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Digital Video and Digital TV: A Comparison and the Future Directions

This paper presents an overview of the recently emerged development and current work into all digital High Definition Television systems based on the MPEG-2 compression scheme. It explores the advantages and disadvantages of Japan's MUSE, European DVB, and U.S. all digital HDTV systems, examines the global HDTV standardization process, and provides a comprehensive and technical survey of HDTV in Asia, Europe and the U.S. It also analyzes the consumer acceptance and market potential of all digital High Definition Television, and predicts the future merge of broadcast video and computers.

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Introduction

At the dawn of a new millennium, an information revolution is taking place that is bringing fundamental changes to today's digital video technology. Digital video technology has been developing so quickly that it has had a significant economic impact on the computer, telecommunications, and imaging industries. New consumer products in digital video are now emerging in order that the functions of the telephone, computer, and television will be combined together. Recent advances in digital video hardware and the establishment of international standards for digital video compression have already led to various multimedia desktop digital video products, all digital High Definition Television (HDTV), as well as digital visual communications products, such as video-conferencing, video-phone, video-fax, and video-e-mail, etc [1–44].

Video Compression Standards

Exchange of digital video between different applications and products requires digital video format standards. Without video coding standards, the encoders and decoders can not communicate with each other. Video data needs to be exchanged in compressed form, which leads to compression standards (see Table 1). The standard display resolutions in the computer industry, the digital studio standards in the TV industry, and standard network protocols in the communications industry have already been established. Because the advent of digital video is bringing these three industries ever closer, standardization across the industries has also started recently (A. Murat Tekalp, 1995).

Digital TV

Overview

Conventional TV, arguably the most commonly used image communication system in the world today, was developed in the 1930s. The following lists the major milestones of television's development:

- 1930 Black and white TV
- 1950 Cable TV

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Table 1. World Standards for Video Compression

Standard	Bit rate	Application
H.261	$p \times 64$ kbps	Video conference
H.263	$< P \times 64$ kbps	Video conference
MPEG-1	1.5 Mbps	CD-ROM & VCD
MPEG-2	10–20 Mbps	DVD & DTV
MPEG-4	4.8–32 kbps	Multimedia
MPEG-7	Underway	Multimedia

- 1954 Color TV broadcasting
- 1973 Giant-screen projection color TV
- 1982 Surround sound is introduced
- 1986 Satellite TV broadcasting
- 1994 Digital satellite TV
- 1996 Web TV
- 1998 Digital TV/HDTV

Conventional TV transmission standards are based on technology that is more than 40 years old, and the world has been split into three discrete television systems—NTSC, PAL and SECAM—that are incompatible with each other and difficult for international program exchange. As a result, there has been widespread interest in the consumer electronics industry towards developing more advanced TV systems, including digital High Definition Television.

What is digital TV?

Digital TV (DTV) refers to digital representation and processing of the signal as well as its digital transmission. Digital TV broadcast involves converting images and sound into digital code. This digitization of images and sound (and data) starts with compression in order to minimize the capacity required of the transmission channel. In all advanced digital TV systems, compression is performed to the industry standard MPEG-2, then modulation occurs whereby the code is formatted for propagation along terrestrial, satellite or cable media.

The DTV transmission standard uses digital processing and compression to achieve simultaneous transmission of several different television programs or reception of a single program at a picture quality level that depends on the complexity of the receiver. In any event, the quality of the signal received is equivalent to the studio output. DTV represents a dramatic change for the production and broadcast industries, as well as the users. New technologies have recently brought tremendous flexibility in the use of different picture formats using digital compression systems. Moreover, because of the digital nature of the picture information and the emergence of powerful high-speed processors, the computer industry is directing its main business to the TV world. These converging technologies are modifying the existing TV environment completely.

DTV closed captioning will allow simultaneous transmission of captions in multiple languages and at multiple reading levels. Current analog closed captioning can be transported at 960 bits per second (bps), while DTV closed captioning under the new standard will work at 9600 bps—10 times the analog capacity. DTV closed captioning is also more user-friendly, imitating computer graphics windows. Also, DTV's increased resolution provides more defined representations of character fonts and other objects.

High Definition Television

High Definition Television (HDTV) means high-resolution, wide-screen, digital surround sound, and no artifacts (no ghosts, no snow). It refers to a subset of Advanced Television (ATV) technology that can display at least 1000 vertical measured lines in interlaced mode and has a 16:9 aspect ratio. Sharper wide-screen pictures and CD quality audio are the most apparent characteristics of HDTV, but the most radical change, which will be invisible to the viewer, is that HDTV signals will be transmitted digitally. The following are the differences between conventional TV and digital HDTV:

Conventional TV:

- 4:3 aspect ratio
- Limited resolution
- Limited color fidelity
- Flick
- Color mixing
- Analog transmission

Digital HDTV:

- Wide screen
- 16:9 aspect ratio
- High resolution (>1000 Lines)
- Digital sound (Dolby AC-3)
- No artifacts
- No ghost
- No snow
- Improved color fidelity
- Digital transmission

Table 2. The comparison of analog and digital video/television

	Total lines	Active lines	Resolution	Aspect ratio	Compression format	Bandwidth	Video quality	Sound	Cost
VHS	N/A	240	352 × 240	4:3	Analog	N/A	Poor	Analog	$200
S-VHS	N/A	420	567 × 420	4:3	Analog	N/A	Good	Analog	$400
NTSC	525	486	720 × 486	4:3	Analog	6MHz	Good	Analog	$500
PAL	625	575	720 × 575	4:3	Analog	8MHz	Good	Analog	$500
SECAM	625	575	720 × 575	4:3	Analog	8MHz	Good	Analog	$500
VCD	N/A	240	352 × 240	4:3	MPEG-1	N/A	Poor	Digital	$200
Laserdisc	N/A	420	567 × 420	4:3	Analog	N/A	Good	Dolby Analog Prologic	$500
Multimedia PC	N/A	240 500	352 × 240 720 × 486	4:3	MPEG-1 MPEG-2	N/A	Poor Good	Analog Dolby Digital	$1000– $3000
DVD	525	500	720 × 486	16:9 4:3	MPEG-2	N/A	Good	Dolby Digital (AC-3)	$600
Satellite TV	525	500	720 × 486	4:3	MPEG-2	24-36MHz	Good	Digital	$300
Cable TV	N/A	420	567 × 420	4:3	Analog	6MHz	Good	Analog	$50
DVB	1,250	1,152	1920 × 1152	16:9	MPEG-2	7-8MHz	Very Good	MPEG-2	N/A
MUSE (Hi-Vision)	1,125	1,035	1,920 × 1,035	16:9	Sub- sampling	6-9MHz	Very Good	Digital	$2600 (34″) $3900(56″)
ATSC HDTV	1,125	1,080	1,920 × 1,080	16:9	MPEG-2	6MHz	Very Good	Dolby Digital (AC-3)	$8000

The nature of the digital broadcast removes the synchronicity and real-time requirements of the analog TV and offers many different options. A digital TV standard will unify the computer/workstation and TV industries in the future. A comparison of analog and digital video/television is illustrated in Table 2.

In digital HDTV, the modulating signal carries audio, video, and ancillary data packets on a radio wave at a rate of about 19.3 megabits per second (Mbps) into the 6 MHz TV channel bandwidth—the same size as today's channel. In the home TV receiver the HDTV signal is demodulated and de-multiplexed, and the digital information is decoded and reassembled. While any new HDTV receiver would be required to receive and display the new HDTV signal in full HDTV quality, it is expected (manufacturers are already presenting prototypes) that set-top (or in-NTSC-set) adapters would also be available to down convert the incoming HDTV signal to an NTSC-type signal that is viewable on an NTSC receiver. This output derived from the digital HDTV (or an SDTV) signal will look "cleaner" (i.e., no noise, or ghosts), but not sharper (i.e., higher resolution), than a normal NTSC signal because the artifacts caused by analog NTSC transmission would be eliminated.

Main digital TV/HDTV broadcasting systems

The three main digital TV/HDTV broadcasting standards are MUSE in Japan, the DVB system in Europe, and the American ATSC DTV system. In Japan, HDTV programs are broadcast by satellite every day, and a terrestrial DTV broadcast is commencing that will use the COFDM modulation scheme. In Europe, a Digital Video Broadcasting (DVB) consortium has defined several DVB standards. In North America, this new television system has recently been standardized by the ATSC.

MUSE in Japan

In Japan, HDTV was known as Hi-Vision using the MUSE format. Japan's frequency-modulated MUSE (multiple sub-nyquist sampling encoding), recorded its beginning in 1970 as a wide-band frequency-modulated 1125-line, 60-field system with a signal transmitting bandwidth of 8.1 MHz, and a sampling clock rate of 16.2 MHz. MUSE is an analog system mixed with digital,* and is not compatible with other transmission standards. At present, there are daily HDTV broadcasts via DBS (Direct Broadcast Satellite) in Japan.

Hi-Vision offers viewers the sharpest television images ever, more than doubling the number of scanning lines to 1125 from the 525 used on conventional screens, but the bandwidth needed was increased to 8.1 MHz (from 4.2 MHz). With Hi-Vision, the ideal viewing distance is only three times the height of the screen, compared with

*It uses analog pulse-amplitude-modulation transmission for the visual signal, and digital transmission for sound and auxiliary data.

seven times for conventional TV. Viewers can sit closer to the screen without being distracted by its scanning lines.

Hi-Vision also affords a viewing angle of 30 degrees, compared with the 10 degrees of conventional television sets. This improved, wider viewing angle adds to the sense of personal involvement while providing more vivid pictures. It employs DPCM sound broadcasting technology, a digital format similar to that of compact discs. Hi-Vision allows the enjoyment of 3–1 surround sound, which adds C (center) and S (surround) to the two channels L (left) and R (right) used in conventional stereo broadcasting.

However, because of the incompatibility of the MUSE system with conventional TV, terrestrial broadcasting is not possible. Therefore, Japan has recently settled on an HDTV system comparable to the U.S. 1080-line interlaced format, but using the COFDM modulation scheme similar to Europe's DVB.

DVB in Europe

The Digital Video Broadcasting (DVB) project includes over 220 well-known organizations in more than 30 countries worldwide. The DVB Group was formed in 1993. Members include broadcasters, manufactures, network operators and regulatory bodies, committed to designing a global family of standards for the delivery of digital television.

DVB is based on standard-resolution TV, 625-line, 50-Hz interlaced pictures, and relies on the MPEG-2 video compression and MPEG-2 digital sound (initially stereo only, but upgradable to multi-channel surround). The wide-screen variant has an aspect ratio of 16:9. In the optional high-definition mode, the number of lines is doubled to 1250 interlaced, and the number of pixels per line is also doubled, so as to quadruple resolution and bit-rate requirements. DVB allows for no direct compatibility between high-definition and standard-resolution modes. High-definition pictures are to be simulcast alongside standard pictures. Receivers will convert interlaced transmission into a 625 or 1250 progressive format.

The main DVB standards are DVB-C (for cable), DVB-S (for satellite), and DVB-T (for terrestrial) broadcasting. They are all based on MPEG-2 international digital compression standards. The main differences among the three transmission media are in the way the compressed signal is packaged for transmission: DVB-S transmission is based on Quadrature Phase Shift Keying (QPSK) modulation; DVB-C uses Quadrature Amplitude Modulation (QAM). DVB-T uses Coded Orthogonal Frequency Division Multiplex (COFDM).

COFDM is a digital RF modulation technique, which makes use of multiple redundant carriers to achieve extremely robust signal delivery. Having multiple carriers allows transmissions to survive even in extremely hostile reception conditions. According to the tests' results, COFDM system operates extremely well in the conditions likely to be found in heavily built-up areas such as towns and cities. COFDM makes it possible to make constructive use of the unavoidable "multi-path echo" signals, which are caused by reflected signals from buildings arriving at the receiving antenna.

DVB-T offers significant advantages over other proposed transmission systems. DVB-T has been demonstrated to receive television signals on the move (at speeds up to 275 km/h), and is capable of delivering many different kinds of service, from HDTV to standard definition (SDTV), to multimedia content and interactive services. It is the only market-ready standard which supports the indoor set-top antenna, portable and mobile reception of digital television. It is also the only standard developed internationally by cross-industry cooperation in countries with a variety of different terrestrial broadcasting environments. All countries in Europe have agreed to adopt DVB-T, thus Europe will have a single TV standard instead of the incompatible analog systems with SECAM and PAL.

The sound coding system specified for all DVB systems is the widely used MPEG Layer II audio standard (MUSICAM). MPEG Layer II is a digital compression system, which takes advantage of the fact that a sound element will have a masking effect on other nearby lower-level sounds (or on noise). This is used to facilitate the coding of the audio with low data rates. Sound elements, which are present, but would not be heard even if reproduced faithfully, are not coded. The MPEG Layer II system can achieve a sound quality which is very close to Compact Disc. The system can be used for mono, stereo, or multilingual sound, and in the future MPEG-2 audio can be used for surround sound. Although it can provide six channels of sound and its fidelity is high, there are no multi-channel MPEG decoders for consumers to buy and the first-generation digital TV receivers have no socket for connection to a multi-channel decoder. So broadcasters have no plans to transmit multi-channel sound. Instead, digital TV in

Europe will launch with digital stereo, with matrixed Pro Logic sound.

The work of the DVB project has reached a high level of maturity, but has not ended yet as numerous design activities are still ongoing. Among these the design of the software structures for the next-generation Multimedia Home Platform (MHP) is the most challenging.

DTV in the US

Despite the failure of trying to launch a hybrid analog-digital HDTV system (HD-MAC) in the early 1990s, the exploration of broadcasting HDTV programs has been ongoing. Five HDTV simulcast systems were examined by the Advanced Television Systems Committee (ATSC) in 1992: Narrow-MUSE, an analog system proposed by NHK; DigiCipher, a digital system proposed by The American Television Alliance (General Instrument Corporation and the Massachusetts Institute of Technology); Digital Spectrum Compatible HDTV (DSC-HDTV), a digital system proposed by Zenith and AT&T; Advanced Digital HDTV (AD-HDTV), a digital system proposed by the Advanced Television Research Consortium (ATRC) which includes David Sarnoff Research Center, North American Philips, Thomson Consumer Electronics, NBC, and Compression Labs, Incorporated; and Channel Compatible DigiCipher (CCDC), a second digital system proposed by the American Television Alliance.

The four digital systems were judged better than Narrow-MUSE for interoperability with digital technology, NTSC, film, still images, and interactive systems. But they all have some disadvantages and need to be improved, even in the two leading systems, DigiCipher and AD-HDTV. However, none of these systems alone satisfied ATSC's tough requirements.

On May 24 1993, the four digital system proponents announced that they had formed a 'Grand Alliance' which would make a single system proposal to the Advisory Committee combining the best features of each of the individual proposals. In October 1993, the Grand Alliance announced that the video compression algorithm would be MPEG-2, main profile, high level; the MPEG-2 transport mechanism would be used; the Dolby AC-3 audio system would be used; and three modulation techniques, 4-level VSB, 6-level VSB, and 32 QAM (quadrature amplitude modulation), would be tested to complete the specification. On April 12 1995, ATSC members approved the Digital Television Standard for HDTV Transmission. The US Federal Communications Commission (FCC) approved the standard for domestic terrestrial HDTV transmission on December 24 1996.

The Grand Alliance standard differs from all existing TV standards in three major ways. First, it is all digital standard—to be broadcast with a packet transmission. Second, it supports multiple formats. Third, it is designed to be primarily compatible with computers rather than existing NTSC television.

The core of the Grand Alliance concept is a switched packet system. Each packet contains a 4-byte header, and a 184-byte data word. Each packet contains video, audio, or auxiliary information. For synchronization, the program clock reference in the transport stream contains a common time base. For lip sync between audio and video, the streams catty presentation time stamps that instruct the decoder when the information occurs relative to the program clock.

The terrestrial transmission system is an 8-level vestigial side band (VSB) technique. The 8-level signal derived from a 4-level AM VSB and then trellis coding is used to turn the 4-level signals into 8-level signals. Additionally, the input data is modified by a pseudo-random scrambling sequence, which flattens the overall spectrum. Cable transmission is by a 16-level VSB technique without trellis coding. A small pilot carrier is added. This pilot carrier is placed so as to minimize interference with the existing NTSC service.

The ATSC established 18 different picture-resolution formats for DTV, but only four concern home viewers today. There are two HDTV and two SDTV formats (see Table 3), where the picture is progressively scanned (−p) or interlaced (−i).

The HDTV format with the greatest resolution today is the so-called 1080i format. It has 1080 interlaced scanning lines, each with 1920 pixels (the picture-elements that make up a picture), to deliver more than 2 million pixels per picture frame. The other HD format

Table 3. ATSC DTV formats

Format	Resolution	Aspect Ratio	Frame Rate
HDTV	$1{,}920 \times 1{,}080$	16:9	30i, 30p, 24p
HDTV	$1{,}280 \times 720$	16:9	60p, 30p, 24p
SDTV	704×480	16:9 4:3	30i, 60p, 30p, 24p
SDTV	640×480	4:3	30i, 60p, 30p, 24p

is called 720p, whose 720 progressively scanned lines carry 1280 pixels each, totaling nearly a million.

The two SDTV formats also are progressive, with 480 scan lines each. One is for the same wide-screen 16:9 proportioned picture as HDTV and delivers 337,920 pixels per frame. The other carries 307,200 pixels to make a picture with the 4:3 width-to-height proportions as today's TV.

Today, DTV format, especially progressive/interlaced scanning, is the hottest topic among PC professionals, broadcasters and consumer electronics manufacturers, considering cost, compatibility, and future expandability in the multimedia era for various uses of the contents expressed in the DTV format. Interlacing, which was once thought of as a great advance, has been found to suffer from some troubling artifacts, such as interline flick in vertically detailed areas and defective rendition of vertical motion. In addition, interlacing greatly complicates or seriously disables the signal processing, such as transcoding, picture modification in spatial size and/or motion speed, and deinterlacing. Therefore, it seems to be unadvisable to use interlaced scanning in new DTV systems. On June 2, in Geneva, the International Telecommunications Union (ITU) adopted 1080p for the worldwide HDTV standard.

In order to transmit DTV, stations need a separate channel from the one they currently operate. To accommodate them, the FCC has allocated unused UHF and VHF frequencies in each market. The bandwidth of the DTV channel is the same 6 MHz as for analog TV. But digital technology provides ways to squeeze or compress the information going into the pipe, then decompress or reconstitute it back to full strength in the TV receiver. This is the reason why the ATSC chose digital transmission as the standard for the US.

With its digital compression, DTV offers broadcasters great flexibility in how they use their 6 MHz pipeline. They can send a single channel of high-definition TV (HDTV) programming, or use a lower picture resolution called Standard Definition TV (SDTV) and split the channel to simulcast multiple programs.

The ATSC HDTV system is clearly designed with future computer and multimedia applications in mind. The use of MPEG-2 will permit HDTV to interact with computer multimedia applications directly. For example, HDTV could be recorded on a multimedia computer, and CD-ROM applications could be played on HDTV systems.

HDTV broadcasts everything with the Dolby Digital/AC-3 audio encoding system. This is the same digital sound used in most movie theaters, DVDs, and many home theater systems since the early 1990s. It can include up to 5.1 channels of sound: three in the front (left, center, and right), two in the back (left and right), and a subwoofer bass for a sound you can feel (the .1 channel). Sound on digital TV will be "CD quality" with a range of frequencies lower and higher than most of us can even hear.

The comparison of MUSE, DVB-T and ATSC DTV
Although the different US, Japanese and European digital TV standards all make use of the same MPEG-2 options for compressing their images, there are considerable differences in terms of modulation, sound coding and service information (See Table 4).

Among the three systems evaluated by ATSC, the Japanese MUSE system is the worst simply because it has no interoperability with computers.

Both DVB-T and US ATSC systems use MPEG-2 for compressing the video information. The US system makes use of the proprietary Dolby AC-3 audio encoding system, where as DVB uses MPEG-2 digital sound. The most important difference between the two standards is the RF modulation technique known as 8-VSB, where DVB-T makes use of the COFDM. 8-VSB, the digital terrestrial system proposed in the US by ATSC and adopted by FCC, makes use of single-carrier 8 Vestigial Side Band (8-VSB) modulation. Although it promises a slightly higher bit rate, 8-VSB requires a fixed directional rooftop antenna for HDTV. Mobile reception and gap-filling using overlapping transmitters broadcasting on the same frequency are not possible. By using DVB, portable, mobile reception is possible. The

Table 4. The Comparison of MUSE, DVB and TSC

	MUSE	DVB	ATSC
Video compression	Sub-sampling	MPEG-2	MPEG-2
Audio compression	DPCM	MPEG-2	Dolby AC-3
Modulation	FM/PAM	COFDM	8-VSB
Bandwidth	6–9 MHz	7–8 MHz	6 MHz
Portable/mobile reception	No	Yes	No
Inter-operability	No	Yes	Yes
Cost	Expensive	Expensive	Cheaper

8-VSB modulation system can provide excellent results in suitable conditions, and is less complex and might therefore be initially cheaper to implement than COFDM. The U.S. system is markedly less rugged than COFDM in conditions where multi-path interference is likely to occur. The major benefit of COFDM is that the serial base band bitstream, which needs to be transmitted, is distributed over many closely spaced individual carriers (frequency division). This spreading makes the signal robust against the effects of multi-path and narrowband interferers. COFDM has also been adopted by the Japanese standard group DiBEG for use in the Japanese terrestrial DTV system, Integrated Services Digital Broadcasting (ISDB). Both DVB and the ATSC DVB system are interoperable with computers.

The future of digital video and digital TV

Digital video

While MPEG-2 continues to dominate the existing TV and computer applications, a number of new digital video coding and compression standards are expected to become available.

MPEG-4 is an emerging coding standard that supports new ways (notably content-based) of communication, access and manipulation of digital audio-visual data.* It is the next audiovisual coding standard from ISO after MPEG-1 and MPEG-2. However, it is the first video-coding standard that supports the encoding of not only rectangular video frames but also arbitrarily shaped video objects. This work is not, in principle, aimed at digital TV broadcasting, but at interactive multimedia applications at the interface between audio-visual and computer (radio) communications, such as video-telephony based on LAN, ISDN, and standard telephone or radiotelephone networks. For these applications, MPEG-4 is going to define new coding principles, including being object oriented to ease editability and interactivity, and various scalability possibilities to allow easy adoption to a variety of transmission channel capacities MPEG-4 allows the user to interact with objects within the scene, whether they derive from so-called real sources, such as moving video, or from synthetic sources, such as computer-aided design output or computer-generated cartoons. Authors of content can give users the power to modify scenes by deleting, adding, or repositioning objects, or to alter the behavior of the objects. With MPEG-4, future television sets will no doubt accept content from both broadcast and interactive digital sources. Accordingly, MPEG-4 provides tools from seamlessly integrating broadcast content with equally high-quality interactive MPEG-4 objects. Recently, digital copying of audio from the Internet has become popular. For video, the same situation will arise when MPEG-4 encoding and higher bandwidths become widespread and as digital storage prices continue to drop.

To give even more support for interactive applications, the next release of the MPEG-4 standard, which is to be published in December 1999 (at the time of writing), will define MPEG-J. This is an MPEG-4 specific subset of the object-oriented Java language.

Of all the new and useful features in MPEG-4, perhaps the most entertaining is its ability to map images onto computer-generated shapes. When the shapes are animated, the gap between synthetic and real can be bridged quite efficiently. In addition to the Internet, the standard is also designed for low bit-rate communications devices, which are usually wireless. MPEG-4 moves beyond that to fully interoperable display of objects and will ultimately be three-dimensional. MPEG-4 was not meant to replace MPEG-2, instead, it enables new applications and new types of content, as well as more types of connections. In fact, the Moving Picture Exports Group is now designing ways for MPEG-4 and MPEG-2 to work together. As broadcast becomes digital worldwide and TV sets come to resemble interactive terminals, a new phase in the evolution of multimedia has begun (Koenen, 1999).

MPEG-7, which is still in the conceptual phase, is aiming to standardize the description of multimedia material: pictures, sound, and moving images. It is scheduled for approval in September 2001. MPEG-7 will be useful to describe multimedia data regardless whether in local storage, remote databases, or broadcast. Examples are finding a shot in a movie, finding music that sounds like a favorite compact disc, or picking a digital broadcast channel from the hundreds available.

A current issue in defining the standard is choosing useful descriptors at all levels in terms of their content, the previous examples being high-level, and color, texture and audio spectrum being low-level. MPEG-7 will also specify hierarchical schemas using multiple

*MPEG-4 was released in November 1998, and became an official International Standard in January 1999.

descriptors of this kind, as well as a language for defining these schemas.

One of the latest developments of digital video is streaming media. Streaming makes audio, video and other multimedia available over the Internet and Intranets in real-time. You can begin playing the video before the entire file is downloaded, reducing wait time. While streaming is widely used by Internet news sites, such as *www.cnn.com* and *www.cbs.com*, it is also valuable for business communications.

High Definition Television

The fully digital era in consumer video applications is only just starting, and rapid and numerous changes in the services digital video offered to the public are to be expected in the coming years. Digital TV broadcasting film-quality pictures and theatrical surround sound has been more than a decade in coming. The phenomenal images are now riding the airwaves following the launch of high-definition telecasts in the US on November 1st 1998. According to the report, on or about November 1st, 1998, 42 stations began digital broadcasting and 100 DTV sets were sold in the US. As of April 20, more than 60 stations in 24 markets had converted to digital, well ahead of the timetable set by the FCC. 140 stations are expected to be converted by the end of 1999, representing the nation's top 30 markets and over 50% of all US households. The details of the FCC timetable are as following:

- November 1998—At least 26 stations have filed their intention to begin digital broadcasts.
- May 1999—All network affiliates in the 10 largest markets must begin digital broadcasts.
- November 1999—Network affiliates in the 30 largest markets must begin digital broadcasts.
- May 2002—All commercial stations in the US must begin digital broadcasts.
- May 2003—All US. stations, commercial and non-commercial, must begin digital broadcasting.
- May 2006—Analog TV signals completely eliminated in the US.

The development of the HDTV market has its own characteristics. Firstly, there are some problems with implementation of the ATSC standard which will have to be solved before we see HDTV really succeeding.

- HDTV is not, at least initially, a replacement for the mass medium of NTSC. The Japanese and Europeans have known for more than a decade that HDTV is a niche product for those who can afford top-of-the-line home theater systems.
- The 8-VSB modulation standard has serious problems with dynamic multi-path, leading to reception problems in many areas. The United States might have to consider switching from its current use of 8-VSB modulation to the European standard COFDM.
- The marketplace is confused by the turmoil that surrounds the launch of DTV receivers. The areas of confusion include: cost; multiple emission and display formats; interconnection of receivers with cable and other set-top boxes; encryption; and compatibility with the Internet and emerging digital media standards.
- The lack of a standard for data broadcasting and interactive digital media, which will allow DTV receivers and emerging categories of digital media appliances to interoperate with bits delivered via Cable, DBS, DTV, DVD, and Internet.
- The dual-channel (NTSC/ATSC) migration strategy is too expensive for terrestrial broadcasters in smaller markets, and problems with tower citing in the large markets like New York and Chicago may delay deployment for years.

Secondly, whether consumers are willing to buy HDTV depends on the availability of HDTV programs: no HDTV programs, no market. However, HDTV programs are not inexpensive to produce. TV stations would not want to broadcast HDTV programs if there are only limited number of viewers because HDTV will not generate more commercial TV income. Also, consumers would be more likely to purchase high definition television sets when the price becomes affordable. But manufacturers could only reduce the cost in mass production. This problem occurred during the development of conventional television. As illustrated in Figure 1, the cost of one conventional color television was higher than consumer acceptance in 1955 when conventional color television began to appear in the US. In the following years until 1964, the cost of television was reduced by more than 50%, but consumer acceptance did not increase sharply. This was because NBC was the only television network that was broadcasting color television programs. Consumer acceptance increased dramatically only after the three commercial networks began broadcasting color TV programs during prime time in 1965.

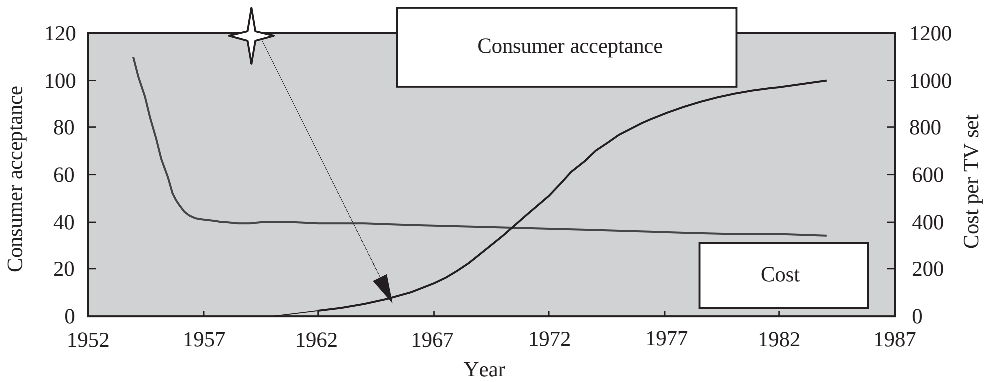

Figure 1. The relationship between consumer acceptance and cost of conventional color TV; three major national TV networks started broadcasting color TV programs in prime time.

According to the survey conducted by the American Electronics Association, every nine people on earth owned a television set in 1989. Among 605,000,000 television sets, 54% were color. If only converting 1% of 326,700,000 color television sets, this equates to over 3 million sets; bigger than today's PC market! If converting 10%, it would be hard to imagine its affect on the world's semiconductor market (Zheng Zhi-Hang, 1998).

Based on the analysis presented, it is concluded that HDTV definitely has a bright future; however, the mass consumer acceptance will not occur overnight. There was already an early indication of slower than expected HDTV transition reported in Television Broadcast's latest Semi-Annual Digital Television Survey. It is the authors' prediction that will take about 10 years before consumer acceptance increases significantly. Not only will the cost of HDTV be dramatically reduced from today's \$8000–\$15000 to the \$800–\$1500 range, but enough HDTV programs will be made available to mass viewers; thus, a \$730 billion HDTV market will be created in the year 2010.

The merge of broadcast video and computers

Digital technology and the convergence of the various digital media will introduce many more options besides the traditional one-to-many form of communication that we understand by ''television'' today. New services making use of the advanced features of digital

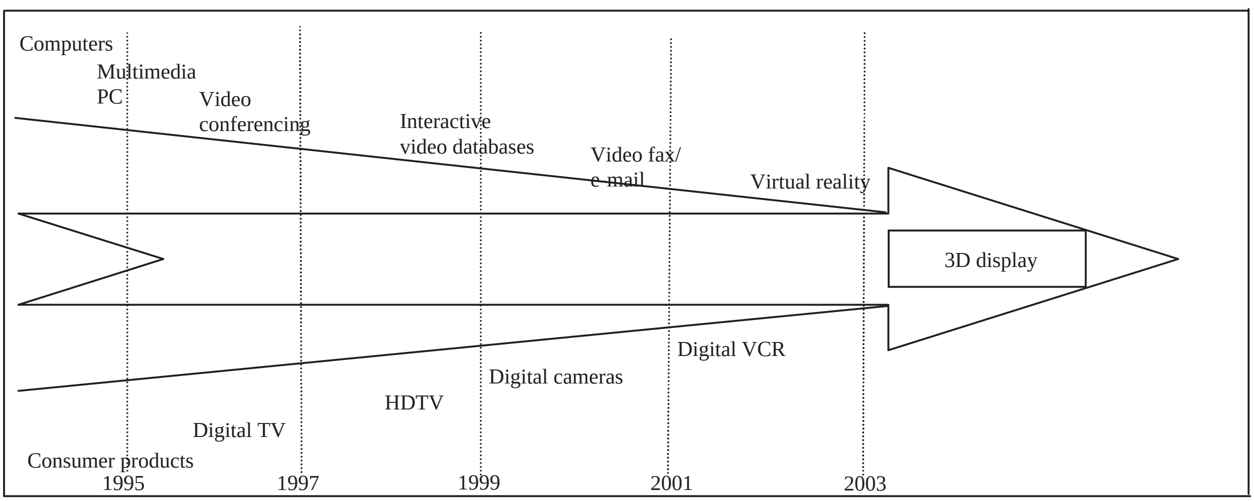

Figure 2. Roadmap for computing and TV merger

Table 5. The evolution of digital video and digital TV

	Digital Video					Digital TV		
	Multimedia PC	Video tele-conference	DVD	Interactive video database	Video fax/e-mail	Digital camera	Satellite TV	Terestrial HDTV
Year	1994	1996	1997	1999	2001	1998	1994	1998
Coding	MPEG-1 MPEG-2	H.261 H.263	MPEG-2	MPEG-7	MPEG-4*	MPEG-2	MPEG-2	MPEG-2
Aspect ratio	4:3	4:3	16:9 4:3	4:3	4:3	16:9 4:3	16:9 4:3	16:9 4:3
Lines	240 500	150*	500	N/A	N/A	480 720 1080	500	480 720 1080
Resolution	352 × 240 720 × 485	180 × 144*	720 × 486	N/A	N/A	704 × 480 1280 × 720 1920 × 1080	720 × 486	704 × 480 1280 × 720 1920 × 1080
Scanning	Non-interlaced	Non-interlaced	1:1p 2:1i	Non-interlaced	Non-interlaced	1:1p 2:1i	1:1p 2:1i	1:1p 2:1i
Platform	DOS; Mac; Windows	Windows; Mac	Win 95/98 /NT, Mac	Windows; Mac	Windows; Mac	Window; Mac	Windows; Mac	Windows; Mac
Bandwidth	N/A	N/A	N/A	N/A	N/A	N/A	24–36 MHz	6 MHz
Bit-rate	1–3 Mbps 10–20 Mbps	384 Kbps 19.2–160 Kbps	10–20 Mbps	N/A	4.8–32 kbps	10–20 Mbps	10–20 Mbps	10–20 Mbps
Frame Rate	24 Hz, 25 Hz, 30 Hz	15f/s 6.25–25 f/s	30 Hz	N/A	N/A	24, 30, 60 fps	30 Hz	24, 30, 60fps
Sound	Analog; digital	Digital	Digital	Digital	Digital	Digital	Digital	Digital
Video quality	Good Good	Poor	Good	Poor	Poor	Very good	Good	Very good
Audio quality	Good Very good	Good	Very good	Good	Good	Very good	Very good	Very good
User friendly	Yes Yes	N/A	Yes	Yes	Yes	Yes	Yes	Yes
Cost	$1000–$3000	$30,000– $40,000	$600	N/A	N/A	$1500– $100,000	$300*	$8000– $15,000
Future direction	Online 3D	Price drop; improve reliability	DVD-RAM DVD-RW	Quality & speed improved	Quality & speed improved	Price drop	HDTV	3D HDTV

Note: *Estimated data.

technology will present many-to-one, many-to-many and one-to-one communication, including interactive quiz shows, internet over the air, and a mix of television and Web-type content. Everything you can do on your personal computer, you will be able to do on your TV, and vice-versa.

A new generation of television—a computer in a set-top box that provides digital TV and a lot of more, from shopping to surfing—was announced by IBM on April 13 1999. A new chip that consolidates the capabilities into a single quarter-sized chip was developed by IBM Endicott's Digital Video Product Group. This new micro-processor will radically change the way people watch television. While watching a high resolution digital TV, viewers can look up information on something they are watching by clicking the product in the TV program, or even make purchases directly via the program.

More than this, the new enhanced and interactive services (which could include high speed internet over the air) could also be delivered to moving receivers. For example, with a GSM mobile phone connected to your laptop, and a DVB-T terrestrial DTV receiver plug-in card, you will be able to browse the World Wide Web at 2–14 Mb/s, 1000 times faster than with a 28.8 k modem.

The broadcast video and computer worlds are beginning to merge because of the quickly developed compression technology (see Figure 2 and Table 5). In the computer world, video conferencing via computer was the first extension of today's multimedia trend. Video fax or Video e-mail will be the following. A video e-mail system will make it possible for users to exchange interactive, multimedia messages containing voice, text, video and graphics. It should allow users to attach any type of video, audio or binary file onto a conventional e-mail message. Techniques that were previously restricted to specialized CAD/CAM tools and immersive Virtual Reality (VR) systems are now being extended to the mass market. The photo-realistic facilities offered by quick-time VR and the model-based renderings of VRML (Virtual Reality Mark-up Language) provide sophisticated tools for interface design. As a result, three dimensional visualization techniques are being widely exploited in the financial services industry, entertainment industry, airports and even offshore oil production. For the consumer products, the digital broadcasting service is spreading all over the world. Digital programming is becoming more prevalent every day in markets where DTV sets are beginning to be sold. There is a strong demand in the market to expect an early appearance of the digital recording VCR for the digital broadcast with a reasonable price. Most of the approaches are based on the D-VHS standard (as an application of the MPEG format). The VCR should have a capability of recording the digital bitstream of the digital broadcasting, and a compatibility with the current VHS VCR. In order to maintain compatibility, the mechanism is basically the same as VHS. The tape is based in S-VHS oxide material and improved for the D-VHS cassette. Digital cameras are appearing on the market. They are equipped with a FireWire connector (IEEE-1394), which allows the direct transfer of digital audio and compressed video data as well as time code, control messages, and error correction bits. FireWire-type digital interfaces are used for interconnections with future advanced television receivers, PC workstations, and already existing digital VCRs. Beyond the year 2000, the transmission and display of 3D video will be most challenging.

Conclusion

Based on the research in digital video compression techniques, analysis on analog TV and digital TV, and comparison of MUSE, DVB, and ATSC HDTV systems, the authors expect the future of digital video technology to be an eventual merge of broadcast video and computers in a 3D display. Everything you can do on your personal computer, you will be able to do on your TV, and vice-versa.

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