Pegasus Network Architecture

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Abstract

This paper will describe the architecture of a digital video delivery system that is designed to complement Hybrid-Fiber Cable (HFC) networks. The paper will discuss the evolution of the network from a pure digital broadcast system into an interactive system and ultimately into a true video-on-demand capable system. This paper will include significant learning's about interactive network system design from the Orlando Full Service Network as well as integration of these designs with analog and digital broadcast systems.

INTRODUCTION

NETWORK ARCHITECTURE GOALS

The Pegasus Network Architecture is designed to meet the following set of key goals:

Integrated Service Delivery

This is achieved by integrating broadcast and interactive services into a single network architecture. The same mechanisms used to deliver digital broadcast services[1] will be used to provide advanced services like video-on-demand and home shopping. In this way, initial deployment for broadcast services sets the foundation for on-demand services. Incremental investment in the headend shall be the only requirement to provide on-demand services.

Cost Effective at Low Peak-Usage

It is critical that early deployment of interactive services can be cost effective even when there is a low utilization of those services. It must be possible to spread the cost of shared resources at the headend across a sufficiently large customer base (and revenue stream) to justify the investment in those resources.

The Pegasus network architecture is designed to be very flexible with respect to peak usage. The broadcast nature of the HFC plant is used to provide aggregation of demand across a large area (the size of a distribution hub or approximately 20,000 homes passed). As demand increases, more resources can be added as required.

Standard Service Encryption

Historically, analog cable systems have been tied to a single vendor solution by the access control mechanism; each vendor implementing their own proprietary scrambling and headend control systems. To promote multi-vendor digital set-tops, a standard service encryptor must be agreed. This allows multiple, independent providers to control access to their services while employing a single service encryption algorithm.

All services need access to a common, secure transport layer. This is provided by service encryption in hardware. A single encryption algorithm reduces hardware complexity. The access control mechanism must support a wide range of tiered services from broadcast to interactive.

In October 1996[2] some major elements of an interoperable digital cable systems specifications were agreed by CableLabs and its members:

- The agreement was based on existing standards (MPEG-2[3], ATSC Systems Information[4], ITU-T J.83 Annex B[5], DES encryption[6],[7]).
- The agreement was deliberately defined to be the minimum intersection of multiple CA systems:
  1. The adoption of a standard service encryption algorithm based on DES standards.
  2. A common control word generation method.

3. Use of existing features in the MPEG-2 systems layer to allow multiple CA systems to co-exist within a single digital channel.

This agreement represents the final and the most difficult step in long history of standardization. Because the CA system provides many features, it significantly differentiates one vendor's product from another. By separating the CA system into two parts (the service encryptor and all other components), each vendor is still able to innovate and add features to their CA system without introducing incompatibilities at the service encryptor level.

Support for a wide range of services

There are a wide range of possible services and service providers. There is no one platform that is optimal for all service providers - some services are broadcast, some are on-demand, others narrow-cast. Therefore it must be possible to connected many different service providers and servers to the network.

Growth of Server Capacity.

Application and media servers represent a significant investment and this will be true for some time. As more cost-effective servers are developed, it must be possible to deploy them while still gaining return on initial server investment. This means that all servers must support common interfaces and operating environment. Equally, as demand increases it must be possible to expand server capacity in economic increments.

Distributed Client-Server Communications

The client/server architecture is a powerful software paradigm that is well suited to large-scale interactive networks; the server provides shared resources and the client provides a rich user-interface.

The Pegasus Network Architecture supports a client/server architecture by providing real-time, two-way data communication between the client and the server.

Efficient Use of Network Resources

The HFC upgrade was initially designed to provide reliable, high-quality broadcast services. To enable interactive networks, additional bandwidth must be allocated to two-way communications. The efficient use of this bandwidth is crucial because the headend infrastructure costs (switching, modulation, and server capacity) scale directly in proportion to required bandwidth.

SERVICES

The Pegasus Network Architecture is designed to allows the integration 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 expect on-demand services to follow rapidly on the heels of digital broadcast deployment and, because the incremental cost of an interactive set-top is relatively small, it makes good business-sense to deploy interactive-capable set-tops.

Digital Communication Channels

The Pegasus 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)

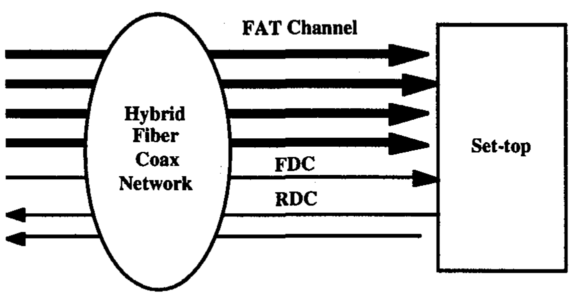

Figure 1 Digital Communication Channels. The arrow thickness is in proportion to the channel bandwidth.

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

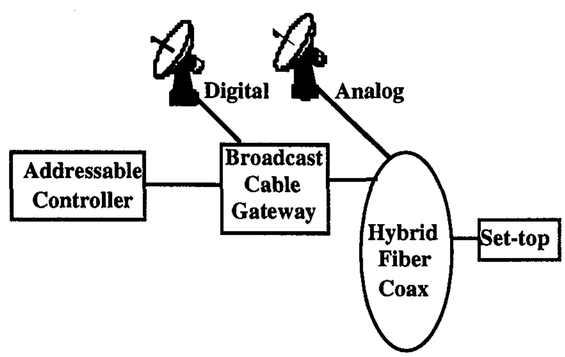

Figure 2 Digital Broadcast Architecture

A possible digital broadcast 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. Although this architecture provides channel expansion, it has some serious limitations:

- Interactive Services are not supported.
- High-speed Data Services are not supported.

- The out-of-band signaling supports impulse pay-per-view only.
- The network remains closed and proprietary - effectively locked-in to a single vendor.
- Proprietary networks are actually ***more*** expensive than standards-based networks.

PEGASUS PHASE 1

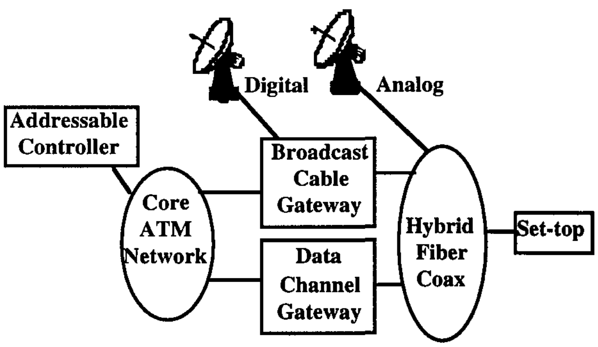

Figure 3 Interactive Digital Architecture

Pegasus Phase 1 adds a two-way, real-time data communications infrastructure. Figure 3 shows 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.

Implementation

A typical Time Warner Cable division is shown in

Figure 4 after the HFC upgrade is complete. There are one or more headends and a large number of distribution hubs. Each distribution hub serves, on average, 20,000 homes-passed.

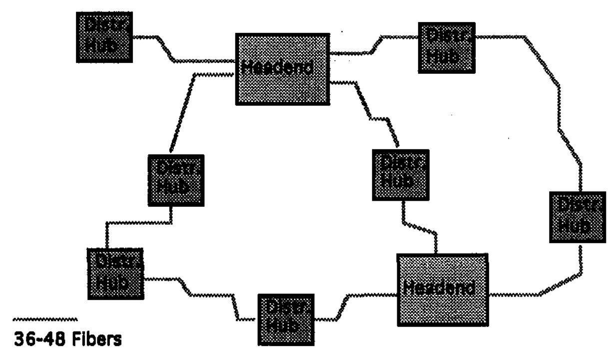

Figure 4. A Typical Upgraded Division

Figure 5 shows the actual components that will be deployed in a Phase 1 headend.

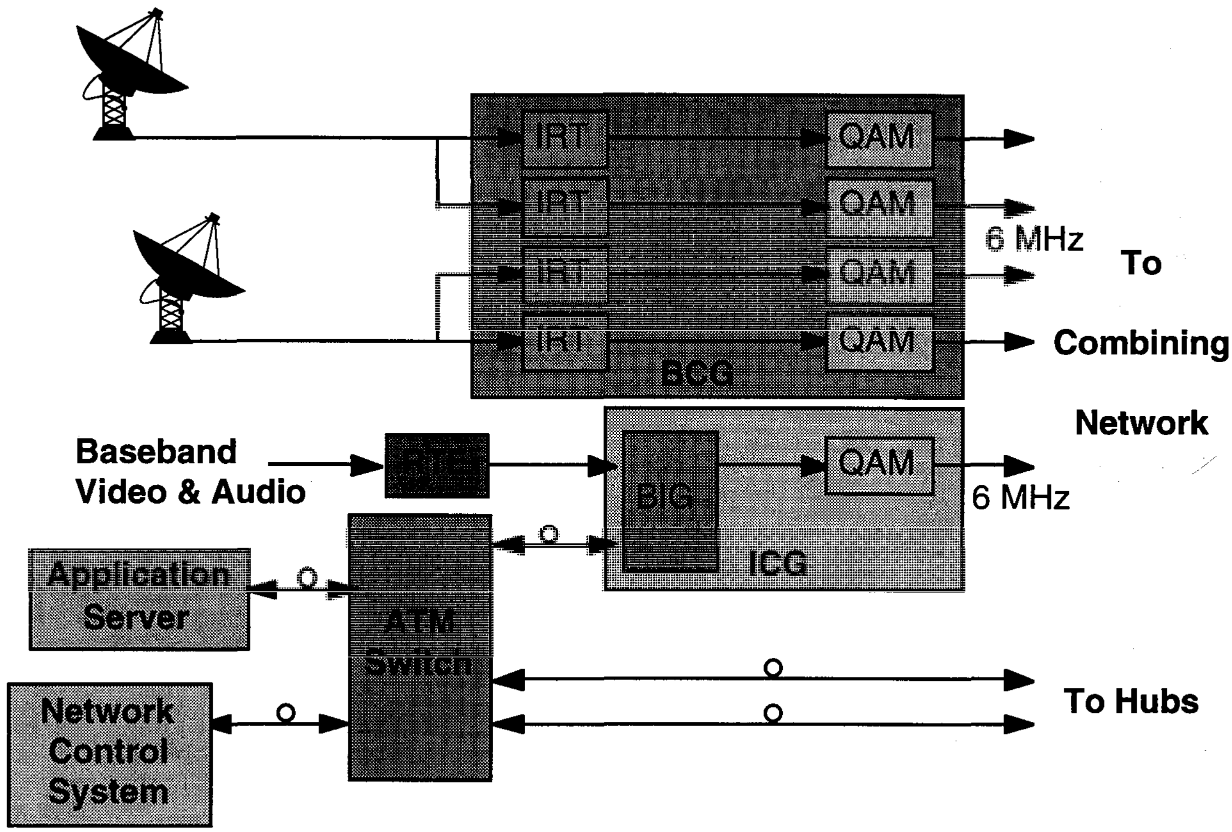

Figure 5. The Pegasus Phase 1 Headend

The components in Figure 5 will now be described in more detail:

Broadcast Cable Gateway (**BCG**)

The Integrated Receiver Transcoder (IRT) receives an QPSK signal from satellite and decodes it to provide a clear MPEG-2 Transport Stream. This is fed into the QAM Modulator which performs service encryption, inserts Entitlement Control Messages (ECMs) and inserts ATSC System Information.

Each IRT/QAM pair adds 6-8 digital channels in 6 MHz of cable spectrum.

Network Control System

The Network Control System supports the Pegasus Set-top Terminals and also provides Element Management for Pegasus Headend and Hub components.

The Network Control System runs on a standard UNIX platform and is located in a secure location within the Business Office.

ATM Switch

The Asynchronous Transfer Mode (**ATM**) switch concentrates out-of-band traffic from the Distribution Hubs. All connections are provided by OC3 single-mode fiber interfaces.

The ATM switch also switches out-of-band traffic to Distribution Hubs from the Network Control System and the Applications servers. A 10 Gbps ATM switch can support up to 60 Hubs.

Interactive Cable Gateway (**ICG**)

A Broadband Interactive Gateway (BIG) receives data via an OC3 single-mode fiber interface from the Network Control System and Application Servers.

The QAM Modulator adds service encryption and conditional access. In Phase 1, the ICG supports the DAVIC Data Carousel. This is used to provide system data to the Pegasus set-top terminal, for example, software updates and program guide information.

Real-Time Encoder (RTE)

The Real-Time Encoder receives a baseband NTSC video and baseband stereo audio input. A Real-Time Encoder is required per *locally-encoded* digital channel.

Real-Time Encoders cost approximately $50,000 per channel and so they are not recommended unless it is essential to encode programming locally because it is not available in MPEG-2 format from satellite.

Application Servers

Application Servers will be introduced in Pegasus Phase 1.1. (Examples are interactive program guide servers, WEB servers, and game servers.)

Application Servers require a UNIX platform and an ATM OC3c interface.

Distribution Hubs

Figure 6 is a diagram of the equipment located at the Distribution Hub.

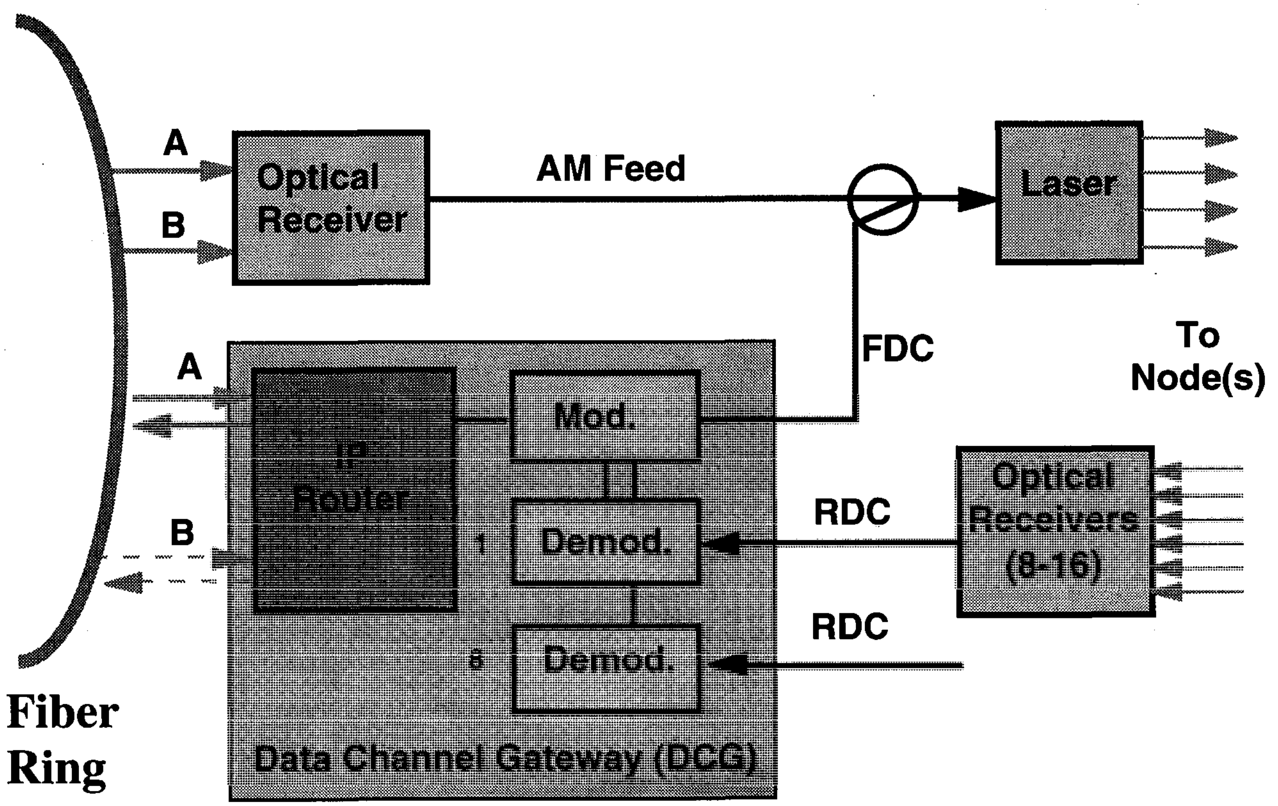

Figure 6. The Pegasus Distribution Hub

The components in Figure 6 will now be described in more detail:

Data Channel Gateway

The Data Channel Gateway consists of a standard IP Router and a number of DAVIC-standard[8] QPSK Modems. The IP Router transfers out-of-band signaling, control and data between the Headend components and the QPSK Modem. The IP Router is connected to the ATM switch at the headend by an OC3 single-mode fiber interface. A reach of up to 60 Km is possible (without repeaters) at 1310 nm.

The QPSK Modem is actually a combination of a single Modulator and up to 8 Demodulators working together to provide a high-speed, real-time, two-way path to the Pegasus set-top.

The QPSK Modem is located in the Distribution Hub for the following reasons:

• To control noise aggregation in the reverse path.

• To allow the FDC and RDC bandwidth to be progressively increased by sub-dividing the fiber nodes into smaller groups. More FDC and RDC bandwidth will be required as Pegasus set-top penetration increases and as interactive services are widely deployed.

Pegasus Phase 2

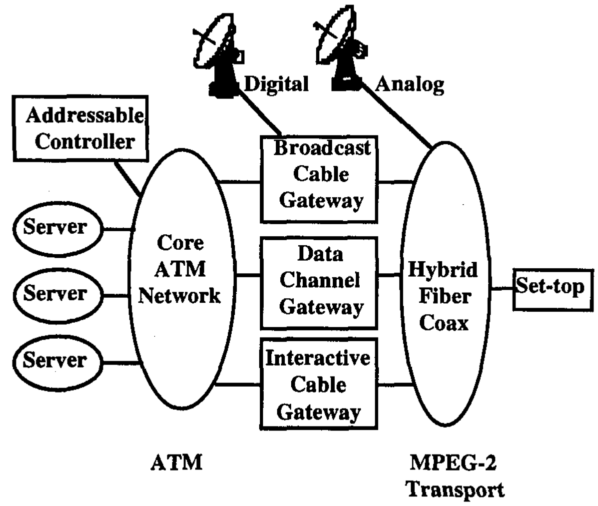

Figure 7. Pegasus Phase 2

Figure 7 shows the addition of on-demand services. Servers may be connected to a core Asynchronous Transfer Mode (ATM) network. An Interactive Cable Gateway (ICG) translates from ATM into MPEG-2 transport[9].

This provides the following advantages:

- Smooth migration to Video-On-Demand.
- Video-On-Demand can be supported even at very low penetration (e.g. <1%) because server investment can be shared across an entire division.
- Standard server interface enables multiple server vendors.
- Seamless integration of broadcast, interactive and on-demand services.

Implementation

As on-demand services are added, the only location affected is the Headend. Figure 8 shows the **additional** components in a Pegasus Phase 2 Headend.

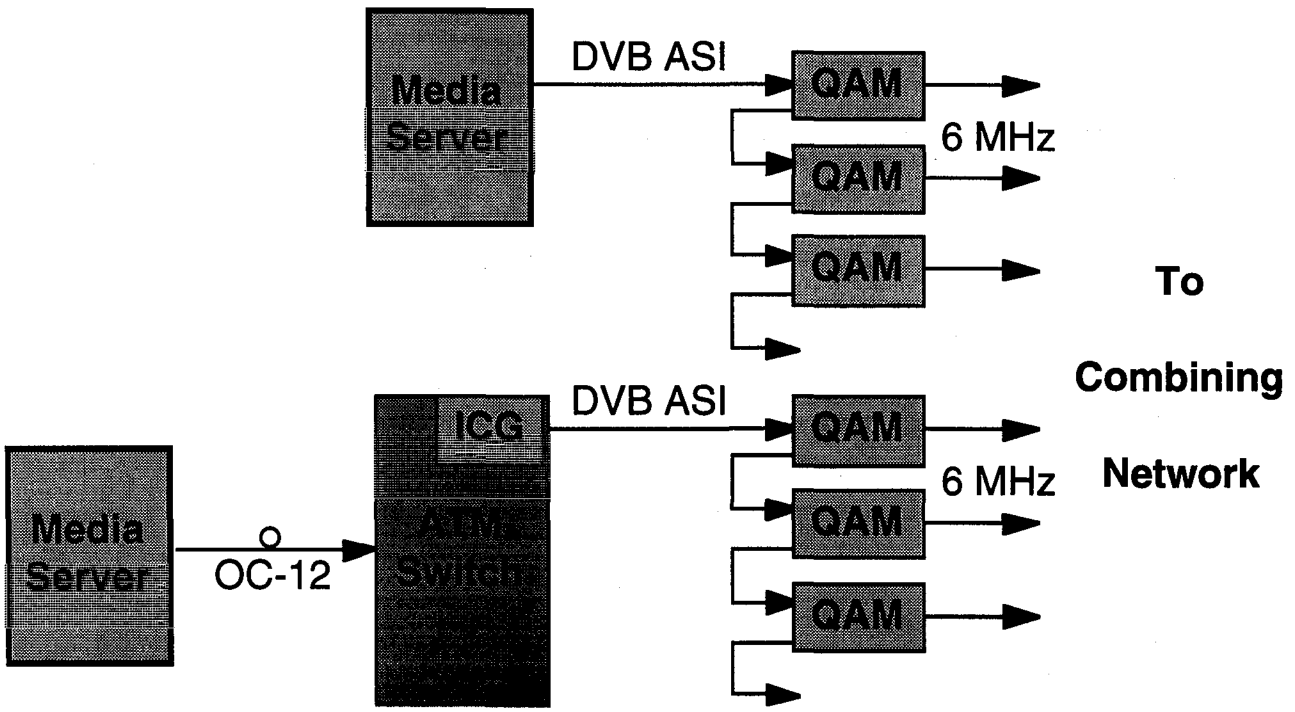

Figure 8. Phase 2 Pegasus Headend

The components in Figure 8 will now be described in more detail:

Media Servers

Media servers are required to deliver on-demand programming to the subscriber. Two types of media servers are envisioned:

1. Small-scale Video-On-Demand media servers which provide a DVB ASI[10] (Asynchronous Serial Interface). No ATM switch or ICG is required for a limited number of titles and where the server is located within the headend.

2. Large-scale media servers which provide an OC12c interface. This interface allows a large-scale server to be located remotely - for example, at a regional library center.

The Interactive Cable Gateway (ICG) will be packaged into an line-card in the ATM switch to reduce cost.

SUMMARY

Pegasus Network Architecture realizes a genuine communications network, allowing new services to be added as they become available.

Standard protocols (IP routing and ATM switching) are used to build an open network at lower cost than existing proprietary approaches.

MPEG-2 Transport is used to supports ***integrated*** digital broadcast and interactive services.

ATM is to ***switch*** interactive multimedia only where justified by the application.

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