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AN OVERVIEW OF NEW VIDEO TECHNIQUES

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Abstract

Current video transmission and distribution systems at CERN use a variety of analogue techniques which are several decades old. It will soon be necessary to replace this obsolete equipment, and the opportunity therefore exists to rationalize the diverse systems now in place.
New standards for digital transmission and distribution are now emerging. This paper gives an overview of these new standards and of the underlying technology common to many of them. The paper reviews Digital Video Broadcasting (DVB), the Motion Picture Experts Group specifications (MPEG1, MPEG2, MPEG4, and MPEG7), videoconferencing standards (H.261 etc.), and packet video systems, together with predictions of the penetration of these standards into the consumer market.
The digital transport mechanisms now available (IP, SDH, ATM) are also reviewed, and the implication of widespread adoption of these systems on video transmission and distribution is analysed.

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1 INTRODUCTION

Standards for the transmission and distribution of video signals are principally based on those for broadcast television. Until recently these standards have evolved very slowly; for example, the colour television standard NTSC, and its derivatives PAL and SECAM, were adopted more than 10 years after the standards for monochrome television. This slow evolution was principally due to the huge installed base of television receiving equipment, which was based on discrete components, expensive to produce, and had a long expected lifetime. Backwards compatibility was therefore essential whenever new standards were adopted.

In the last few years however the rapid pace of technological advance in certain areas has changed the situation dramatically.

2 TECHNOLOGICAL ADVANCES

Technological advances in the following areas have been of crucial importance to the television and video industry:

- Very Large Scale Integration (VLSI): low cost availability of complex integrated circuits with the possibility of implementing multiple standards
- Digital Signal Processing (DSP): enabling complex processing of TV images
- Predictive coding: using spatial and temporal redundancy, and motion prediction, for video compression
- Modulation techniques: increasing the possible data rate on different transmission media (copper twisted pair, terrestrial TV channels, satellite transponders, etc.).

3 DATA TRANSPORT

3.1 Time-Division Multiplexing

Digital transmission of telephony signals using time-division multiplexing (TDM) was introduced in the 1960s, progressively replacing analogue frequency-division multiplexed (FDM) circuits. FDM required many discrete components, especially for filters and other tuned circuits. TDM on the other hand was easily implemented by digital integrated circuits.

The original TDM systems are now referred to as ‘PDH’ (Plesiochronous Digital Hierarchy). A variety of data rates are defined which are ‘nominally synchronous’, and the standards describe how several lower speed channels (‘tributaries’) are multiplexed on to a higher speed channel. Different hierarchies of data rates have been adopted in Europe, North America, Japan, and elsewhere. For example, the following data rates are used in Europe:

- 2.048 Mbit/s
- 8.448 Mbit/s
- 34 Mbit/s
- 139 Mbit/s
- 540 Mbit/s

PDH networks are now in widespread use around the world to provide a global digital backbone network. At the time of LEP construction an extensive PDH network was installed at CERN, interconnecting LEP and SPS sites, and various locations on the Meyrin and Prévessin sites.

The fact that PDH bit streams are only nominally synchronous leads to considerable complexity in the multiplexing equipment. For this reason, and because of the diverse PDH standards in different parts of the world, a new time-division multiplexing technique has been adopted which is totally synchronous, and is therefore known as SDH (Synchronous Digital Hierarchy). SDH is an open-ended standard, with no upper limit for data rates. Equipment is currently widely available at the following data rates:

- 155 Mbit/s
- 622 Mbit/s
- 2.4 Gbit/s

SDH has many advantages over PDH:

- simpler, and therefore less expensive, multiplexing equipment
- reduced error rates due to total synchronism
- reduced jitters
- possibility of extracting low (eg. 2 Mbit/s) data rate channels from a high speed channel without the need to pass through intermediate levels of multiplexing.

All major telecommunications carriers now implement extensive SDH networks which, whilst still being used principally for telephony traffic, increasingly carry data-oriented traffic such as frame-relay, ATM, and IP. The two latter protocols will now be described briefly, as they are particularly relevant for video applications.

3.2 Asynchronous Transfer Mode

Asynchronous Transfer Mode (ATM) is based on the fast transmission and switching of 53-byte data ‘cells’. It is important to differentiate between the ‘clock rate’ and the ‘bit rate’ of the user interface. The clock rate is fixed and continuous, for example at the (SDH) rate of 155 Mbit/s. The bit rate depends on the frequency with which the user requires (or is allowed) to send cells to the network. There are several possibilities defined:

- CBR (Constant Bit Rate): cells are sent to the network at regular and unchanging intervals
- VBR (Variable Bit Rate): cells are sent to the network at a rate dependant on the application’s instantaneous requirement
- ABR (Available Bit Rate): the network and the user negotiate a bit rate dependant on many factors such as user requirements, network congestion, tariffs, etc.

There are also different types of connection which can be established, the most important being:

- PVC (Permanent Virtual Circuit): the circuit is established by the network management software, and is permanently available thereafter
- SVC (Switched Virtual Circuit): the circuit is established by the user for a limited time, in a manner similar to a telephone call.

ATM connections can be set up to have a guaranteed ‘quality of service’: the user has a guarantee of a certain bandwidth availability, cell delivery delay, error rate, and so on. This is particularly important for video applications. Moreover, the VBR option is particularly useful for bursty traffic, which is exactly the traffic pattern generated by compressed digital video.

3.3 Internet Protocol

Internet Protocol (IP) is one of several protocols defined in the early days of data networking, and is the reason why the world-wide network of computers interconnected using IP is known as ‘the Internet’. IP provides error-free communication between connected hosts (computers).

There are several fundamental problems which prevent the widespread use of IP networks as a data transport method for digitally encoded video. In particular:

- Error correction by re-transmission: introduces unpredictable delays, whereas the consequence of the error, <u>for video</u>, would probably be insignificant.
- Multiple routing: IP networks split data streams into packets which can be routed along physically different paths: packets do not necessarily arrive at their destination in the order in which they were sent, and the re-arrangement of the packets can cause unpredictable delays.
- Lack of guaranteed bandwidth: network congestion, even on a single link, can introduce further unpredictable delays.

However, two factors have to be considered. Firstly, it is now possible, especially in a privately managed network, to configure ‘virtual networks’ where the bandwidth and performance is guaranteed. Secondly, the latest version (version 6) of IP has built in to it the concept of quality of service. When IPv6 becomes widely adopted, video (and audio) transmission over IP networks will become much easier.

4 VIDEO TRANSMISSION AND DISTRIBUTION

4.1 MPEG

The MPEG family of standards covers various aspects of digital video. The name is derived from the Motion Picture Experts Group, who devised them. The family is made up of:

- MPEG1: storage and retrieval of moving pictures and associated audio, eg. on CD-ROM
- MPEG2: digital television, including HDTV
- MPEG4: multimedia
- MPEG7: content representation for information search.

The basic principles of MPEG compression are to use the redundancy in a television picture to reduce the bandwidth required for storage or transmission. Spatial redundancy results from the fact that the neighbours of each pixel (the adjacent pixels above, below, to the left, and to the right) tend to be the same as the reference pixel. Similarly the corresponding pixel in the previous (and subsequent) frame also tend to be the same. MPEG compression exploits this by only coding the differences from a predicted situation. Further compression is achieved by motion prediction: an object which is moving across the screen relative to a background will tend to continue moving.

MPEG gives a typical compression ratio of about 30:1, thus a broadcast quality TV image requires 3–8 Mbit/s. Of course, when the picture changes totally from one frame to the next, there is no alternative but to transmit all the new information, hence the applicability of data transport methods optimized for bursty transmission, such as ATM.

4.2 DVB

The Digital Video Broadcasting (DVB) specifications were devised as result of an initiative by the European Broadcasting Union to harmonize digital television standards.

The core technology for DVB is based on the MPEG-2 standard referred to above. It consists of four 'levels' (of definition, or picture quality), and five 'profiles' (sets of compression tools). Not all of the possible combinations of 'levels' and 'profiles' are implemented.

The most important standards for digital video which have been adopted, for transmission and distribution, are the following:

- DVB-PDH: transmission of digital video over PDH networks
- DVB-SDH: transmission of digital video over SDH networks
- DVB-S: distribution of digital video by satellite
- DVB-T: distribution of digital video by terrestrial TV transmitters
- DVB-C: distribution of digital video by cable (community access) TV systems.

Digital television transmission by satellite is now widespread, and the first terrestrial digital transmissions were started in November 1998 in the UK. It is now only a matter of time before consumer equipment becomes ready to receive digital signals to the DVB standard.

4.3 Packet video

The ubiquity of IP networks is likely to enhance the market penetration of delivery of video to the consumer by packet-switched technology. With the implementation of IPv6, packet video seems certain to play a major role in video transport.

5 CONCLUSION

It is certain that digital technology will profoundly change the way in which video images are transported and distributed in the very near future. It is not yet clear which combination of technical standards will achieve predominance in the consumer market. However, whatever solution emerges, it will provide CERN with a timely opportunity to rationalize its video systems, quite possibly by integrating them into a unified multimedia backbone network capable also of transporting audio (telephony) and data.

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