Challenges in a Digital, Server-Based Broadcasting Environment

By Richard J. Echeita

DIRECTV, Inc., initiated operations at its all-digital Castle Rock Broadcast Center (CRBC) in Colorado on June 17, 1994. The broadcast center contains a 512 x 12 SMPTE 259M serial digital router, controls more than 300 digital VTRs, and transmits nearly 200 channels via the DIRECTV geosynchronous direct broadcast satellites. This paper describes the issues and challenges facing DIRECTV in evolving the CRBC and its other facilities toward a "server-based" architecture. Tentative conclusions may change as requirements change and technology matures. It is also intended to provide a basis for industry discussion of key issues.

In more than 50 years of commercial broadcast television, few changes have affected the medium more than the conversion from analog standards to digital. Only now has this change been introduced in such a manner that an entirely digital broadcast system can receive, process, and deliver a digital signal to an end user. This opens the market to various types of broadcast products that can be delivered, from video on demand (VOD) to interactive video data services (IVDS). Possible strategies for implementing a digital broadcast site are discussed in this paper.

Since the basic waveform characteristics of the operating medium have changed from analog to digital, many of the governing criteria have gone from waveform shape and levels to data error correction and network integrity. The basic system has evolved from an analog signaling system to a data network. To accommodate such changes, the traditional broadcaster's orientation needs to evolve to that of a data network administrator.

The digital, server-based, broadcast facility is faced with five major challenges:

- Site video/audio/data formats
- Intrasite video/audio/data networking
- Video/audio/data storage and retrieval
- Real-time video/audio/data insertion
- Intersite video/audio/data networking

These challenges have multiple solutions and cover a number of segments and subsegments of the digital, server-based broadcast facility. The digital broadcast center can be broken into six major areas: preprocessing/compression, analog/digital conversion, internal signal distribution, data storage, data assembly, and consumer distribution segments. Ancillary systems worth noting are the interactive data, program authorization, and interplant data delivery segments. Each of the five challenges will be covered and the relation or impact on the segments and subsegments shown.

Site Video/Audio/Data Formats

Most data received by digital broadcast centers is in either an analog or digital format. It usually cannot be distributed in its native formats by the digital broadcast plant without reformatting. Two of the major segments, preprocessing/compression and analog/digital conversion, reformat the incoming material into a homogenous format readily accepted by the digital broadcast site. Taped or "nonlive" material arriving at the digital broadcast plant travels to the preprocessing/compression segment. Any material to air "live" needs to be processed in the analog/digital segment. Both of these segments provide preprocessing and compression, but the extent of this processing is time-limited for the live signal.

First, let's examine the live material case. The analog/digital segment converts all material taken in by satellite, over-the-air, along with terrestrial fiber formats, into a standard digital signal synchronized with the plant's internal timing. The DIRECTV experience has been with various analog and digital signal formats received via the Videocipher, B-MAC, Leitch, Digicipher, and 45 Mbit/sec fiber-optic systems.

The signal can be handled in three possible ways:

- Convert the analog signal into a digital intermediary format, and compress and wrap it with a data transport.
- Receive an already digital signal and transcode it from the current format into the digital plant's native format.
- Receive a data stream in the plant's own native format, updating destination and time stamp information for the intraplant distribution.

If an analog signal is received, it could be converted immediately into a digital format — say SMPTE 259M, D-1, which is a popular candidate for intraplant distribution. The majority of the resulting difficulties arise from the initiated signal from the uplink. Items such as lack of frame sync, improper equipment grounding, and overall poor source quality can be falsely attributed to data compression problems. The picture that airs will only be as good as its source; thus, the digital broadcaster diligently polices all incoming material.

Preprocessing of analog signals consists of, for example, simple high-frequency filtering. The encoder engine then compresses the signal into a standard format, such as MPEG-2, and uses various standard transport formats,

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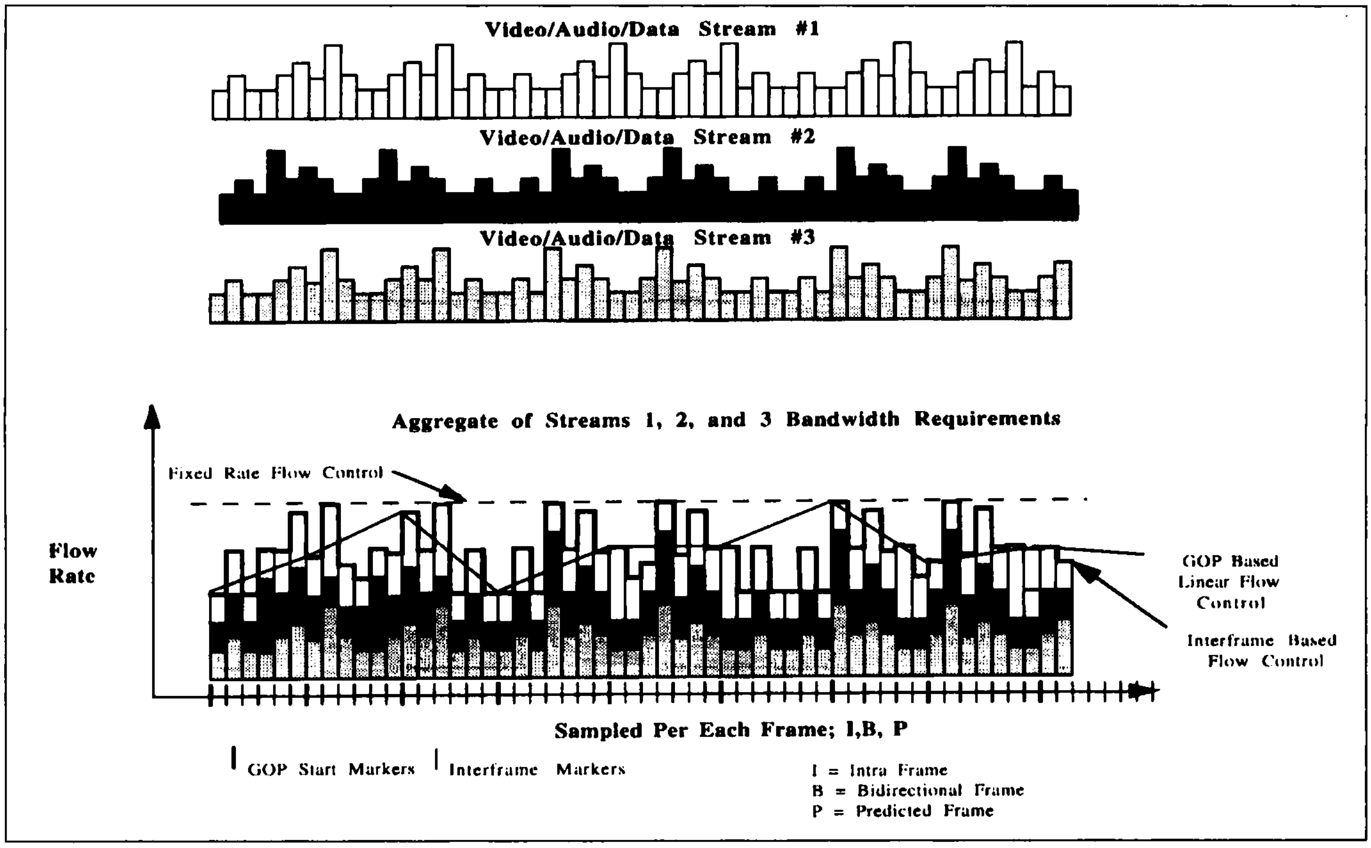

Figure 1. Interlocked data streams.

such as the Digital Satellite System (DSS) or digital video broadcast (DVB) formats. Both of these transports are fine for airing the signal, but they lack the capability to be addressed in a networked environment. Therefore, another wrapper, such as the asynchronous transfer mode (ATM), is needed for internal data delivery.

Before continuing with the distribution, let's return to the other type of material received by the digital broadcast plant, the "nonlive" media. The "nonlive" media can be received in the same manner as the "live" media, but the digital broadcast plant has much more time and preprocessing leeway in handling the material. The material can arrive in one of various tape forms, in a data stream not compatible with the digital broadcast site, or in a certified, compatible data stream that meets the digital broadcast site's format requirement.

The amount of time spent preprocessing and compressing the data depends on the received data's format. An item in an analog format first needs to be converted to digital, then preprocessed to eliminate possible artifacting components, and finally compressed into the suitable format. When trying to optimize the data stream for maximum bandwidth usage, the greatest gains are at this stage. This part of the data stream is a foundation in which data is optimized and interlocked with other streams for maximum bandwidth usage (Fig. 1).

As shown in Fig. 1, the data, once assembled, could provide information to the real-time compression units. The real-time data streams, when concentrated with the precompressed data streams, will maximize the bandwidth usage. Many of the precompressed streams could be stored in the partially concentrated format if the programming schedules are known far enough in advance. Since the programming department will be driving the bandwidth requirements, it is imperative that this allocating function be an integrated part of the digital broadcast system.

Software tools are now developing as part of traffic systems to account for the bandwidth allocation potential of the digital broadcast environment. In time, these systems could extend to traditional and terrestrial broadcasters.

Intrasite Video/Audio/Data Networking

Once the signal compresses into a standardized digital format that can be transported throughout the digital plant, a method to deliver this data is needed. Here, the road forks. Currently, the most popular, uncompressed, digital distribution format for the digital broadcast signal is SMPTE 259M. This is limited by the point-to-point routing, the nonaddressable network, and the fact that compressing the stream leads to either a fractional use of the 270 Mbits/sec or to the need for decompression and recompression of the data at the network endpoints. This last option only adds to equipment cost and complexity.

The competition on the horizon, the ATM AAL 5[1] via a SONET network,[2] is based primarily on using precompressed data (MPEG-2) as the internal cell format. This data then breaks up from its native length into 53-byte cells and then routes via the ATM network.

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This spring, the film industry will converge on Los Angeles for the most important inaugural industry event—SMPTE's First Annual Spring Film Conference and Exhibit. It is the place where buyers will discover new ways to improve their businesses. The Spring Conference and Exhibit is the place for exhibitors who want to target serious buyers from the film production and post-production markets. Los Angeles is home to one of the nation's largest commercial production communities—a place where SMPTE attendees will come to evaluate, influence, recommend, and approve purchases.

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CONFERENCE SESSIONS

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  Chaired by Edmund DiGiulio, Cinema Products Corp., and co-chaired by John Hora, ASC. This session, produced in association with the American Society of Cinematographers, will examine the technical and creative aspects of getting the story on film.

- **Laboratory**

  Chair: Frank Ricotta, Technicolor, Co-chair, Paul Law, Consolidated Film Industries. This session will emphasize improvements in film restoration practices, and is being produced in association with the ACVL.

- **Post-Production**

  Chaired by Paul Carey, Marketing Specialists, Inc. and Jon Erland, Composite Components. This session will look at editing, telecine transfer, effects, and more.

- **Distribution/Exhibition**

  Ioan Allen, Dolby Laboratories, chair of this program, will examine projection systems, screens, sound, formats, and theater quality. The session is being presented in conjunction with ITEA.

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THURSDAY MARCH 20, 1997

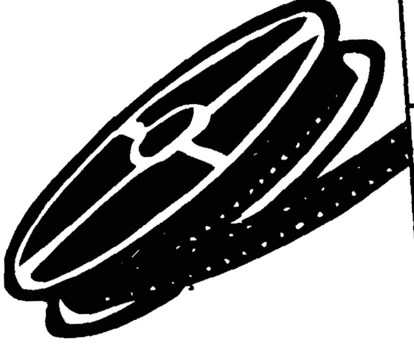
DAY-LONG SEMINAR

Sponsored by the Hollywood Section of SMPTE, *The Nature of Film*, will be chaired by John Mason, Eastman Kodak Co. This all-day program is devoted to the fundamentals of film, and the objective of the seminar is to introduce the basics of film technologies to professionals who may be new to the medium and provide a refresher course for the more experienced film technicians.

The morning session is devoted to color theory, sensitometry, tone reproduction, various film types, formats, and naming conventions. The afternoon session will cover conventional and nonconventional negative and distribution films, film cleaning, and handling procedures. The program will conclude with a series of special topics including telecine transfer, digital sound, and Keykode number and applications.

Presentations are scheduled by these industry standouts:

- Color Theory: Sensitometry, Tone Reproduction, How Film Works?, Ken Fowler
- Film Naming and Conventions: Film Negative-Intermediate Print, Formats 8, 16, 35, 65, 70, Types IR, B&W, Sound, and Reversal, Greg Arnold
- Traditional Paradigm: Speed-Grain-Sharpness Triangle, New Paradigm, Special Look Stocks, Special Application Stocks, Steve Powell
- Conventional Distribution: Dye Transfer Prints, TV Transfer Film, John Pytlak
- Film Handling (Splicing, Safelights, Static) Cleaning (PTR, Aqueous/Organic Solvents), John Pytlak
- Special Topics: Hybrid Imaging, Telecine Transfers and Tools, Digital Sound, Alan Masson



Program-At-A-Glance

	THURSDAY	FRIDAY	SATURDAY
MORNING SESSIONS 8:30 - 12 Noon	Day-long Seminar "The Nature of Film" Chair: John Mason	Production Chairs: Edmund DiGiulio & John Hora	Post-Production Chairs: Paul Carey & Jon Erland
LUNCH	12 - 1:00 p.m.	12 - 1:00 p.m. 1:00 p.m. Guest Speaker	12 - 1:00 p.m.
AFTERNOON SESSIONS 1:30 - 5:00 p.m.	Seminar Continues 1:00 - 6:00 p.m.	Laboratory Chairs: Frank Ricotta & Paul Law	Distribution/Exhibition Chair: Ioan Allen
EVENING	6:00 p.m. Evening Reception	6:00 p.m. Showscan Tour	6:00 p.m. Screening

The SMPTE Conference Features Four Comprehensive Sessions

A full complement of programs is offered and is structured to provide techniques, ideas, and information that you can apply to your film operation, regardless of the size of your production staff or market. *Film: Still the Master in a Digital World* features papers on the technologies that are changing the face of the film production and post-production communities, and laboratory practices. Here we present the conference sessions and a small sampling of the papers scheduled for presentation.
Note: Papers are subject to change.

FRIDAY MORNING
PRODUCTION

Chaired by Edmund DiGiulio, Cinema Products Corp. Co-chaired by John Hora, ASC

- Eastman Vision 200T/250D Camera Negative Film, Esther Betancourt and Sue Zygo, Eastman Kodak Co., Rochester, N.Y.
- A Review of the Fuji Super F-Series of Motion Picture, Products, Bruce Berks, Fuji Film, Hollywood, Calif.
- Unified Color Management System, Ron Garcia, Consultant, Pacific Palisades, Calif.
- Panel Discussion: Cinematographers and Digital Artists: Friend or Foes? Robert Primes, Consultant, Hollywood, Calif.

FRIDAY AFTERNOON
LABORATORY

Chaired by Frank Ricotta, Technicolor. Co-chaired by Paul Law, Consolidated Film Industries

- New Eastman Soundtrack Negative Film, Alan Masson, Eastman Kodak Co., Hollywood, Calif.
- Archiving Magnetic Film Sound Elements, Robert Heiber, Chace Productions, Burbank, Calif.
- Film Asset Management, Rick Utley, FPC, Inc., Hollywood, Calif.
- The Matinee Idol Restoration, Grover Crisp, Sony Pictures Entertainment, Cerritos, Calif.

SATURDAY MORNING
POST-PRODUCTION

Chaired by Paul Carey, Marketing Specialists, Inc., and Jon Erland, Composite Components

- The Digital Enhancement of High Resolution Multi-Format Cinema Imagery, Michael Ostrelich and Lewis Merritt, Image Graphic, Inc., Shelton, Conn.
- Practical Aspects of Using TSC System from the Point of View of Tele-Cine Colorists and DP, Y. Neyman, S. Riviere, and H. Sisko, Gamma & Density Co., Inc., Studio City, Calif.
- Truetime: An Alternative Approach to the Marriage of Film and Video, Luke Freeman, Sony Electronics, Inc., San Jose, Calif.

SATURDAY AFTERNOON
DISTRIBUTION/EXHIBITION

Chaired by Ioan Allen, Dolby Laboratories

- Compact Distribution Print: Coexistence of Quality and Economy, R. Vetter, C. Davis, and B. Pinkston, United Artists Theatre Circuit and The Todd-AO Corp., Pacific Palisades, Calif.
- Monitoring Sound in the Close Field Environment—Park II, TMH Corp., Los Angeles, Calif.
- High-Magenta and Cyan Analog Soundtrack: A Progress Report, Paul Goldberg, Zoran, Santa Clara, Calif.
- Are Movies Too Loud? Ioan Allen, Dolby Laboratories, Inc., San Francisco, Calif., and Tom Scott, EdNet, San Francisco, Calif.
- The Dolby CP500 - Optimal Approach to Signal Processing, Del Hatch, Scott Robinson, and John Neary, Dolby Laboratories, San Francisco

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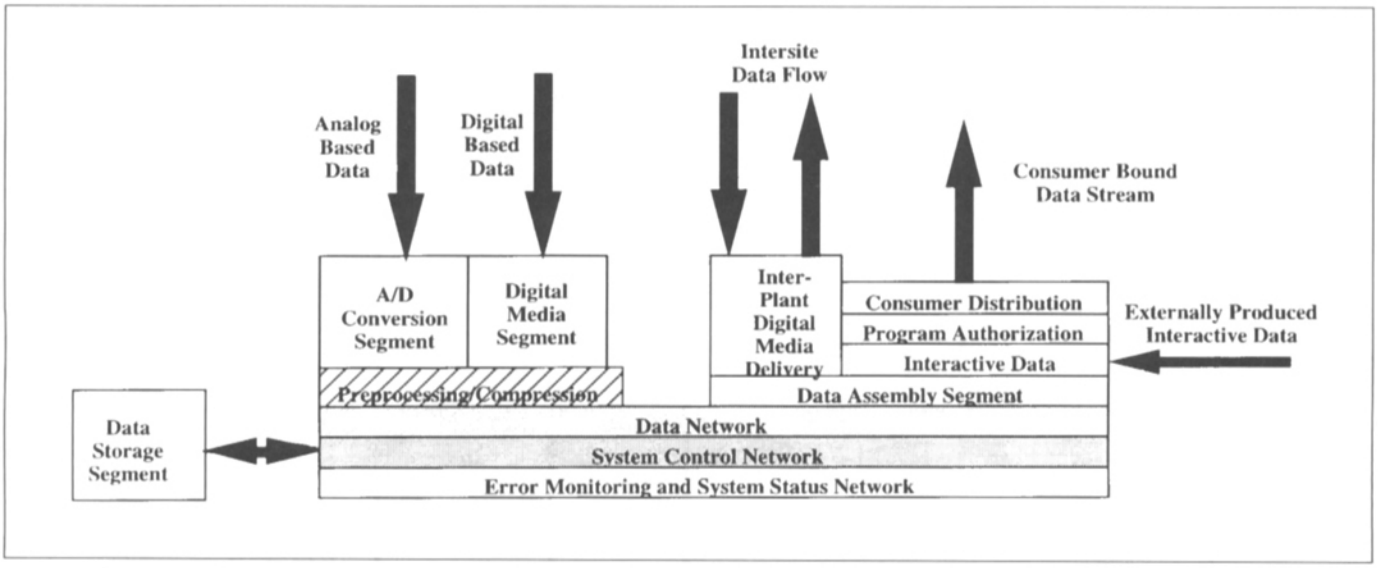


Figure 2. Digital broadcast site layered view.

However, SMPTE 259M could be carried via an ATM format. It is entirely plausible to use the ATM wrapper on a SMPTE 259M signal, but the overhead for such a signal would require signal transmission at virtually double the current 270 Mbit/sec rate. This would not be cost effective.

The ATM is a newcomer with its own set of challenges. Lack of multivendor interoperability, industry inconsistencies regarding the segmentation and reassembly (SAR) techniques prescribed for AAL 5 with MPEG-2, and the complexity of resource allocation of the ATM circuits pose interesting challenges. Though the majority of these challenges still are being worked out, the ATM seems likely to provide a far more flexible and economical solution for the future.

The ATM's strengths are based upon three key characteristics: networkability, industry acceptance, and cost effectiveness. Using a single network to route all data greatly reduces the cost of hardware, but the price goes up in the software. The complexities once being handled in hardware now need to be modeled in the software. However, the trade for these cost impacts is greater flexibility in the digital broadcast system as technology changes. A simple model of the network required to support the digital broadcast site is shown in Fig. 2.

Figure 2 shows that the network is actually three networks, each supporting enough major traffic to warrant three separate loops. The data network supports the heaviest load, that of moving data within the network for airing, storage, and intraplant delivery. Using the ATM networking model, one could easily picture a permanent virtual circuit (PVC) with a resource managing system to control the circuit configuration based on the network's needs. Since much of the programming does not change during the day, this circuit is fairly static.

The system control network isolates from the other networks to prevent bottlenecks of data and to ensure a timely response to critical commands. This network provides all commanding and configuration information for the system, from routing switches to encoding equipment. Levels of authorization and access, as in any properly built network, isolate various entities from cross-commanding or illegally commanding any of the units.

The final layer is the error monitoring and system status network, which monitors the entire digital broadcast site and notifies the control system and operators of changes. Certain alarms and corrective actions can be placed into this system to set a piece of equipment in a "safe off-line" mode. This, at least, gives the system control network a standard starting point. Much time and planning is required to properly define this network, its alarm levels, and corrective actions. This task, a full-time endeavor, never seems to end.

If such a layered network were to be realized in a simple ATM structure, it could look like Fig. 3. Note that this figure is defined for a digital broadcast site complex.

Figure 3 shows just the basic data network and part of the system control network, involving the traffic system, the PVC resource system, and the transponder assembly system. The compression aspect of the system has been pushed from the consumer data delivery point to the data entry side of the digital broadcast site. By doing this, the intraplant data flow derives from homogenous, controllable streams. This also greatly aids in transferring data to separate sites with minimum post-processing. Unfortunately, this type of plant is still in the design stage.

Video/Audio/Data Storage and Retrieval

Extensive data transfer requires a reliable, fast, effective storage and retrieval system. The major requirements to store and retrieve digital broadcast site data are archival, interstitial, on-line near video on demand (NVOD), and interactive (IA).

Archival Storage and Retrieval

The archival method stores or retrieves materials that are not being aired within a given period, say a week or more. It acts like a library and uses a system that works in an off-hour format. The system can load material onto the other systems for airing during the

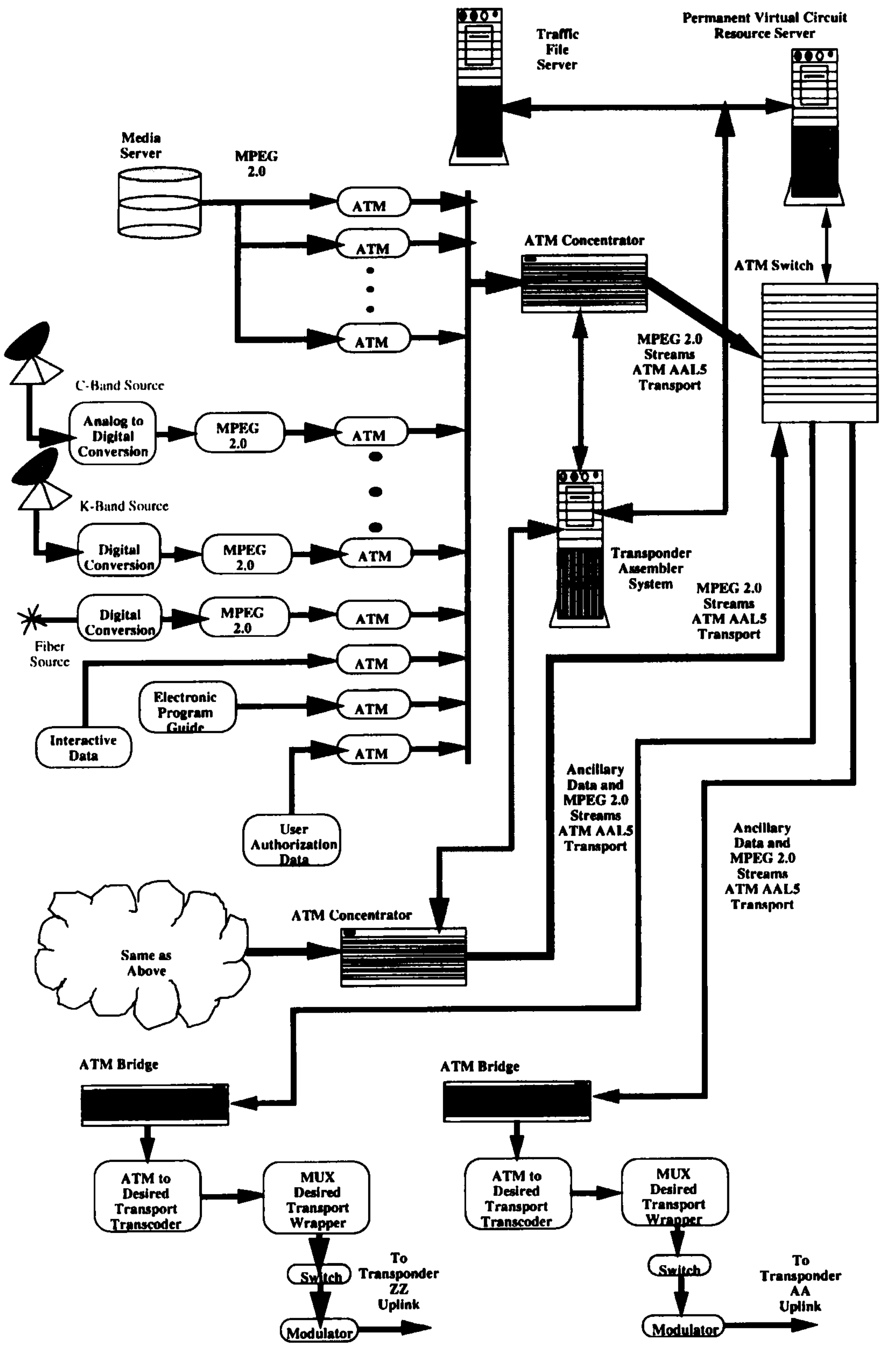


Figure 3. Possible ATM distributed digital broadcast site.

week or day. Since the transfer rate of this system is not as critical as its quality and reliability, digital tape-based systems are ideal for this task. Two main types of materials, which are both contract sensitive, can be stored: interstitial/promotional and feature media data.

Supplier agreements are a concern because of a simple fact: contracts can stipulate the storage duration of the media. The contract also can define the format in which the data is received. For example, preprocessing and compression formats could be negotiated so that the deliverable format is compatible with the digital broadcast system's native format. This, however, would affect the plant's ability to reprocess the media for optimization, unless negotiated in the contract.

In addition, the broadcaster has the option of using an escrowed data warehouse where many providers stock data, and where material is brokered and formatted to various specifications. However, this does not alleviate the need for a backup archival system.

In terms of interstitial material, the archival system could collect such data as past promotions, seasonal advertisements, and standard public service announcements. The object is to minimize the archive's size while maximizing its depth.

Interstitial Storage and Retrieval

Any broadcaster who relies on advertising dollars needs interstitial storage/retrieval systems. These systems require extreme flexibility to allow for last-minute updates, in coordination with an equally capable traffic system. Storage/retrieval systems with such characteristics include redundant array independent drives (RAID), digital multiple tape systems, and random access memory (RAM) buffer systems.

The RAID system meets the flexibility, cost effectiveness, and reliability demands of a good interstitial storage/retrieval system, while providing very high transfer rates and multiple input/output (I/O) stream capabilities.

The digital multiple tape storage/retrieval system can meet multiple I/O requirements and offer decent transfer rates, but it falls short on reliability because of the tape drives' mechanical wear. Also, it needs more space for tape storage than the RAID. The tape expense and the reliability factor add drawbacks not found with the RAID systems.

The RAM buffer storage/retrieval system uses enormous amounts of RAM to build a huge memory matrix. This makes it possible to store and retrieve many materials in a real-time computing system with little delay, via multiple data streams. It is as reliable as the RAID system, but its storage depth is more limited because of the memory devices' physical constraints. However, cost is the system's biggest drawback. Despite its limitations, the RAM storage/retrieval system has a very promising future, especially when performing commercial insertions into a real-time compressed stream.

NVOD Storage and Retrieval

The on-line NVOD storage/retrieval system can be implemented by one of three technologies: magneto-optical (MO), digital tape-based, and RAID storage/retrieval systems.

The MO system is the least likely to be implemented at this time, since the technology lags behind currently available RAID storage/retrieval systems. In time, though, this might be a viable solution. The digital tape-based storage/retrieval system is a viable solution now, but as noted, its reliability and cost effectiveness trail that of the RAID system.

The RAID system provides the most popular digital storage/retrieval solution at this time. Its reliability, flexibility, and cost effectiveness make it hard to beat. Current constructs use RAID 3 or RAID 5 structures as basic multimedia storage/retrieval systems.[3,4] Both of these structures provide for good systems and are proven, although limitations do occur. Among the most notable are the use of homogeneous hard drives and the failure tolerance of just a single hard drive.

Work is under way to develop more robust systems, using a RAID 7 structure.[5] The advantage of such a system is that, with an embedded operating system (OS), it can independently control each hard drive's read/write head. The system, which supports 12 hosts independently, can be networked into scalable storage systems. Unlike RAID 3 or 5, the RAID 7 system tolerates up to four hard drive failures and a heterogeneous mix of hard-drive sizes and types.

The RAID system stands as the best solution for on-line NVOD storage/retrieval at the all-digital broadcast site. The key for a digital broadcast plant is to select the optimum modular size of the basic building block for the plant's storage/retrieval system. If the system is too large, its ability to redirect resources might be limited, and the basic cost will be substantial. If it is too small, it will be outgrown as services are added.

The basic size should accommodate a sizable fraction of the storage/retrieval requirements. Also, the storage/retrieval systems must be networked and controlled by a resource managing system. Each system can expand independently in terms of depth and I/O. The ability to store in a precompressed format also becomes an issue.

By storing precompressed data, passing information becomes easier from a distribution standpoint, but more difficult from an editing or insertion standpoint. The storage/retrieval system must accommodate the desired precompressed format and have the proper data transport format for easy distribution. The advantage in using precompressed data is that information on the stream's optimum play rates and other statistics can be bundled with it. This information then could further optimize the consumer channels' bandwidth.

Interactive Storage and Retrieval

Interactive storage/retrieval systems are a type of file server that might be required to synchronize with other data streams, or they might run independent of other data streams. These servers could be part of the digital broadcast site, or they could be treated as digital streams that need reassembly to meet the digital broadcast site's needs. Since most of the information is digital, the interactive storage/retrieval system is likely to be a RAID system or a file server.

Real-Time Video/Audio/Data Insertion

One item remaining to be discussed is the challenge of inserting compressed material into an existing real-time compressed stream. No one yet has demonstrated a commercially available system that can perform this task. Also, the ATM environment has not demonstrated, nor has it made provisions to define, "clean" insertion points in which the compressed stream from a storage/retrieval device can "break into" and "break out of" a real-time compressed stream with no artifacts at the consumer end. This needs to be resolved to make the ATM a viable inter- or intraplant distribution methodology.

Site Integration

Now that the system has been discussed from the entry, internal distribution, and storage perspectives, the next logical step is the data assembly segment. This segment is where the electronic program guide (EPG), video/audio (V/A), program authorizations, and interactive data (IA data) are combined into concentrated streams.

The concentration of these streams can take place at a single point or can begin early, as shown in Fig. 3. In this figure, the traffic system predetermines the channel constructs for each DBS transponder. The ATM streams then concentrate and switch to their final delivery point where they transcode into the deliverable format for the consumer. The ATM concentrator takes the place of the data multiplexer, currently used by a number of digital broadcasters. Although realizable, the art of data transcoding is currently a major stumbling block.

Another challenge that impacts the ATM-based system is that, when concentrating the data, early changes need to ripple through the system. This delay may be unacceptable in some cases. The alternative is to perform only a partial concentration of material early on and a final concentration prior to the data transcoding.

Once the streams are concentrated and transcoded, and the correct transport is attached, the system sends the data to the consumer distribution segment. Dependent on the delivery methodology, this aspect of the plant should be as flexible as the consumer's integrated decoder receiver. Changes should support not only current consumer use but also future usage.

The type of data can vary over time, and implementation of more interactive-intensive channels may require large amounts of data to coincide with the synchronous transmission of the V/A data. This translates into a need for greater capacity storage, higher transmission rates, and more complex synchronization schemes. High-definition television (HDTV) will pose its own set of challenges, along with myriad possible data services. In all, the consumer link should be as robust and reliable as it is flexible.

As part of the long-lead planning for future digital broadcast sites, special attention should be paid to externally produced interactive data. Without an integration strategy, the site may receive a wide variety of proprietary formats. One approach is to encapsulate differing formats within a protocol layer. This would protect the content from augmentation and ease the interfacing requirements. This also brings up the need for standards to regulate the encapsulation of data.

Intersite Video/Audio/Data Networking

Finally, let's address interplant data delivery systems, which use either standard terrestrial or satellite links. Intersite data delivery might be required for backup sites, or multicultural/multilingual distribution sites, that rely on several distribution points for the programming. The key capabilities are to remain in synchronization, and to transfer control in the case of backups. As for synchronization of multicultural/multilingual distribution sites, audio data variations and electronic program guide variations become factors in a multiple site system.

Conclusion

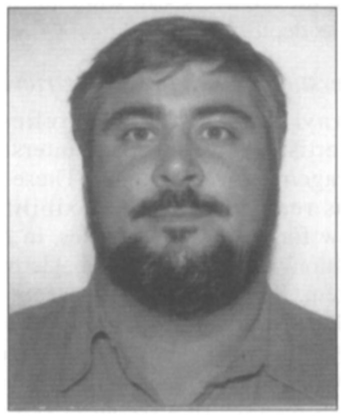
Current and emerging digital technologies are making distribution, storage, processing, and delivery easier but also creating new challenges for the designer of a digital facility.

- The digital broadcast site needs a long-term plan with standards that guarantee compatibility and an evolutionary path.
- In dealing with the new digital medium, challenges in compression, insertion, editing, storage, and distribution must be addressed.
- There has been a shift in the digital broadcasting environment, so that the traditional broadcaster must become a data network specialist.
- Finally, there is a need for IA data standards to encapsulate, distribute, and interface digital broadcast sites for content developers and distributors.

Endnotes

1. AAL 5 is the Application Adaptation Layer for ATM that has been adopted as a transport format for video related data. See "ATM Forum UNI Specification," V 3.1, 1995, for details.
2. SONET (Synchronous Optical Network) is a physical transport over fiber-optic cables with transmission rates of OC-3 at 155.520 Mbits/sec and its multiples, as outlined in ITU.T Rec. G.707, G.708, and G.709.
3. RAID 3 is a redundant array of individual disks in which a single parity drive is used for redundancy.
4. RAID 5 is a redundant array of individual disks in which the parity information is spiraled across all the drives.
5. RAID 7 is a proprietary system developed by Storage Computer Corp. in 1991, which incorporates the usage of an embedded OS, independent control, and data paths, and supports multiple host interfaces.

THE AUTHOR



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