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Digital television transmission based on asynchronous transfer mode*

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Abstract: This paper introduces a method to realize digital television transmission based on asynchronous transfer mode (ATM), a technology based on fast packet switching. Choosing the integral multiple length of an ATM cell payload to equal to the length of an MPEG transport stream packet, an MPEG transport stream packet can be inextenso loaded by several ATM cells and transformed into ATM cells. Using ATM virtual connection technology and B-ISDN, the interoperability between ATM and DTV may be realized, and DTV signal transmission may also be realized finally.

Key words: Digital television transmission, Asynchronous transfer mode (ATM), ATM cell, MPEG transport packet, Interoperability

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INTRODUCTION

With the development of the technology of A/D, DSP, optic fiber communication and broadband packet switching, integration of telephone, television and Internet will become a reality.

Asynchronous transfer mode (Zhang and Qiu, 1997), different from common IP, is a connection-oriented and fast packet switching technology using virtual connection technology and transfers data in cells of a fixed size. ATM integrates multiplexing and switching functions, is well suited for bursty traffic (in contrast to circuit switching), and allows communications between devices that operate at different speeds. Unlike packet switching, ATM is designed for high-performance multimedia network, supports all kinds of high-level protocols, and provides flexible bandwidth allocation, high bandwidth utilization, simple routing, class-of-service support for multimedia, scalability in speed and network size, and common LAN/WAN architecture. ATM allows for the integration of networks, thus improving efficiency and manageability. ATM provides a single network for all traffic types—voice, data, and video. Due to its high speed and the integration of traffic types, ATM enables the creation and expansion of new applications such as multimedia to the desktop. Because ATM is not based on a specific type of physical transport, it is compatible with currently deployed physical networks. ATM can be transported over twisted pair, coax and fiber optics. So it is an ideal protocol for all traffic types—voice, data, video and other complex multimedia data transmission.

The standards for DTV have been in place since 1994. At present, there are three digital television standards, namely, Digital Video Broadcast (DVB, Europe), ASTC Digital Television (ATV, USA) and Integrated Service Digital Broadcasting (ISDB, Japan) (ASTC, 1995; Jerry, 2002; Murat, 1998). All the three standards adopt MPEG-2 compressed format, and DTV signal is transmitted by MPEG-2 transport stream, whose transport mechanism is similar to that of IP transport. The process by which DTV trans-

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forms several analog video, audio and data streams into a single transport stream is as follows. First, a video or audio stream is compressed to become an elementary stream (ES). Then, it is divided into a packetized elementary stream (PES) with variable-length packets. Next, during the encoding process, PESs are further divided into fixed-length transport packets of 188 bytes each. This packet size was initially chosen to simplify mapping of MPEG-2 packets over ATM, which uses cells with a payload of 47 bytes. Once the audio or video stream has been divided into transport packets, it is multiplexed, or merged, with similarly packetized content for other services. A multiplex stream composed of one or more services is called a transport stream. Each packet in the transport stream, whether containing audio, video, tables or data, is identified by a number called PID, or packet identifier. PIDs enable the decoder to sort through the packets in a transport stream.

This paper describes how to realize digital television transmission by ATM technology.

DTV TRANSMISSION BASED ON ATM

Comparison of ATM cell and MPEG-2 transport stream packet

As mentioned above, DTV signal is transmitted by MPEG-2 TS on the network. The length of an MPEG-2 TS packet is 4×47=188 bytes. The structure of an MPEG-2 TS packet and its transmission process are shown in Fig.1 (Fang, 2003; Lu, 2002; Li, 1997) showing that an MPEG-2 TS packet consists of a 4-byte packet header, optional transport packet adaptation field (x=0~4 byte(s)) and payload data ((184−x) bytes). The packet header is used to realize the functions of packet synchronization, packet ID (used to identify the application type of the TS), error detection, condition access and so on. The packet header supports the applications of video, audio, program and system control information and so on. The payload is just behind the packet header, and may contain audio, video or data information which needs to be transmitted. The length of the payload is equal to 184 bytes. Sometimes an adaptation field needs to be inserted in the payload. When the length of the payload is insufficient (<184 bytes), this adaptation field is used to complement the payload, and the adaptation field is also used to insert the program clock reference (PCR) according to the need. The entire length of an MPEG-2 TS packet being 188 bytes is an advantageous and important foundation of DTV transmission based on ATM.

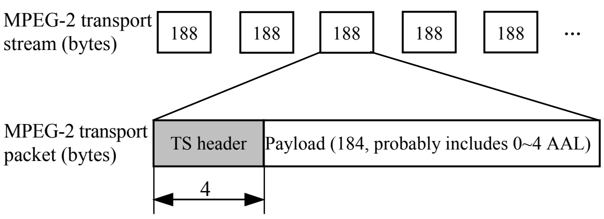

Fig.1 Structure of an MPEG-2 TS packet and its transmission process

The basic carrier that ATM uses to transport message is ATM cell. The characteristics of ATM channel format are the key to all kinds of video applications. An ATM channel is expressed by a group of fixed-length cells consisting of 53 bytes. The first 5 bytes contain cell-header information, and the remaining 48 contain the payload (user information). The cell header is similar to the head of a transport packet, the payload is actually used to transport sound and image information. The structure of an ATM cell and an ATM channel are shown in Fig.2 (Lu, 2002; Zhang and Qiu, 1997). ATM cell header is very important in the information switch and transmission. For example, the switching path of an ATM cell is contained in the routing information of every ATM cell header, whose concrete compositions are shown in Table 1.

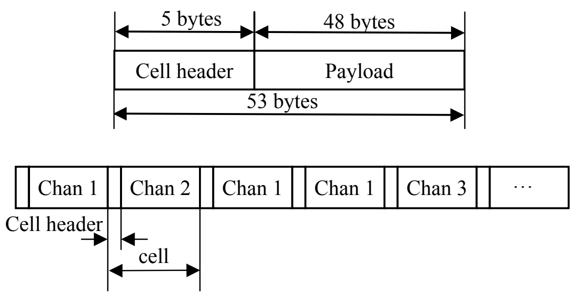

Fig.2 Structure of an ATM cell and an ATM channel

The main functions of ATM layer are to provide multiplexing and switching process for data transmission. The essential factors of the protocol include routing information, and also several data fields used to indicate payload type. Some other data are also

Table 1 Composition of ATM cell header

GFC	A four-bit general flow control word segment, used to provide local functions, such as identifying multiple stations that share a single ATM interface. This field is typically not used and its default value is set to 0.
VPI	An eight-bit virtual channel identifier, in conjunction with the VCI, identifies the next destination of a cell as it passes through a series of ATM switches on the way to its destination.
VCI	A sixteen-bit virtual circuit identifier, in conjunction with the VCI, identifies the next destination of a cell as it passes through a series of ATM switches on the way to its destination.
PT	A three-bit indicator of payload type, indicates in the first bit whether the cell contains user data or control data. If the cell contains user data, the bit is set to 0. If it contains control data, it is set to 1. The second bit indicates congestion (0=no congestion, 1=congestion), and the third bit indicates whether the cell is the last in a series of cells that represent a single AAL5 frame (1=last cell for the frame).
CLP	A one-bit sign of cell loss priority, indicates whether the cell should be discarded if it encounters extreme congestion as it moves through the network. If the CLP bit equals 1, the cell should be discarded in preference to cells with CLP bit equal to 0.
HEC	An eight-bit header error control word segment, used to examine, correct fault code in ATM head and cell delimitation, HEC function is realized in the physical layer.
AAL	ATM adaptation layer, used to calculate checksum only on the first 4 bytes of the header. HEC can correct a single bit error in these bytes, thereby preserving the cell rather than discarding it.

contained in the cell header and are used to carry out the following functions:

(1) Help to control the service flow in UNI;

(2) Establish the priority for cells;

(3) Be convenient for header error control, etc.

In addition, an essential characteristic of ATM is that every cell may be marked and transmitted independently according to the request. Unlike other network protocols that need a fixed and hierarchical channel rate, it allows assignment of bandwidth of equipments according to the request. All kinds of connection it supports may be permanent or temporary. Moreover, it needs no call-control, and has real-time ability to manage and handle the bandwidth. ATM has flexibility in video and multimedia applications, which is advantageous for transmitting MPEG-2 signal. The differences between ATM cell and MPEG-2 TS packet are shown in Fig.3. Here, what needs to be emphasized is that an ATM cell header has two formats: UNI or NNI. The format of the UNI header is shown in Fig.3a. The format of the NNI header is a little different from that of the UNI header.

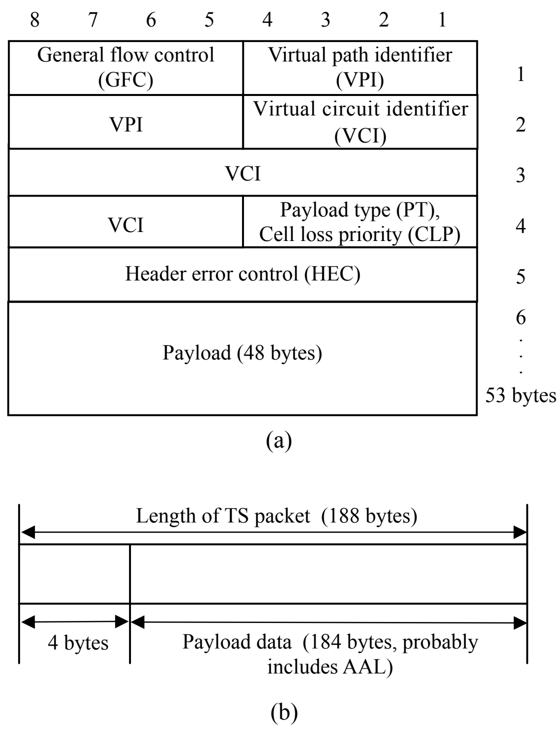

Fig.3 Comparison of the formats between ATM cell and MPEG-2 TS packet. (a) ATM cell format; (b) MPEG-2 TS packet format

Obviously, Fig.3 shows that if we choose one-byte AAL in the payload, four ATM cells may carry an MPEG-2 TS packet-length signal. Correspondingly, an MPEG-2 TS packet may carry the same quantity ATM cells. That is to say, ATM and DTV signal transmissions have interoperability.

Interoperability between ATM and DTV

Comparing the format of ATM cell with that of MPEG-2 TS packet, we may know that ATM is an information transfer mode which can divide all kinds of service data stream into the fixed-length cell for switching. ATM transfers information in fixed-size units called cells, each consisting of 53 bytes. The first 5 bytes contain cell-header information, and the remaining 48 contain the payload. DTV or HDTV transfers information in fixed-size units called transport stream packets, each consisting of 188 bytes. Therefore, if we choose that the integral multiple length of an ATM cell payload is exactly equal to the length of an MPEG TS packet, a DTV MPEG TS packet can be inextenso loaded by several ATM cells and transformed into ATM cells, we may realize the interoperability between ATM and DTV (ASTC, 1995; Lu, 2002). In the 48-byte ATM payload, we may adopt 0~4 byte(s) as ATM adaptation layer (AAL). If we choose 1 byte as AAL, the actual user information is 47 bytes, so we may realize DTV signal transfer task—4 ATM cells (every cell containing one-byte AAL) can load a DTV transport stream packet by the square (47×4=188 bytes). Of course, we must ensure that each TS packet header align accurately with the starting position of a certain ATM payload, as Fig.4 shows.

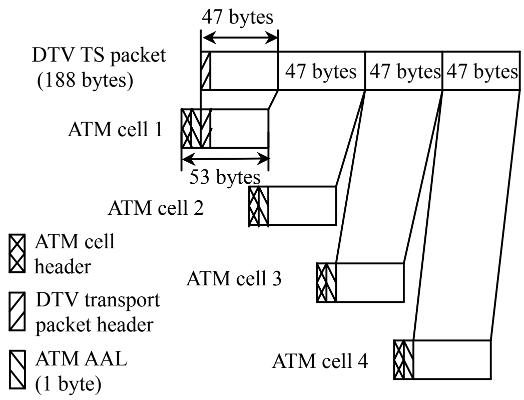

Fig.4 Four ATM cells (every cell containing one-byte AAL) carry a DTV TS packet

Here, what needs to be emphasized is that MPEG-2 transmission layer and ATM layer have respectively different functions in the application of video transmission. The MPEG-2 transmission layer is used to realize MPEG-2 visual function and multimedia multiplexing function. The ATM layer is used to solve switching function and network adaptation function.

The situation above is the interoperability between ATM cells with one-byte AAL and DTV. Certainly, we also may realize the interoperability between ATM with two-byte AAL and DTV. For example, in the video on demand (VOD), program sources are provided by video server or real-time encoder, signal sources are stored in the disk of video server generally by VCD or DVD format, we can recode them into MPEG-2 transport stream format. In VOD system, when the user sends a service request, the program streams are transmitted to set-top-box (STB) through video server, ATM network and connection network, and are decoded by STB and shown in TV screen finally. The transmission procedure of the MPEG-2 transport stream (TS) based on ATM network is shown in Fig.5 (Lu, 2002).

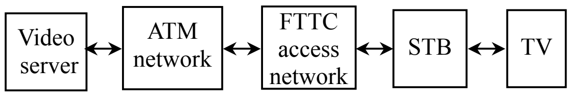

Fig.5 Transmission procedure of DTV MPEG-2 transport stream based on ATM

ATM is one kind of fast packet switching technology, which can decompose the information stream of sound, image and data services into fixed-length data blocks (48 bytes), and set the address and other control information in front of the data block, and form a fifty-three-byte cell. It can adopt asynchronous time-division multiplexing to assemble the cells from different information sources, and line them up in a buffer. The cells in the line are output one by one to transmission circuit, and form cell stream of "one cell header following another cell tail". VPI/VCI included in the cell header is taken as the address mark, and the network transfers cells according to the cell header mark.

Hierarchical coding and transmission of DTV signal based on ATM

According to the hierarchy of MPEG-2 standard (ASTC, 1995; Jerry, 2002) and the two transport-priorities of ATM (Zhang and Qiu, 1997), we may adopt hierarchical coding technology (for example sub-band coding, wavelet transform coding, etc.) to divide the image quality into different levels. ATM network provides two equal quality levels in the cell header to provide two quality-level logical channels. Video information is divided into basic layer and enhanced layer in hierarchical coding, the information in the basic layer is transmitted in the high-quality channel, and the supplementary information for improving the image quality is transmitted in the non-priority channel (namely enhanced coding). When the network is crowded, the non-priority channel cells will possibly be lost, so it can keep the basic image quality good and also keep the channels smooth.

Structure and interface of transmission network based on ATM

The structure and interface of transmission network based on ATM are shown in Fig.6 (Yu and Yu, 2003; Sun and Jiang, 2001).

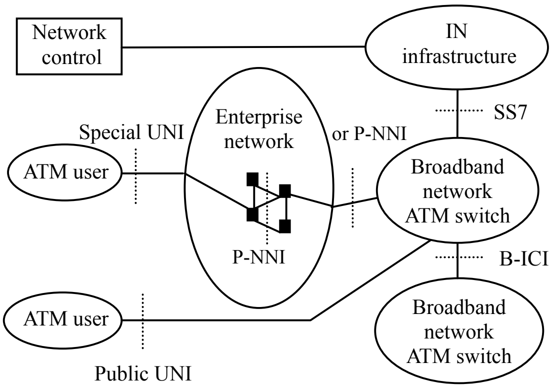

Fig.6 Structure and interface of transmission network based on ATM

The ATM user is connected directly to the public network by the public UNI, the interface standard was made out by the ANSI and ITU, which conforms completely with the B-ISDN reference model. The special-purpose UNI (Private UNI) is the interface which connects the ATM user to the enterprise network, and is optimized according to the local environment. B-ICI (B-ISDN Inter-Carrier Interface) is the interface between two different public ATM network providers or loaders. The standard also includes the specific service and managing function when the loaders are crossing LATA limits. The P-NNI (Network Node Interface) is the interface which is specially used between two ATM switches, and includes two protocols: one is used to distribute topology and routing information, the other is used to establish the signal command for the connection surmounting the special network.

CONCLUSION

ATM technology has quite flexible characters in digital audio signal, video signal and other data signals transmission and assignment, but also has its disadvantages. The first one is the overhead of cell header (5 bytes per cell), which influences badly the efficiency of information transmission. The second one is its complex mechanisms for achieving QoS, which will increase the development cost of the system. The last one is the network congestion, which may cause cell losses. As a whole, The B-ISDN which takes the optic fiber as the transmission medium and takes ATM as transfer mode may probably become the main facility of the information highway in the future.

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