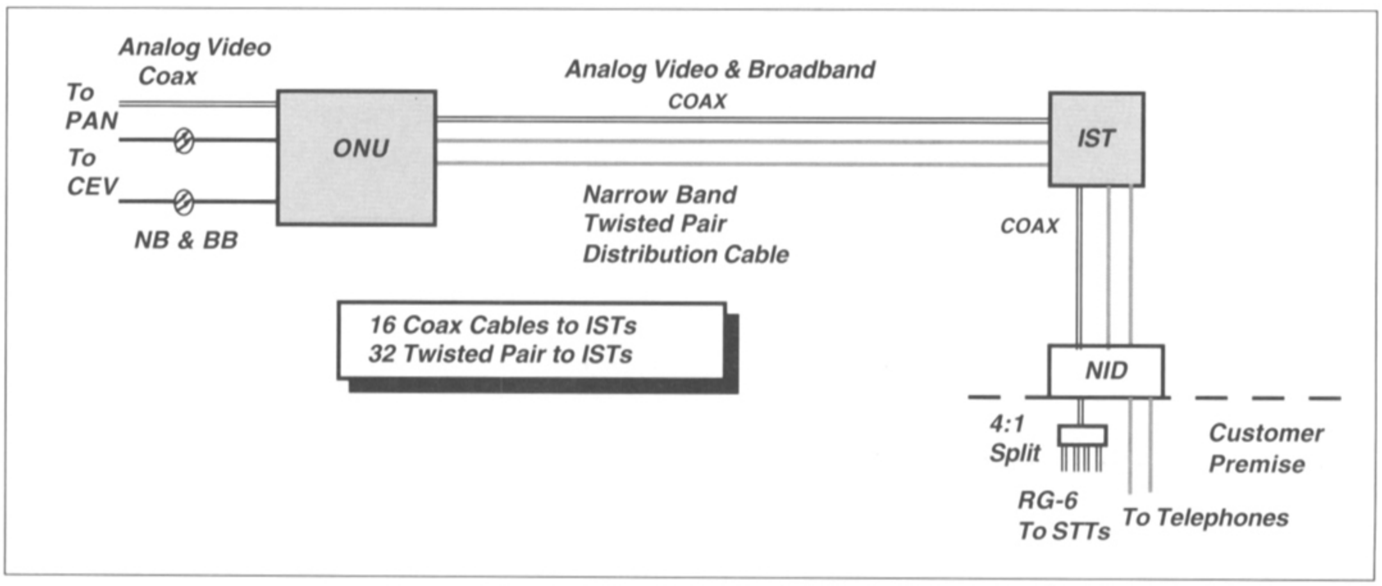

Figure 3. Richardson drop configuration.

The ONU is functionally shown in more detail in Fig. 4. The broadband and telephony services, on the transmitting and receiving fibers from the HDT to the ONU, are demultiplexed in the broadband subsystem of the ONU. The digital broadband signals are modulated by a carrierless amplitude phase (CAP)-16 modulator. This modulated digital signal is combined with the analog video and sent over coaxial cable to the customer premises. The digital broadband signals are carried in the frequency band of 5 to 25 MHz, and 60 analog 6-MHz channels are carried downstream in the 54 to 450-MHz band. The ONU does not terminate the ATM cells, but is instructed by the HDT to route them to the appropriate subscriber.

The telephony services are channelized in the narrowband subsystem of the ONU and transported along with electrical power to ring telephones over twisted pair cable. Upstream information for the interactive digital services is carried in the 27 to 30-MHz band on the coaxial cable and is filtered off to a quaternary phase shift keying (QPSK) demodulator and then multiplexed onto the optical cable and sent upstream to the HDT.

The last gain stage for the analog RF signal is provided by the amplifier in the ONU. To achieve a high-quality video signal and minimize maintenance in the field there are no line amplifiers. An addressable on/off tap allows central control of the analog service to each subscriber.

The ONU being deployed in the Richardson trial is designed to serve 16 homes. This device is capable of providing 16 broadband coaxial cable drops and 48 VF drops; however, the typical Richardson ONU will be equipped with eight broadband coaxial cable drops and 24 DS0s. Up to four T1 drops will be available in a future configuration.

The PAN, shown in Fig. 1, provides the power node and analog node functions. The power node is connected to the local power company grid and rectifies the 115-V, 60-Hz AC power to a 60-Hz trapezoidal wave form for transmission to the associated ONUs. Up to four ONUs can be supported from a PAN. A string of batteries provide backup power for the telephony system in case of an AC failure for up to 8 hr of operation.

The PAN also includes the analog community antenna television (CATV) node and converts the optical analog video signals transmitted over the Linear LightWave system to the standard RF frequency band for transport via standard coaxial cable. (The coaxial cable from the PAN carries the power for the ONU and the analog video broadcast signals.)

The majority of the HDTs in the Richardson network are located in controlled environment vaults (CEVs). A functional diagram of the HDT is shown in Fig. 5. The narrowband portion of the HDT consists of the high-bandwidth access resource manager (HBARM) and the digital distribution shelf (DDS). Up to 56 DS1, two effective TR-303 systems, can be output, and a future release will allow support for four TR-303 systems. The TR-303 interface was chosen because it represents the most advanced direct digital interface into a digital switch with variable concentration and direct ISDN connectivity.

The telephony signals are intrabay cabled to the FLX shelf for multiplexing with the digital broadband signals. Up to four DS1s, 96 lines, can be routed to a particular ONU. ONUs for Richardson are designed for 16 living units and will use one DS1, 24 lines, to serve the 16 homes. Line concentration can be accomplished in the narrowband system, and a 6:1 concentration ratio, across the 2880 lines on an HDT, is being designed for Richardson. The concentration ratio

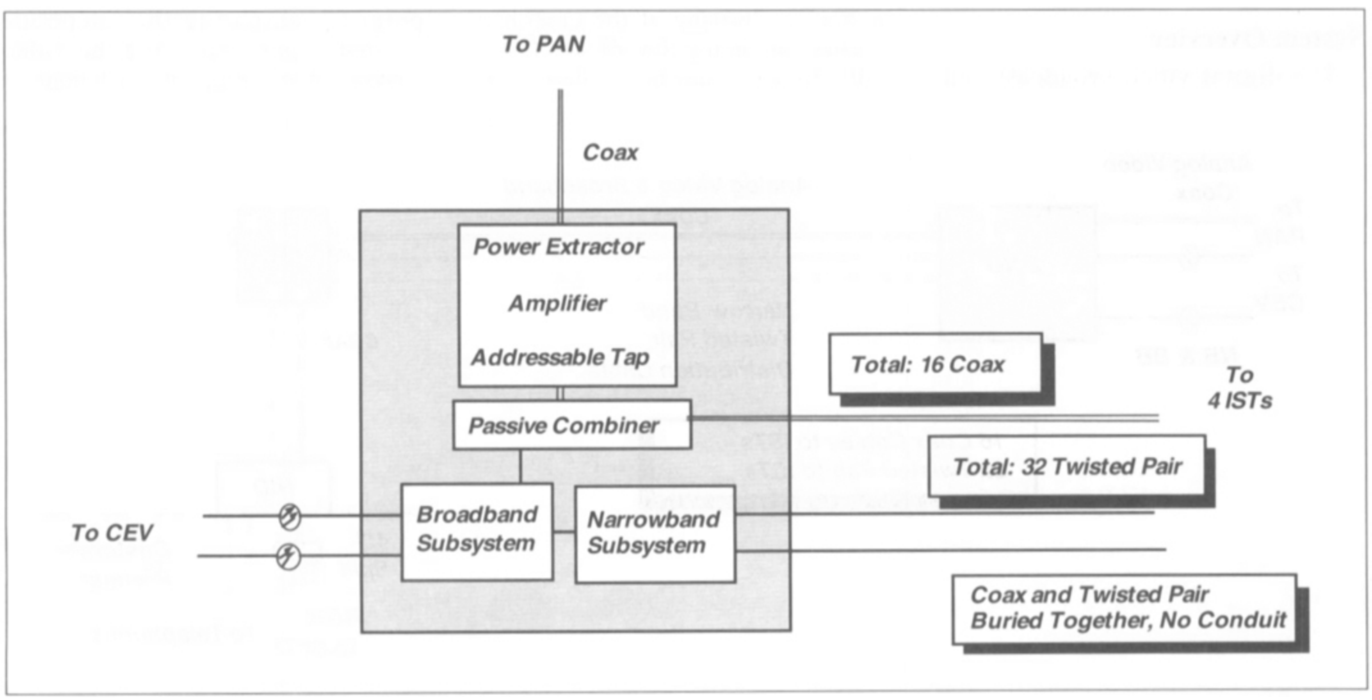

Figure 4. Optical network unit (ONU).

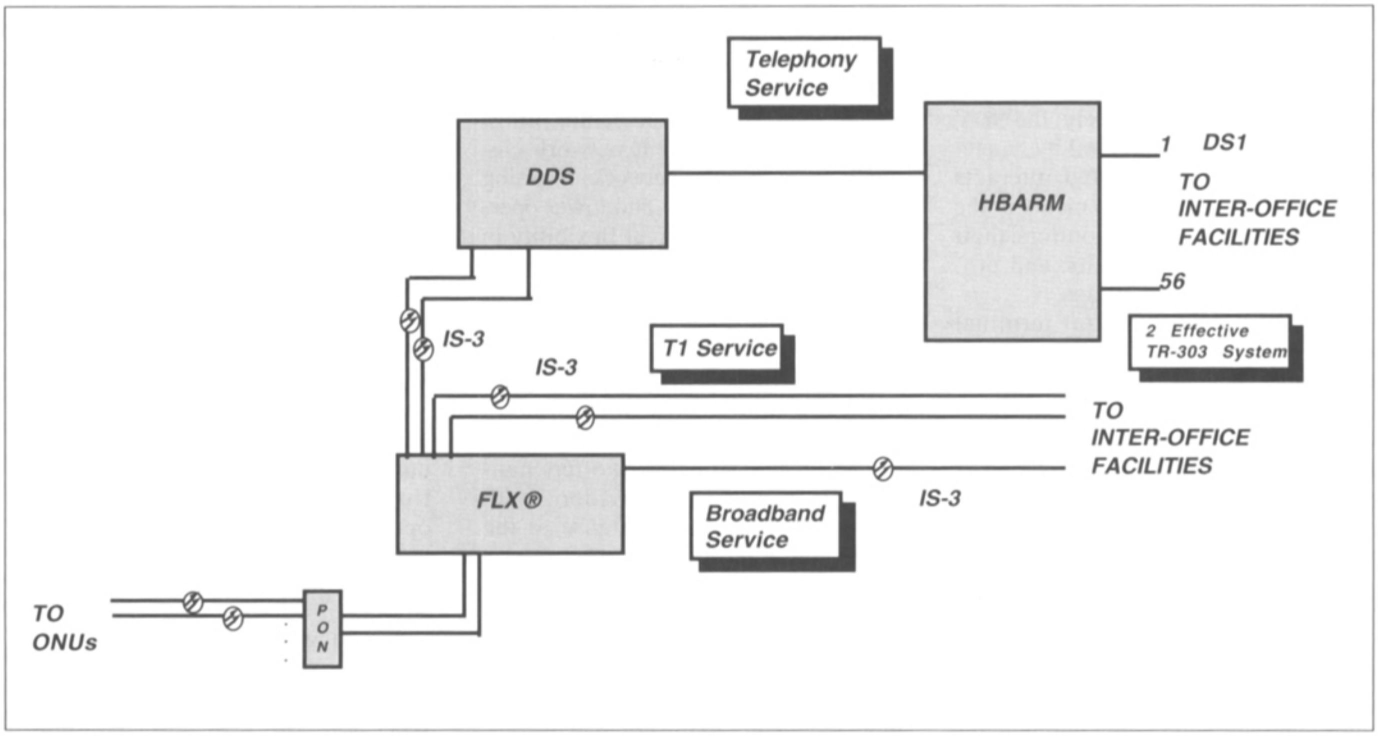

Figure 5. SLC-2000 Access System with FLX SDV HDT.

and the number of DS1 facilities (output of the HBARM) provisioned to the 5ESS determine the number of living units that can be supported by an HDT.

The broadband side of the HDT includes the ATM network interface (ANI) card on the FLX shelf where the OC-3c facilities carrying the digital broadband services are terminated. The FLX shelf routes any particular service to the digital-video subscriber through the appropriate ONU. The next section will discuss the functionality of this shelf and the broadband subsystem in the ONU in greater detail.

Also within the CEV is a Linear LightWave system that terminates the optical signal from the CO and retransmits the signal optically through splitters to multiple PANs. The digital signals, both narrowband and broadband, are transmitted to the CO with the use of DDM-2000 SONET multiplexers. The narrowband telephony signals are multiplexed/demultiplexed by a DDM-2000 OC-3 ring system for integration into the 5ESS in the CO. The network control signals and the interactive video programs and applications are transmitted over a point-to-point DDM-2000 synchronous optical network (SONET) optical carrier level standard 12 (OC-12) system. Both unidirectional and bidirectional OC-3c facilities are provided. Since the majority of the bandwidth requirements are downstream (e.g., movies being sent to subscribers), the use of unidirectional facilities and nonassociated signaling allow significant cost saving in the ATM network. The content and signals are routed by the BSS ATM switch located in the Richardson CO.

The digital broadcast signals are transported on a unidirectional ring, a new DDM-2000 OC-12 feature, which allows the inner and outer ring to carry unidirectional traffic. Eight OC-3c unidirectional facilities can be transported by the OC-12 system. This ring connects all of the HDTs to the HE. Most HDTs are in CEVs; however, subscribers close to the CO are served by HDTs in the CO.

Control and management of the interactive video/applications is done via a video manager (VM) that communicates among the BSS ATM switch, HDTs, STTs, and the HE servers. The VM uses a session level message set to communicate with the STT and server. Through this dialogue, the VM determines what network resources are needed and how they will be provided. The VM uses network-layer protocol over UNI interfaces to the ATM switch and the HDT to cause the network to establish ATM switched virtual channel (SVC) connections between the STT at the home and the server at the HE. Measurements provided by the VM include session related counts for billing purposes, as well as network and service usage information.

The broadcast digital video service is provisioned, administered, and controlled by the video administration module (VAM). (Note: The VM is the control system for interactive digital applications, whereas the VAM controls broadcast digital services.) For digital broadcast services, the VAM provides support for viewer statistics collection, narrowcasting, pay-per-view scheduling, and can provide subscriber security for impulse purchases. The VAM's functionality will be expanded upon in the next section.

The SDV network has been designed with extensive performance and fault monitoring capabilities that enables the assurance of high-quality telephony and broadband services.

Utilization of extensive software systems allows future system upgrades via software download. To utilize these capabilities effectively, the SDV access network is supported by an element manager system that interacts with the SDV network elements in the provisioning process, monitors their performance, detects faults, and provides restoration capabilities.

The Lucent host digital terminal element manager (HDT-EM) provides the element management layer (EML) functionality and provides an interface to the higher level network management layer (NML). This EM is responsible for coordinating the HDT and its subtending units in the access network such as the ONU. It provides provisioning, memory backup and restore, and alarm and event collection interfaces for the HDT. All OAM&P functions for the digital broadband and narrowband subsystems and their subtending components in the ONUs, are consolidated at the HDT-EM.

FLX-2500 Switched Digital Video (SDV) Access System

The FLX-2500 Switched Digital Video System is BroadBand Technologies' second-generation fiber loop access (FLX) System. It is an access system that was developed to serve residential, commercial, and business customers, and which offers a full range of video services. The modular architecture allows the cost-effective deployment of any combination of video services.

The FLX FTTC architecture brings fiber and the intelligent network elements deep into the network, resulting in increased reliability and lower operations costs. It offers real flexibility in deployment options and can be configured initially for the full service set or evolve to that point from a variety of start-up configurations. Upgrades to new services and higher penetration rates are made with only plug-in changes.

The FLX SDV network offers multiple drop options for video, both twisted pair or coax, or reuse of the inside house wiring.

With this network, ATM is brought directly to the home and the set top; there are no service-specific elements between the video information source and the set top. This network provides more bandwidth to the home than competing video delivery technologies, and the capacity is sufficient to deliver multiple services to the home over the long term. In addition, this network offers the economic advantage of baseband transmission for high-bandwidth services and distributed switching.

Because of its switched digital architecture, the FLX SDV network assures video/information channel security and privacy. And throughout, this architecture complies with existing and emerging industry standards (SONET, TR-303, MPEG, etc.) allowing network and operations flexibility.

The major components of the system and its capacities and services are briefly described in the following sections.

Major Components of the System

The major components of the digital broadband network are the FLX Shelf, which resides in the host digital terminal (HDT); the FLX Node, which resides in the optical network unit (ONU); and the video administration module (VAM) which is the operations support system (OSS) for video services.

The FLX Shelf

The FLX Shelf (Fig. 6) provides all the video functions and transports the telephony and HiCAP signals to the HDT and integrates narrowband/wideband/broadband services onto one common optical link to the ONU. The FLX Shelf supports up to 1280 video subscribers.

The FLX Shelf contains up to 20 optical line units (OLUs), which route ATM cells containing digital video on the FLX Shelf backplane to the subscriber's dedicated video time slot on the fiber to the ONU, each serving up to four ONUs.

A fully loaded FLX Shelf contains the following:

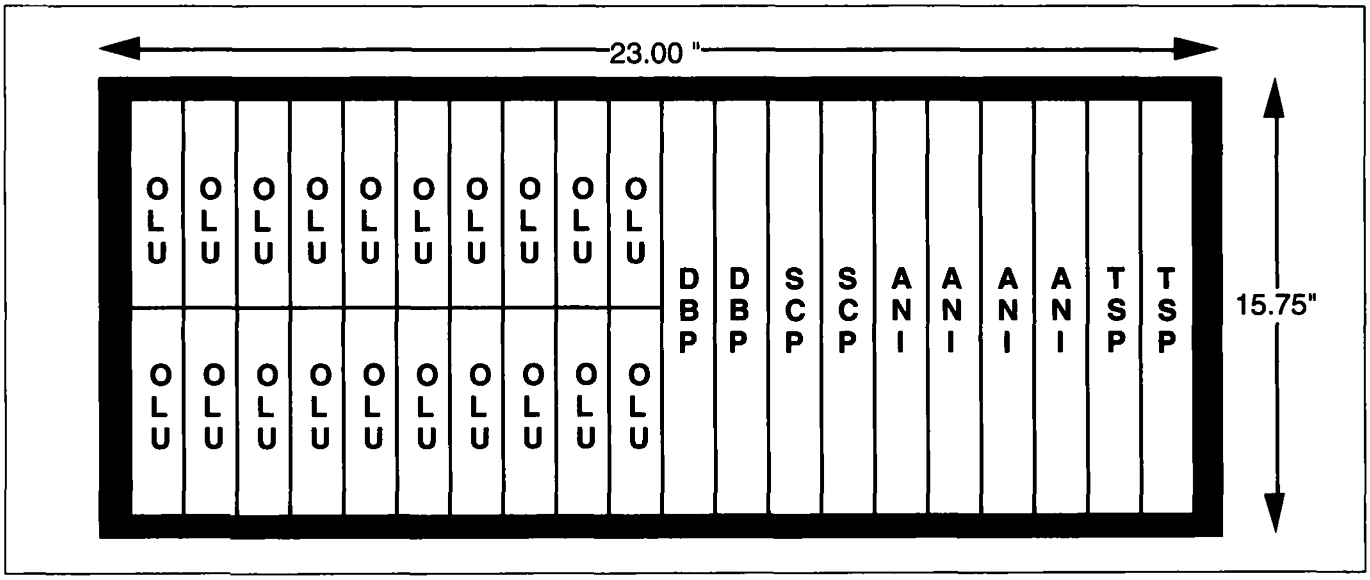

Figure 6. FLX Shelf card layout.

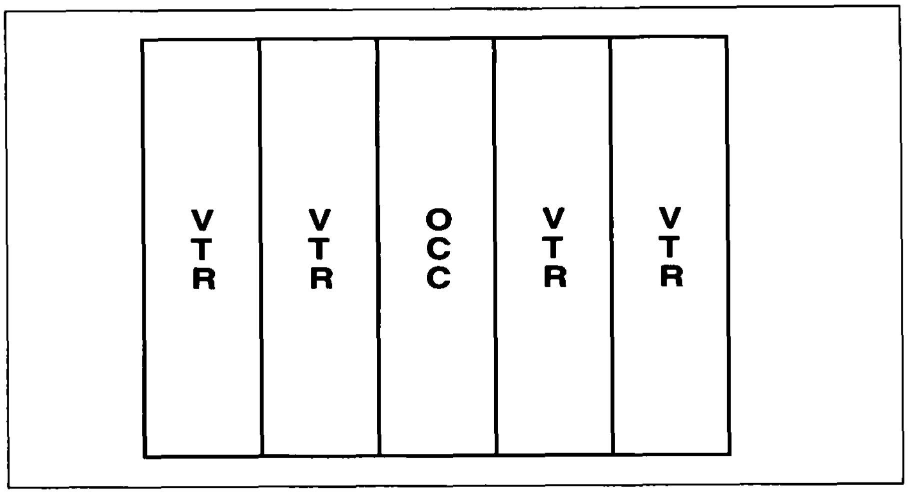

Figure 7. FLX Node card layout.

- 20 optical line unit (OLU) cards
- Four ATM network interface (ANI) cards
- Two telephone signal processor (TSP) cards
- Two shelf control processor (SCP) cards
- Two digital broadcast processor (DBP) cards
- FLX Shelf backplane

The FLX Shelf provides the digital video interface. ANI cards terminate digital video signals over IS-3c links from the SONET/ATM video transport facility. Subscribers share nonblocked access to any permitted video content received by the HDT. With the complementary software on the set-top box, the HDT can deliver basic and enhanced CATV services, as well as interactive multimedia TV and archival services.

Interfaces are provided for connections to a video signaling network, telephony OS, and the VAM for the provisioning and administration of video services.

The FLX Node

The FLX Node (Fig. 7) can terminate 8, 16, 24, or 32 video drops per ONU in point-to-point or point-to-multipoint configurations. In a point-to-multipoint configuration, a passive optical network (PON) is used, which may be up to 1:4 split. Up to four additional (optional) DS1s can terminate on the ONU to support high-capacity (HiCAP) special services.

The FLX Node is comprised of the backplane, an optical common controller (OCC), and multiple video transmitter/receivers (VTRS).

The ONUs are available in a variety of compact and cost-effective mounting arrangements to satisfy multiple outside plant configurations. Video drop sizes include 4, 8, and 16 (with 24 and 32 as future options). Telephone line sizes include: 12, 24, 32, and 48 lines. Enclosures (cabinets) come in aerial, pedestal, and wall-mount options. All mounting options for the ONUs are designed to meet the appropriate requirements of TR-57, TR-950, and TR-909.

FLX-2500 Switched Digital Video Services

Digital video is supported in two main forms: on-demand and digital broadcast. On-demand is a point-to-point service that establishes a dedicated pipe between the viewer and the service provider. Digital broadcast offers some of the same benefits in a point-to-multipoint service.

On-Demand Broadband Services

On-demand broadband services include VOD, shopping, electronic yellow pages, HDTV, multiplayer games, and data services such as Internet access, LAN extension, and work-at-home.

Digital Broadcast Services

Digital broadcast services include basic and premium CATV, IPPV, NVOD, viewer statistics, electronic program guide, and other interactive devices.

Security and Privacy

ATM routing ensures that signals are routed from the network exclusively to the set-top box requesting the service. The advantages of this approach are security of communications provided by the switched digital architecture, and the ability to download service applications at very high speed to run on set tops. Since communication is secure, service revenues are protected from piracy.

Interactive Multimedia TV

The system can download software applications to the set-top box, so video information providers (VIPs) can tailor their services to their customer population and/or offer new and exciting services as soon as they become available. These applications are independent of the FLX System and therefore not limited by its software.

The latency issue is important to certain services. By providing end-to-end ATM connections, SDV has the lowest network latency. For fast action games and immediate viewer feedback, there must be software running in the set-top box for immediate reaction. These applications must be downloaded into the set-top box, which then becomes a computer or game player. All set-top boxes will have the capability to accept downloaded applications. The FLX-2500 makes it easy to download over the video transport network.

Archival services are fully supported by the FLX-2500 System. Archival services allow subscribers to watch their favorite broadcast programs on demand; hours, days, or even years after the initial broadcast. On-demand bandwidth may be consumed in varying data rates so that MPEG-1, MPEG-2, or any other data rate video can be used. Nonvideo data, such as audio and data services, also may be carried. Interactive signaling is supported via a SONET-based ATM network.

Video Administration Module (VAM)

BroadBand Technologies' VAM is a digital broadcast video OS system. All the provisioning, billing, performance monitoring, and testing func-

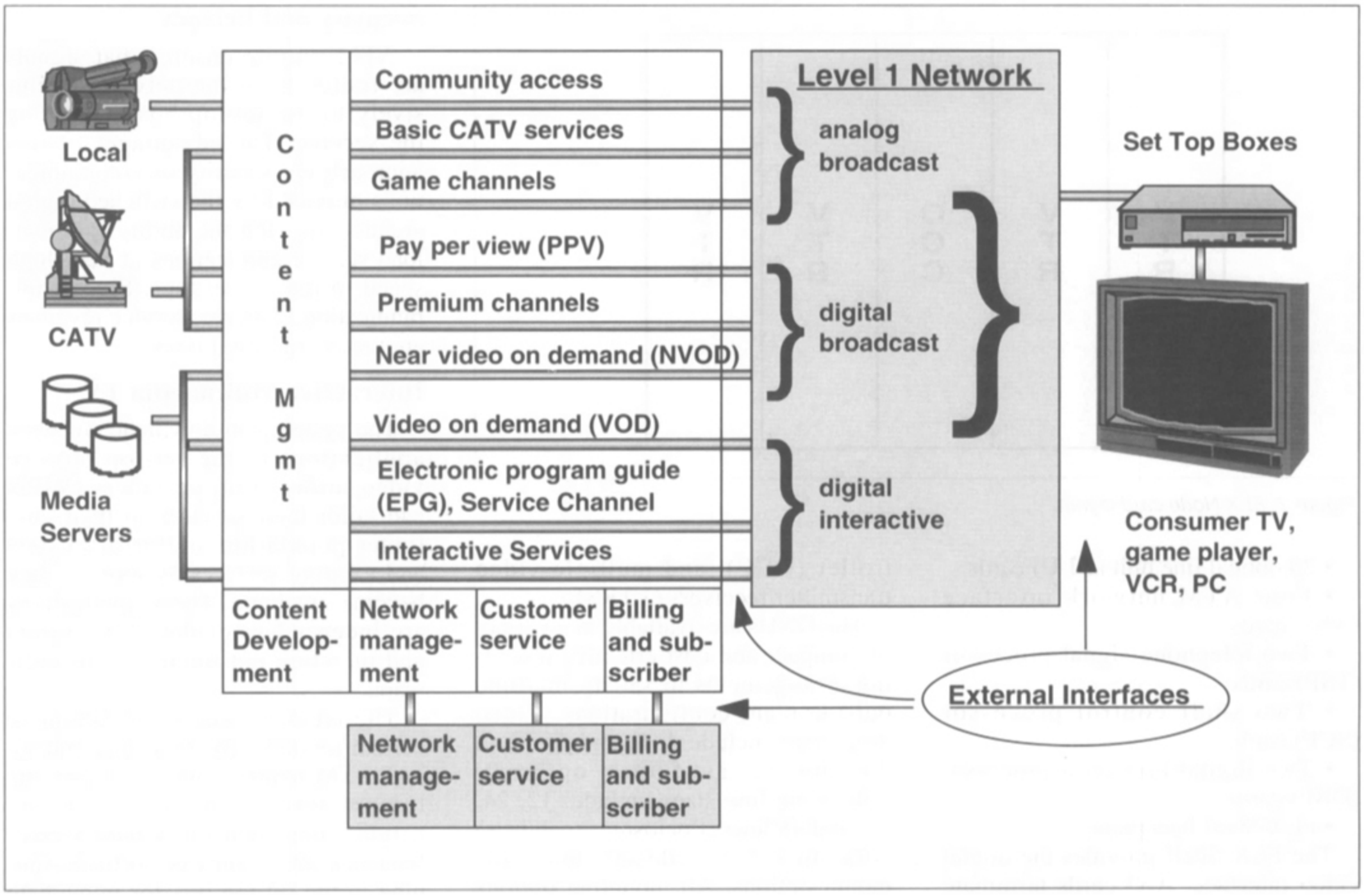

Figure 8. Richardson trial Level-2 capabilities.

tions for digital broadcast video services are performed through the VAM. This system administers and controls the interactive broadcast services for subscribers and VIPs, making it possible to provide service in an environment where there are hundreds of interactive broadcast channels and many different VIPs.

The VAM has been supporting switched digital interactive broadcast video service to RBOC customers for over two years. Future evolution of the VAM will allow for integration into a new generation of telephone company OSSs.

VAM Features and Functions

• *Multiple VIP administration and control.* The most important aspect of offering open video system (OVS) service is to be able to open the network up to many different VIPs, while ensuring security and privacy of content.

• *Narrowcasting.* This is the ability to send different video sources to different neighborhoods, allowing VIPs to tailor their programs to the varying demographic characteristics.

• *Viewer statistics.* As a potential revenue source, the system collects valuable subscriber usage data which can be sold to advertisers. Every 12 sec, the HDT reports how many set-top boxes are tuned to each channel.

• *Set-top administration.* The VAM provisions all services in the set top based on VIP input, and the VAM maintains information about the channels and services each set top is authorized to receive as a customer profile.

• *Channel management.* The profile of channel features defines how VIPs can sell their channels: as a regular channel, a premium channel, and/or an impulse channel.

• *Promotion.* An important revenue-generating feature of this function is the ability to easily and quickly establish barker, teaser, and trial services for promotion to viewers, who can be encouraged to purchase a channel on impulse by simply pressing a remote control button.

• *VIP billing system flow-through.* VIPs can use their own billing system, because an interface called the generic VIP interface (GVI) allows machine-to-machine communication between the VIP's computer and the VAM.

• *Billing messages.* When subscribers buy impulse pay-per-view (PPV) events and choose channel offerings on an a la carte basis, billing messages are created. The VAM stores the messages and reports them to the appropriate VIP billing system over the GVI.

• *User interface.* The VAM offers user friendly graphic user interfaces (GUIs) for all users with complete UNIX security features, such as user IDs and passwords.

• *Transaction logging.* The VAM logs all transactions over the GVI and all transactions sent to the HDTs.

In summary, the VAM is a sophisticated and advanced OS system, developed by BBT with close cooperation from its customers.

Level-2 Integration Functions

SBVS contracted Lockheed Martin to be the Richardson trial system integrator with the charge to integrate the components comprising the Level-2 head end and the set-top box with the Level-1 network.

The Richardson trial is both a technology and market trial. As such, the Level-2 head end is a fully integrated system with conventional CATV services, content management services, interactive application servers, billing and subscriber management services, and network and security management services. The capabilities of the Richardson system are illustrated in Fig. 8.

SBVS selected americast, a consortium composed of Disney and several telephone companies, as the foundation of their Level-2 head end. americast encompasses a full range of applications, including near-video-on-demand (NVOD), an electronic program guide, and subscriber services. Other services, such as video-on-demand (VOD), catalog shopping, and banking, although not present in the initial deployment, will be incorporated later. The americast architecture provides a platform that is designed to be capable of growth and enhanced capabilities.

Having chosen americast as the underlying architecture, Lockheed Martin's task as the system integrator is to encapsulate americast functionality into a system providing the full range of head-end services required for the Richardson trial. As the Richardson trial Level-2 system integrator, Lockheed Martin faces significant system integration challenges. Two major challenges are to deploy a system that provides desired and easy-to-use services to the consumer while meeting budget and schedule constraints. These two challenges have a tendency to polarize a design; on one hand adding features, and on the other hand reducing costs. However, Lockheed Martin and SBVS have worked together through many iterations of requirements and design to achieve a system that is both technically feasible and fiscally competitive.

One of Lockheed Martin's strengths is its many years of experience integrating large systems for the government. The Richardson trial, however, brings its own unique challenges. The system is complex in that there are many different software and hardware components, many of which are developed by different companies, often working independently. Understanding the functionality of each of these components to ensure that they collectively fulfill the requirements is a challenge in itself. Working with the many companies to ensure that the individual components work together and function as a system is another significant challenge. Nearly all com-

			street address guide, alarms, trouble ticket status					
			subscriber payment posting, movie pricing/availabilty dates					
EXTERNAL BILLING								
	ACQUISITION SERVICE PROVIDER		credit transactions					
		LOCKBOX BANK	subscriber account update					
billing data	credit transactions		VIP	game channel provisioning			analog/digital broadcast channels, interactive applications	video, audio, IR signal
				SEGA CHANNEL AUTHORIZATION SYSTEM				
			satellite, off-air, community access programming		CATV PROVIDERS			
			EPG, MPEG-2 video/ancillary application/service data			CONTENT PROVIDERS		
			interactive digital applications control				SWBT BROADBAND NETWORK	
								TELEVISION / VCR

Figure 9. Richardson trial major external system interfaces.

ponents within the system are still under development. This also makes the integration process more difficult in that there is no stable foundation upon which to build the integration effort.

Technical challenges continue to exist at this stage of development. Although the details of the Level-1 to Level-2 interfaces have been resolved and documented, issues will continue to surface during integration. As an example, just in the area of establishing an end-to-end virtual circuit through the ATM networks using a standard protocol called UNI 3.1, there are six major components involved (americast server, internal ATM network, BSS ATM switch, video manager, FLX-2500 FTTC system, and the set-top box). These six major components use UNI 3.1 software packages developed by four different vendors. Since this protocol is relatively new, these software packages have not yet been tested for compatibility, and problems are expected. Other areas in which technical challenges continue to exist are content security, system scalability and growth, and set-top box affordability.

As system integrator, Lockheed Martin (LM) plays a major role in the design and development of a total system solution. Its first major function was to work closely with SBVS and TRI to define the system. As described earlier, this involves collecting, documenting, and understanding all of the system level requirements, from which a system architecture is proposed and cost estimates are developed. Formal system level and product level design reviews are held to obtain concurrence from all parties that the requirements and design are satisfactory, prior to proceeding to the next phase of design. In certain critical areas, trade studies are performed to further refine the requirements, technical capabilities, and costs.

Another major role performed by LM is the development of detailed schedules identifying contingencies and risks and developing work-arounds. These schedules encompass all aspects of the trial and require many working meetings with all of the companies involved in the trial. Implicit in this effort is understanding what functional capabilities are provided with each delivery from each company. As a result of these scheduling efforts, many times it is possible to bring the various development efforts in sync. This allows the functionality of the various components to be incrementally implemented, yet allows integration to proceed by providing compatible functionality across all components.

Identifying and defining the system external interfaces is another major role that the system integrator performs. The definition of some of these interfaces, such as the Level-1 to Level-2 interface, involves many meetings with all of the major players in the trial. It often takes many months to get consensus on an interface definition. Much of the work is done via e-mail and telephone conference calls, with the engineers from the various companies working in small groups on specific items of interest. The more formal meetings, typically held once a month, are used to document the effort and to surface issues that need resolution at higher levels.

As an offshoot of understanding the details of the functionality that the various vendors are providing, the system integrator learns the system in great detail. Having this knowledge allows the company to identify problems and provide technical direction to the various vendors.

Having defined the system functions, the development process continues by ensuring that the system level requirements are incorporated in individual product areas, such as content servers and billing and subscriber management. These system level requirements are augmented with product level requirements where needed. Industry surveys, trades, and competitive proposals are performed to select vendors for the various components. The components are procured or developed as necessary and integrated into the system. As the system comes together, testing is performed within an LM facility to ensure that the system requirements are being met. Prior to delivery, formal tests are performed with SBVS to verify that the system not only meets requirements but that it is operationally ready to be fielded. Finally, LM will install and initially operate the head-end system in the field.

As illustrated in Fig. 9, at the system level there are eight major external functions having interfaces to the head end or set-top box. These functions are presented in an N-squared form. The interfacing functions are defined on the diagonal. Data flows in a clockwise direction from the function, with the information being shared between two interfacing functions presented at the functions row/column intersection. Of these interfaces, the major ones from a technical standpoint are the head-end to broadband network and broadband network to set-top-box interfaces.

Conclusion

SWBT's Richardson trial is a large, complex system that incorporates the latest hardware, software, and communications technologies. The Level-1 architecture presented here is the result of close cooperation between SWBT, Lucent, and BBT to identify, study, and resolve issues associated with deployment of a new technology. Lockheed Martin has performed critical systems' integration roles in driving standardization of interfaces, facilitating the implementation issues, and balancing the market desires of the associated companies.

The Richardson deployment is work in progress, and efforts continue to define a total OS plan, reduce costs, provide enhanced features, and to better understand the customer service needs. Detailed traffic modeling of the network is being done to assure high-quality service to subscribers in Richardson. This is readily accomplished for narrowband telephone service; however, there are only limited estimates of the activity for broadband interactive services. The Richardson network is the test vehicle for understanding how new services will shape the Level-1 broadband network.

Requirements definition and flow-down processes have been successfully used to manage the evolutionary development of these new technologies. Detailed project planning has been performed to define dependencies, contingencies, and establish workable schedules. Working with many companies to define new technologies, identifying implementation risks, and performing and tracking detailed schedules have all been crucial activities in implementing this complex system on schedule and within budget.

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