A Broadband Interactive Cable Gateway

Michael Adams
Sr. Project Engineer, Advanced Engineering
Time Warner Cable

Abstract

MPEG-2 and ATM technologies each have their own set of advantages and disadvantages in a Full Service Network. We have proposed the design for a Broadband Interactive Cable Gateway (ICG) that bridges the gap between these technologies and allows each to be deployed where it is best-suited in a digital cable system.

The ICG allows initial deployment of broadcast digital television services to be rapidly and cost-effectively upgraded to on-demand services with no impact to existing subscribers.

This paper will discuss the ICG in detail including protocol conversion, signaling, and management functions and provide a set of requirements for prospective ICG vendors. The paper will also provide an overview of the hybrid ATM/MPEG-2 network architecture and explain why it is optimal for the deployment of a mix of broadcast and on-demand digital services.

INTRODUCTION

The Orlando Full Service Network (FSN) was constructed with available technology a little over a year ago. It is an extremely sophisticated system, capable of satisfying Time Warner's stated goals; to understand the technical, operational, marketing and business issues surrounding interactive television systems.

As we move towards large-scale deployment of Full Service Networks, we need to re-examine our options in every aspect of the system in light of technical developments and our implementation experience in Orlando. One important aspect is the digital transport mechanism from the headend to the set-top [1].

Orlando uses Asynchronous Transfer Mode (ATM) all the way to the home. This is a logical decision in a purely interactive system because ATM is the switching technology used to interconnect media servers with the network [2], [3]. However, with the advent of digital satellite broadcast, another technology, MPEG-2 Transport, has been developed [4]. (MPEG-2 Transport is well suited to the delivery of compressed television channels in broadcast networks.) At the same time, mechanisms for mapping switched, interactive channels into MPEG-2 Transport have also been developed and are now close to standardization. Thus MPEG-2 Transport has emerged as the common transport mechanism that can be shared in an integrated broadcast and interactive network.

An Interactive Cable Gateway (ICG) is required to connect ATM-based media servers to MPEG-2 Transport based networks. The ICG allows us to gracefully extend today's digital broadcast architecture into an on-demand architecture that combines ATM and MPEG-2 Transport technologies. MPEG-2 Transport provides a uniform, efficient distribution mechanism to the set-top while ATM provides the necessary switching and load balancing functions required by on-demand services. This paper will discuss the protocol conversion, conditional access, and management requirements of the ICG.

INTEGRATING BROADCAST, INTERACTIVE AND ON-DEMAND SERVICES

The digital network architecture must integrate broadcast, interactive and on-demand services. First we will define what we mean by these terms:

Broadcast

Digital broadcast services are a direct evolution of analog broadcast. The transmission medium is digital and content is compressed to make more efficient use of spectrum, but otherwise it is the same medium.

Examples of digital broadcast services are higher-quality versions of their analog counterparts; for example, HBO provided by a direct-broadcast, digital satellite service.

Interactive

Interactive services require a two-way, real-time connection from the set-top to the headend. The service can become much more responsive, allowing the subscriber to interact with an application program.

Examples of interactive services are the World-Wide-Web, multi-player games, and home-shopping services.

On-Demand Interactive

On-demand services extend the level of service again; the subscriber is given interactive random-access to the entertainment medium itself. The Orlando FSN is testing the marketplace for on-demand services.

Examples of on-demand services are movies-on-demand, news-on-demand, and sports-on-demand.

We believe digital broadcast will be the first of these services because broadcast is a proven paradigm and does not require a change in the subscriber viewing habits.

Interactive services will follow rapidly on the heels of digital broadcast deployment; because the incremental cost of an interactive set-top is relatively small, it makes good business-sense to deploy interactive-capable set-tops.

On-demand services require a media server to supply an on-demand stream to the interactive set-top. The cost of media servers continues to fall rapidly and on-demand services will soon become cost-effective.

The ICG transforms the on-demand stream from a media server so that it is identical to the digital broadcast format; this effectively extends the life of the interactive set-top by allowing it to receive on-demand programming.

DIGITAL COMMUNICATION CHANNELS

Time Warner Cable's digital network architecture defines three digital communication channels in addition to the conventional analog broadcast channel. These are:

- the Forward Application Transport (FAT) Channel
- the Forward Data Channel (FDC)
- the Reverse Data Channel (RDC)

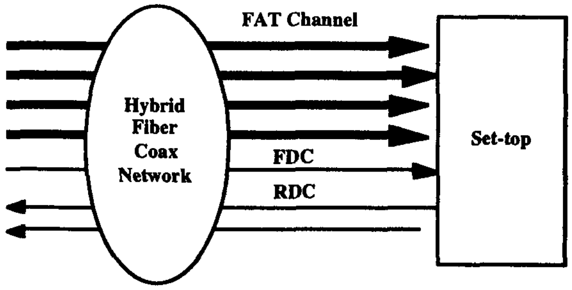

Figure 1 Digital Communication Channels. The arrow thickness is in proportion to the channel bandwidth.

Figure 1 illustrates the three types of channel.

- Forward Application Transport (FAT) channel. The set-top terminal can select any FAT channel by tuning to it.
- Forward Data Channel (FDC). The set-top terminal can always receive the FDC, even while tuned to analog services.
- Reverse Data Channels (RDC). The set-top terminal can only transmit in one RDC. However, more than one RDC may be defined per node for capacity reasons.

All channels are shared by a number of set-top terminals. A FAT channel can carry broadcast digital services in which case it is shared by all set-top terminals, or a FAT channel can carry on-demand services in which case it is shared by relatively few set-top terminals.

Digital Broadcast Network Architecture

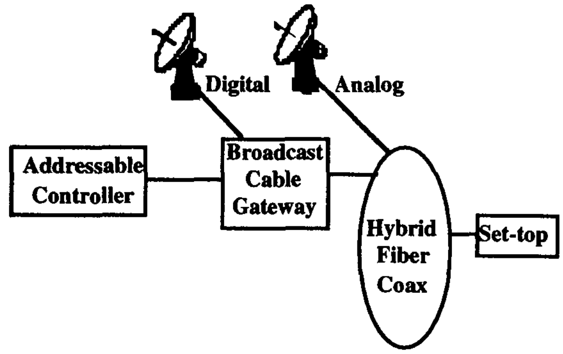

Figure 2 Digital Broadcast Network Architecture

The digital broadcast network architecture is illustrated in Figure 2. The digital services are received from satellite in MPEG-2 transport stream format. The satellite feed is sent to a Broadcast Cable Gateway (BCG) which transforms the signal for distribution over the Hybrid Fiber Coax (HFC) network:

1. The satellite signal is demodulated to recover the MPEG-2 transport stream.
2. The MPEG-2 transport stream payload is decrypted. The MPEG-2 transport stream is demultiplexed into separate program streams.
3. A new MPEG-2 transport stream is created from selected program streams.
4. The MPEG-2 transport stream payload is encrypted to the cable operator's requirements.
5. The MPEG-2 transport stream is modulated into a 6 MHz FAT channel.
6. The FAT channel is combined with other FAT channels, using FDM, and broadcast over the HFC network to all subscribers.

Interactive Network Architecture

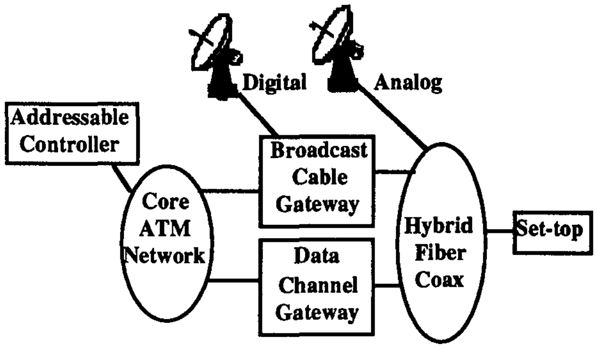

Figure 3 Interactive Digital Architecture

The digital broadcast architecture described so far is merely a one-way, broadcast system. To support interactive services, a two-way, real-time data communications infrastructure is required. Figure 3 illustrates the addition of a Data Channel Gateway (DCG) to support two-way data communications. The DCG supports the Forward Data Channel (FDC) and the Reverse Data Channel (RDC). These channels provide a two-way, Internet Protocol (IP) datagram service between the headend components and the set-top terminal. IP is chosen because it is an open, industry-standard, protocol suite that can support interactive services, as well as management, signaling and application download.

On-Demand, Interactive Digital Architecture

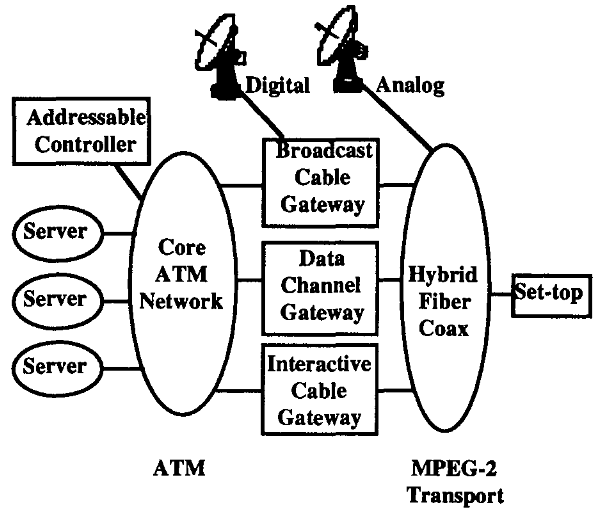

Figure 4 Reference On-Demand, Interactive Digital Architecture

Figure 4 shows the addition of on-demand services. Servers are connected to a core Asynchronous Transfer Mode (ATM) network. An Interactive Cable Gateway (ICG) translates from ATM into MPEG-2 transport. An ATM network is specified for the following reasons:

- Standard physical interfaces are available at very high rates for ATM; 155 or 622 Mbps SONET interfaces can be used to aggregate a number of digital streams into a single physical channel. SONET is an international standard and can be used for local or wide area connections [5].
- ATM can switch an on-demand digital stream from any server to any ICG. This allows new servers to be added incrementally, and service can be offered immediately to all subscribers.
- ATM allows dynamic allocation of bandwidth where it is required (bandwidth-on-demand). For example, a client application that requires 3 Mbps to play a movie can request a 3 Mbps virtual channel and

subsequently deallocate it when it is no longer required.

- ATM is a Wide Area Network (WAN) protocol. This allows the location of servers in the headend or at a distant facility. ATM supports wide-area interconnect over SONET facilities.

- The ATM network also supports data communications between all of the headend components. This avoids the expense of a separate overlay network.

The server encapsulates an MPEG-2 program stream into an ATM Virtual Channel that is routed, by the ATM network, to the ICG. The ICG performs the following transformation of the digital stream:

1. The ATM Virtual Channel is reassembled to recover the MPEG-2 program stream.
2. A new MPEG-2 transport stream is created from selected program streams.
3. The MPEG-2 payload is encrypted.
4. The MPEG-2 transport stream is modulated into a 6 MHz FAT channel.
5. The FAT channel is combined with other FAT channels, using FDM, and narrowcast over the HFC network to a subset of subscribers.

The advantages of a hybrid ATM/MPEG-2 Transport network are:

- Broadcast and on-demand programs are transmitted in an identical format. Therefore, a single, standard, set-top terminal can receive all services.

- Channel bandwidth is used efficiently. MPEG-2 Transport uses 12% less overhead than ATM.

External Device Data Services and Game Applications Reference Architecture

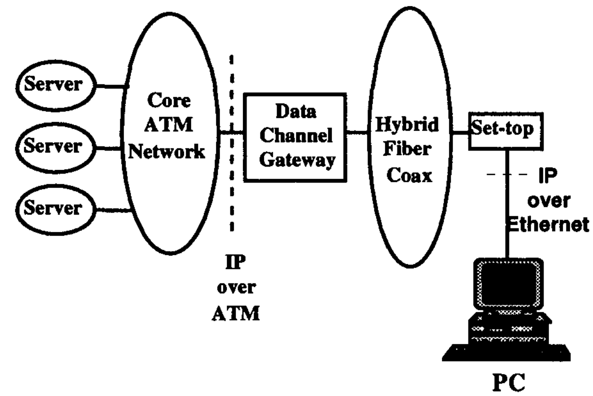

Figure 5 PC Data Services Architecture

The network architecture is also capable of supporting data services and game applications for personal computers and other external electronic devices. Figure 5 illustrates the architecture for personal computer or external consumer device data services. A transparent and secure IP service is provided between an interface in the headend and an Ethernet interface in the home. The service is connectionless and always available to the user. A best-effort, datagram service is provided. Reliable protocols (such as TCP) will be employed at the endpoints to provide re-transmission and sequencing functions when required.

The subscriber sees local area network performance, with high burst data rates and low latency. For example, the Time Inc. New Media LineRunner™ service includes client software for a PC or Macintosh personal computer, and provides access to email, on-line and web-browser services [6].

Game players can also be supported with this same architecture. The Ethernet interface can support two-way communications for multi-player gaming. On-demand download of games is also supported.

INTERACTIVE CABLE GATEWAY

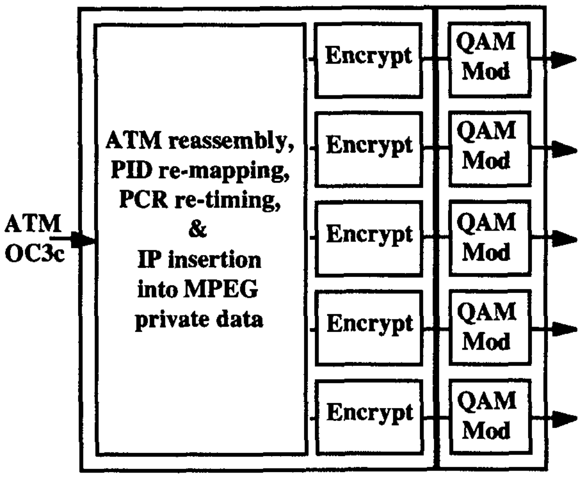

Figure 6 Interactive Cable Gateway

The Interactive Cable Gateway (ICG) transforms the on-demand stream supplied by the media server. Figure 6 is a block diagram of the ICG. The input is a SONET ATM OC3c. The ICG provides up to five FAT channel outputs. The ICG performs the following functions:

- Protocol Conversion
- Rate Conversion
- System Information
- Conditional Access
- Encryption
- Forward Error Correction
- QAM Modulation

Protocol Conversion

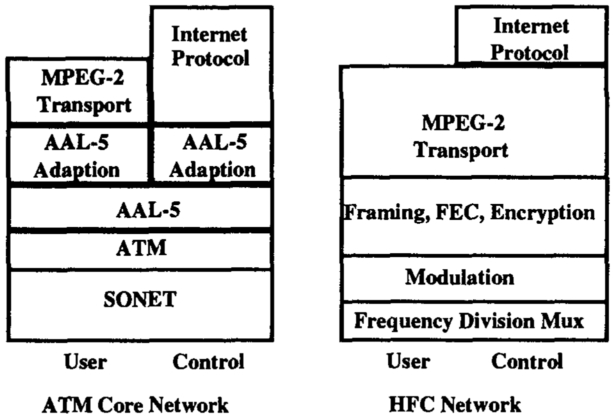

Figure 7 ICG Protocol Conversion

The ICG provides a protocol conversion from ATM Adaptation Layer type 5 (AAL-5) to MPEG-2 transport [7]. The protocol stack of the ATM network and of the HFC network is shown in Figure 7.

User Plane

In the user plane, the ICG receives an ATM Virtual Channel for each single-program stream. The media server assigns fixed Program Identifier (PID) values for program map, video and audio elementary streams. The ICG must re-map these PID values so that they are unique within the new transport stream. The ICG constructs a program-map table and uses this to drive the PID re-mapping function.

1. The ICG terminates and reassembles ATM virtual channels carrying MPEG-2 single-program transport streams.
2. The ICG allocates MPEG-2 PIDs such that each is unique in the output channel.
3. The ICG re-maps the incoming PIDs into their new values.
4. The ICG re-times the MPEG-2 transport streams by adjusting the program clock reference to compensate

for timing errors introduced by the ATM network.

5. A new MPEG-2 transport stream is created from selected program streams.

Control Plane

In the control plane, MPEG-2 Transport provides a high-speed delivery mechanism for Internet Protocol data. The ICG is a suitable point to perform flow-control because the instantaneous output bandwidth of the transport stream is known.

1. The ICG reassembles Internet Protocol (IP) data received on separate ATM connections [8].
2. The ICG inserts IP data into MPEG-2 private data sections [9].
3. The ICG transmits IP data such that it consumes any bandwidth left in the output channel after all video and audio streams have been serviced.
4. The ICG discards IP data if there is insufficient output channel bandwidth to accommodate it.
5. The ICG sets congestion indicators in the reverse direction on ATM virtual channels that experience congestion according to the ATM Forum Available Bit Rate (ABR) specification.

Rate Conversion

The ICG performs a rate-conversion function from SONET OC3c (155 Mbps) to 27 or 36 Mbps payload, suitable for the FAT channel modulator.

System Information

The ICG must generate the program association section (PID 0). Every valid Transport Stream must have a PID 0. The program association section provides a directory of services on the transport stream by listing each by MPEG program number and PID (of each program map section). The program association section also defines the network stream PID.

A program map stream is required for every program stream within the transport stream. The program map stream identifies the PIDs, types, and languages for all elementary streams associated with the program. Each program map stream is supplied by the media server.

The ICG also generates the network stream that may be used to carry various network information [10].

Conditional Access

The ICG must provide a conditional access section (PID 1) for each encrypted transport stream. PID 1 carries the conditional access message that identifies the streams carrying Entitlement Management Messages (EMMs).

EMMs must be uniquely addressed to each set-top and define access rights for each subscriber. EMMs may be sent in-band as part of the Transport Stream or out-of-band on the Forward Data Channel.

Encryption

The MPEG-2 payload from the server is not encrypted. Therefore, it must be encrypted to the cable system requirements before transmission.

1. The ICG encrypts the MPEG-2 payload.
2. The ICG inserts encrypted key information in Entitlement Control Messages (ECM's).

Forward Error Correction

The ICG must apply forward error correction to MPEG-2 transport stream to protect against data errors that occur during transmission over the HFC network.

Modulation

The ICG modulates the payload into a 6 MHz FAT channel.

Management

The ICG must be provisioned with ATM VCI to PID re-mapping information. For conditional access, key information must be provisioned for each encrypted program stream; this is used by the ICG to generate ECMs. A standard SNMP MIB must be defined to allow for centralized management of multi-vendor ICGs in a single system [11].

CONCLUSIONS

The Orlando FSN showed that ATM can be used to deliver interactive multimedia all the way to the home over Hybrid Fiber Coax networks. However, MPEG-2 Transport is a better choice for *integrated* delivery of digital broadcast and interactive services.

ATM is the only available technology that satisfies the *switching* demands of interactive multimedia. Therefore, a combination of ATM and MPEG-2 Transport provides an optimal solution and an Interactive Cable Gateway is required to interconnect the ATM and MPEG-2 Transport domains.

REFERENCES

[1] Communications Technology, "ATM and MPEG-2", M.B.Adams, Dec 1995, Feb 1996.

[2] ATM Forum. ATM User-Network Interface (UNI) Specification Version 3.1. ISBN 0-13-393828-X, Prentice-Hall, Inc., Upper Saddle River, NJ, 07458, September, 1994.

[3] TA-NWT-001113. Asynchronous Transfer Mode (ATM) and ATM Adaptation Layer (AAL) Protocols Generic Requirements. Bellcore, Issue 1, August 1992.

[4] ISO-IEC IS 13818-1, International Standard (1994), MPEG-2 - Systems.

[5] TR-NWT-000235. Synchronous Optical Network (SONET) Transport Systems: Common Generic Criteria. Bellcore, Issue 2, December 1991.

[6] Inter@Active Week, "Time Warner to Offer High-Speed Net Access", S.Vonder Haar, Dec 4, 1995.

[7] ITU-T Document TD-XV111/10. AAL Type 5, Draft Recommendation text for section 6 of I.363. Jan 2, 1993, Geneva.

[8]Internet Draft: Classical IP and ARP over ATM Update (Part Deux). Network Working Group, M.Laubach. 31 Augiust 1995.

[9] ISO-IEC CD 13818-6, International Standard (1994), MPEG-2 - DSMCC.

[10] System Information for Digital Television, Advanced Television System Committee Standard Jan 3, 1996.

11 J.D.Case, M.S. Fedor, M.L. Schoffstall, and J.R. Davin. Simple Network Management Protocol, Request for Comments 1157. DDN Network Information Center, (May, 1990).