

# Digital Video for ITS

## An Overview of Why and How

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## **Abstract**

As Advanced Traffic Management Systems proliferates in the U.S. and abroad, increasingly sophisticated video communications networks are being deployed. One of the more recent technology choices being heavily discussed is that of digital video for ITS communications networks. Indeed, digital video technology is widely believed to become a predominant technology over the next decade for ITS traffic surveillance systems.

This paper serves to achieve each of the following:

1. To explore the motivation for adopting digital video technologies for ITS;
2. To review different digital video compression technologies applicable to ITS;
3. To discuss the barriers that are inhibiting the widespread deployment of digital video over the short term;
4. To recommend a graceful migration path to an all-digital future.

## 1 Introduction

As Advanced Traffic Management Systems proliferates in the U.S. and abroad, increasingly sophisticated video communications networks are being deployed. One of the more recent technology choices being heavily discussed is that of digital video for ITS communications networks. Indeed, digital video technology is widely believed to become a predominant technology over the next decade for ITS traffic surveillance systems.

This paper serves to achieve each of the following:

1. To explore the motivation for adopting digital video technologies for ITS;
2. To review different digital video compression technologies applicable to ITS;
3. To discuss the barriers that are inhibiting the widespread deployment of digital video over the short term;
4. To recommend a graceful migration path to an all-digital future.

## 2 Why Digital Video for ITS?

From the perspective of Department of Transportation (DOT) officials and system design consultants acting on their behalf, there are several potential benefits to selecting digital video technology for ITS traffic surveillance systems. These motivating factors can be summarized as follows:

1. The ability to interconnect with the Public Telecommunications Network and to share information with other agencies;
2. The ability to have a single network to integrate and transport video, voice and data;
3. The ability to withstand signal degradation over extremely long distances;
4. The ability to manipulate and interpret the video images using computerized systems;
5. The desire to purchase technology that will not become obsolete (“Future-proofing”).

Each of these motivations is examined in turn below.

### ***2.1 Interconnecting with the Public Network and Information Sharing***

The ability to interconnect with the public phone system (and hence the Internet, public agencies, etc.) is becoming an increasingly attractive reason for adopting digital video technology. Some ITS networks rely exclusively on the leased lines over the public network to provide connectivity between their roadside surveillance cameras and their Traffic Control Center. Indeed, in such cases, digitizing the Department of Transportation’s video signals is a necessity because leased T1/E1 lines are digital in nature. Regardless of whether the DOT chooses to selectively digitize video signals at the Traffic Control Center or throughout its network, the digitized video signals can be made available over the public network for access by any of the following:

1. Civilian travelers seeking traffic congestion information;
2. Local television and radio traffic announcement services;
3. Public agencies (police department, public transit agencies, etc.)
4. Commercial ventures with an interest in monitoring traffic conditions daily (e.g., taxi services, trucking companies, etc.)

### ***2.2 A Single Integrated Network for Video, Voice and Data***

Many of the ITS networks deployed over the last 10 years have been highly fragmented and involve one network for the transport of video with an entirely separate network for the transport of voice and data.

This disjointed approach works in the short term but leaves the customer with a network that may be difficult to scale as the need arises for growth in the network. Furthermore, the cost of operating and maintaining such a fragmented, unwieldy infrastructure can become burdensome over the entire life of the network. By digitizing voice and video into digital streams of 1's and 0's, the entire traffic surveillance system can be deployed over one unified network architecture that is more readily scalable and manageable.

### ***2.3 Reduced Signal Degradation over Very Long Distances***

Digital transmission systems tend to experience all of their signal degradation in the quantization and compression process encountered as a video signal is encoded into its digital format. Once a signal has been encoded, however, the signal can be transported without degradation over extremely long distances, exactly similar to a phone that extends between California and New York. In contrast, traditional broadband analog transmission methods do not experience this signal degradation at the source. Instead, the video signal in a broadband analog system experiences degradation along the path between the camera and the monitor. The controlled degradation in digital video systems (i.e., confined to the source) makes it an attractive technology as the span of ITS systems continues to expand.

### ***2.4 Video Manipulation and Interpretation***

Many ITS networks employ digital video signals coupled with other technologies to manipulate and interpret video images in real-time. For example, increasingly sophisticated video traffic detection systems use digital video as an input to determine the number of automobiles passing on a given roadway. Similarly, centralized enforcement systems are being used today by officials to achieve automated license plate recognition for toll, speed and weight regulation.

### ***2.5 Protecting Your Investment***

Department of Transportation officials are understandably concerned about the substantial capital investment required in technology that may soon thereafter become obsolete. As such, ITS communications network designers will try to achieve a balance between tried-and-true technologies and those that are likely to dominate in the future. This desire to "future-proof" ITS network designs, coupled with the eventual domination of digital networking for video, is one of the reasons digital video has attracted so much interest within the ITS industry of late. In truth, an investment in digital video technology for ITS systems today must be carefully planned to avoid the pitfalls and risks associated with new technology (as described in the section entitled "*The Path Forward — Suggestions for a Graceful Migration to Digital Video*").

## **3 Industry Trends in Digital Video**

### ***3.1 Digital Video Compression Technologies***

The process for digitization of video is defined by the International Telecom Union organization under ITU R.601. The digital representation of video is a stream of roughly 130 Mbps of raw output, requiring in turn an extraordinary amount of communications bandwidth in comparison with typical voice and data applications. This inordinate bandwidth requirement would make telecommunications infrastructure requirements unrealistically expensive for most applications. The need for more manageable bandwidth requirements has in turn encouraged the development of sophisticated digital video compression schemes. These algorithms take the 130 Mbps digital stream and compress it into an economical size that can be more readily transported over a digital communications networks with other media (e.g., over a SONET network integrated with voice and data).

The following is a list of the common digital video compression technologies available today:

- 1) The MPEG (Motion Picture Experts Group) family of compression standards
- 2) The JPEG (Joint Photographic Experts Group) principle of compression
- 3) The ITU-T's Video Conferencing Set of Standards (specifically H.261 & H.263)
- 4) Other emerging compression technologies (e.g. Wavelet and Fractal Compression Techniques)

The following table illustrates the characteristics of digital video compression technology. A more detailed discussion of each technology along with a brief overview of some relevant terminology is provided in Appendix A.

**Table 1 Digital Video Compression Technologies**

Digital Compression Scheme	Data Rate Required† (Mbps)	Lossy	Spatial Compression	Temporal Compression.	Frame Size	Frames per second
MPEG-1	0.4 – 1.5	Yes	Yes	Yes	352 x 240	25-30
MPEG-2	3 - 100	Yes	Yes	Yes	720 x 480	25-30
M-JPEG	1-10	Yes	Yes	No	160 x 120 - 640 x 480	1-30
H.261	1.5 - 2	Yes	Yes	Yes	176 x 144 - 352 x 288	10 -30
H.263	1.5 - 2	Yes	Yes	Yes	128 x 96 - 1408 x 1152	10 -30
Fractal	0.1-4	Yes	Yes	Yes	160 x 120 - 640 x 480	8 - 30
Wavelet	0.1-4	Yes	Yes	Yes	160 x 120 - 320 x 240	8 - 30

† Typical Application data rates.

In spite of the many unique digital video compression algorithms available for use in ITS, it is likely that one will prevail in dominating the ITS industry. MPEG-2 compression is beginning to emerge as a standard driven by the computing and media industries. MPEG-2's likely dominance in ITS specifically can be attributed to the confluence of the following:

- A Federal Communications Commission (FCC) ruling on ATSC (Advanced Television Standards Committee) stipulates that MPEG-2 as the compression technology of choice for the broadcasting industry – one of the primary industries driving video imaging technology;
- An ongoing requirement for interoperability between ITS systems favors MPEG-2, a standard compression scheme that does not differ from one vendor to the next (unlike, for example, M-JPEG);
- MPEG-2 offers a comfortable quality-versus-cost trade-off, with 3 Mbps required to achieve relatively high resolutions at 30 frames per second;
- The cost of MPEG-2 will likely decline quite rapidly, fueled by its continuing acceptance in other industries with greater demand for equipment (e.g., broadcasting).

Although MPEG-2 is the emerging standard, there will be applications where MPEG-2 will not be appropriate within the ITS industry. For example, in remote low bandwidth (1 T1 or lower) applications, either the emerging MPEG-4 standard or the ITU-T video conferencing H.261/H.263 series may be more acceptable.

### 3.1.1 Digital Video Networking

The telecommunications networking industry has been long at work developing different communications protocols that work well with various sorts of media. A primary example of such efforts is ATM networking, which was originally conceived to transport voice, data, and some video (albeit restricted amounts of video).

This development effort will likely intensify over the next decade as video services become increasingly important in applications from all industries. The eventual convergence to one specific protocol/platform (e.g. video over IP over ATM), however, is difficult to predict given the current supercharged pace of technological advances in the networking industry

Within the context of ITS networks today, the ongoing debates concerning network protocols appear to be justifiably converging on the SONET/SDH-based transport protocols. SONET/SDH offers two significant benefits over and above competing protocols. Firstly, it allows the DOT or public agency the ability to inter-network with large public telecom networks that already exist today. Secondly, and perhaps more importantly, the SONET/SDH standards can cost-effectively provide a constant yet programmable bandwidth link between a video camera by the roadside and a monitor back at the traffic control center in a typical traffic surveillance system. This constant bandwidth allocation allows for a high number of video signals to be transported over the SONET/SDH network with little degradation in quality. Even as future networking protocols emerge, SONET/SDH backbones are likely to continue dominating. This is because as a transport protocol, other networking protocols can be readily overlaid onto a SONET network (e.g., ATM over SONET), making it a flexible protocol to work with.

## 4 Barriers to the Widespread Deployment of Digital Video

In spite of the benefits described earlier to deploying digital video, there is one barrier that continues to inhibit its widespread deployment. That barrier is cost.

Many DOT agencies have explored digital video networking designs only to realize that the costs can be prohibitive to their deployment. Currently the price of deploying a digital video network (using compressed video) is two to three times higher than that of conventional broadband analog systems. Typical costs currently observed in the market along with projected costs longer term are shown in the table below.

**Table 2: End Customer Cost of Digital Video over time (24 channels)**

Terms (months)	Total Cost per Video Channel (US\$)	
	Digital Video	Analog Video
Current	US\$10,000 - US\$20,000	US\$3000 - US\$4000
Short (6 months)	US\$7000 - US\$8000	US\$2000 - US\$3000
Medium (6-18 months)	US\$5000 - US\$6000	US\$1500 - US\$2000
Long (18-36 months)	US\$4000 - US\$5000	US\$1000 - US\$1500

The primary contributor to the high cost of a digital solution is the network backbone equipment cost. High bandwidth SONET/SDH networking equipment is relatively expensive. Existing broadband analog video technology provides a cost-effective solution in comparison to digital solutions. As such, it is expected that digital and analog solutions will co-exist in the network over the next while with digital systems being deployed primarily in the backbone segment of the network, at least until the cost of digital video begins to match that of analog systems.

This “hybrid” approach to network architectures is nothing new in the world of networking. In fact, it makes optimal use of both broadband analog and digital technologies. This hybrid approach parallels the approach taken in the world of public telephony, where the access portion of a network (i.e., the link between your telephone and the Central Office or some other intermediary device) is analog while the backbone network is purely digital. That is, the digitization of real-world analog signals occurs cost-effectively at hub or concentration points in the network but not in the access portion of the network.

To illustrate the concept of a hybrid network, consider a network of 100 roadside video cameras. One approach might be to digitize all 100 video signals at the roadside, but this today would be expensive. In contrast, a more cost-effective approach would be to transport the 100-video signals back to the Traffic Control Center using common broadband analog technology. At the Traffic Control Center, only those signals that require conversion to a digital format would undergo digitization and compression. This approach minimizes the digital video compression equipment required, thereby reducing overall deployment costs for the DOT.

## **5 The Path Forward — Suggestions for a Graceful Migration to Digital Video**

In spite of some uncertainties relating to digital video technology, it is in the best interest of all concerned in the ITS community to make well-educated capital expenditure decisions that do not hinder the ongoing deployment of traffic surveillance systems. As such, there are several approaches to mitigating the risks associated with an evolving technology like digital video. Two of these are briefly outlined in the following sections.

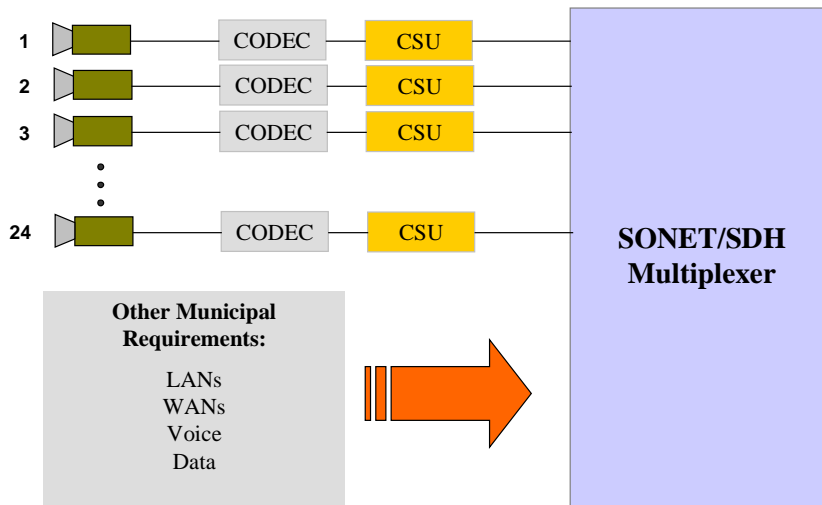
### ***5.1 Digitize Where Necessary***

Although it appears today that the industry is likely to move towards MPEG-2 as the digital compression scheme of choice, uncertainty remains as to what the exact flavor will be. For example, while MPEG-2 as it exists today is favored, the emerging MPEG-4 standard offers comparable quality with lower communications bandwidth requirements, making it perhaps an attractive alternative.

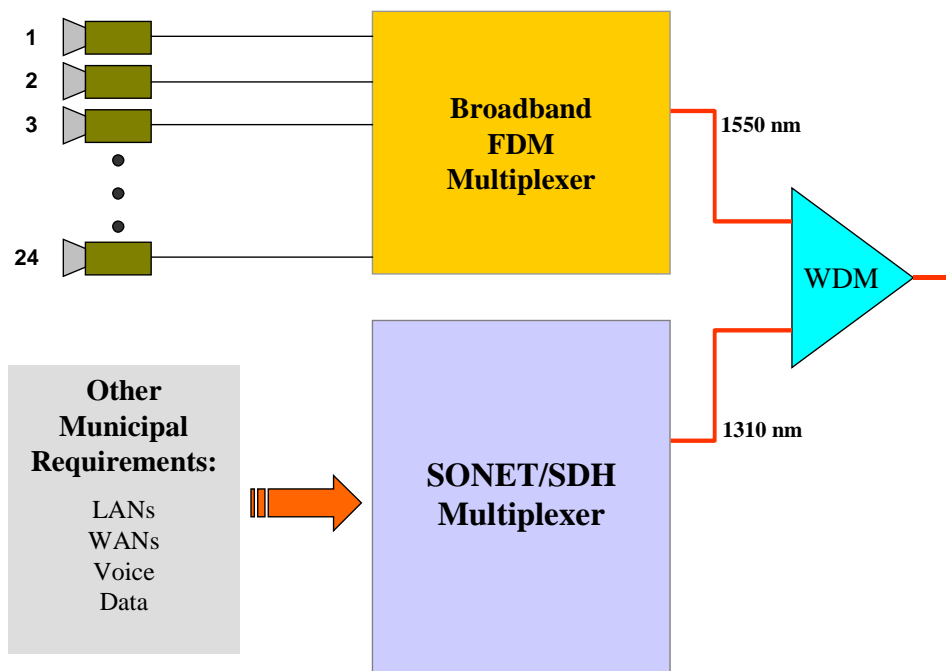
In the face of this uncertainty, an approach to deploying digital video technology today might be to selectively digitize the video signals only where necessary, using more economical, high-quality broadband analog technology to feed these critical points in the network. To illustrate consider the specific cost of two network solutions for a simplified traffic video surveillance network.

Assume that a simplified two-node SONET backbone network using two optical fibers is in place and being currently used to transport data traffic between government agencies. The data will typically include voice, low-speed data, and LAN/Ethernet data (for interconnecting various municipal and/or state LAN networks). The DOT may now decide that it would like to implement a video surveillance system with 24 CCTV cameras that it installed along an interstate highway.

Figures 1 and 2 below depict two competing methods of building the communications network required to achieve the video surveillance system. In Figure 1, the pure digital video solution is shown, with each of the 24 CCTV camera signals used as inputs into 24 corresponding video encoder modules (responsible for digitizing the video signals). The Channel Service Units (CSU) then provide a standard T1/DS1 interface with the existing SONET multiplexer node. A typical encoder today costs in the neighborhood of US\$5000 with a CSU costing about US\$1000. Hence the incremental cost of adding 24 channels of video for the encoding equipment would amount to US\$144,000. The additional cost of SONET T1 mapper card modules will drive this total cost to over US\$150,000. Note that corresponding decoding equipment will be required at the Traffic Control Center, doubling the overall incremental cost to US\$300,000.



**Figure 1.** A pure digital video solution with each of 24 CCTV cameras used as inputs into 24 corresponding video encoding modules.

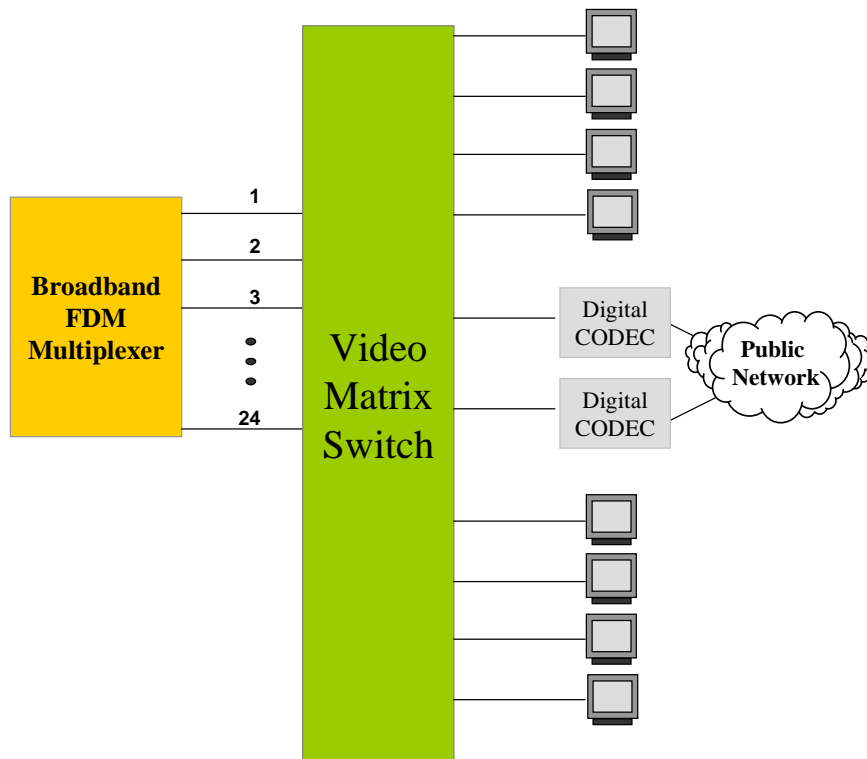


**Figure 2.** A hybrid solution in which 24 cameras, along with their PTZ control data information, feed into an integrated broadband FDM multiplexer, which is in turn wavelength division multiplexed with the SONET/SDH data network. This solution prevents the SONET/SDH data network from getting overwhelmed by the high bandwidth requirements of digital video.

In the broadband analog (i.e., Frequency Division Multiplexing, or FDM) solution illustrated in Figure 2, the 24 CCTV cameras feed into a broadband multiplexer that can typically integrate 16 to 24 channels of video. This integrated signal is then modulated onto either a 1310 nm or 1550 nm optical wavelength for transport over fiber. If the SONET node uses the 1310 nm wavelength, for example, then the network

interface on the broadband FDM multiplexer would use the 1550 nm wavelength. The network output signals of the SONET multiplexer and the broadband FDM multiplexer would then be integrated using an inexpensive, off-the-shelf wavelength division multiplexer (WDM). The total cost of the broadband FDM multiplexer and the WDM module amount to approximately US\$50,000; doubling the cost due to the same equipment requirements at the Traffic Control Center drives the overall incremental cost to US\$100,000. This contrasts sharply with the US\$300,000 required for the pure digital solution. The 200% cost differential is in spite of the typically superior quality video achieved with broadband FDM equipment.

In order to achieve a “best-of-both-worlds” scenario, a “hybrid” approach that digitizes only where necessary can be used. With this approach, the broadband FDM equipment of Figure 2 is used and complemented with a few encoders back at the Traffic Control Center. This approach is shown in Figure 3. Of the 24 video signals, only a few would be required at any given time in their digital format for distribution to other agencies or the public over standard telephone lines. The video matrix switch can be used to select the desired signal for “digitization”, as shown. This approach can be termed “*Digital-on-demand*”, and will invariably be the most cost-effective, risk-minimizing solution until a digital video compression standard emerges in ITS and the cost of digital video compression technology is substantially reduced.



**Figure 3.** The Traffic Control Center configuration has the video signals from the broadband FDM multiplexer feeding into the video matrix switch. The output of the matrix switch is directed to video monitors or digital encoding equipment when the output is intended for distribution to other agencies or the public over standard telephone lines (the Public Network).

## ***5.2 Use of Hybrid Digital/Analog Equipment***

Modular video communications equipment is becoming available today to offer network architects a graceful migration path from analog technology to digital technology as the latter becomes more cost effective. For example, DOT agencies today can install transmission equipment chassis in which low-cost, high-quality broadband analog video modules can be installed. These systems can co-exist with digital networks (like SONET) which are used to carry voice and data requirements. As the cost of equivalent digital video encoder/decoder equipment becomes cost effective, the DOT gradually replaces or complements the analog modules with digital video modules that pull in video signals from the field and dump them out through standard interfaces (e.g., T1) into the existing SONET backbone equipment. By using such equipment with this inherent hybrid capability, the DOT can gradually build a fully digital system without having to make anxious decisions to “fork-lift” out at a significant cost all of the existing broadband analog video systems at once.

## **6 Conclusions**

There are many compelling reasons for DOT officials to begin planning for digital video networking. These include interoperability with other public agencies and commercial customers seeking access to the video surveillance information on the DOT’s network. Another benefit is “future-proofing” the capital expenditure to ensure that dollars spent today are not wasted on technology that will be obsolete tomorrow.

In spite of the benefits, there are two barriers that impede the widespread deployment of digital video technology. The first of these is cost, as it will be several years before digital video networking is achievable at the same cost as existing broadband analog technology. Secondly, uncertainty concerning which specific technologies to deploy over the short term can hinder the decision-making process and progress in achieving functional ITS networks.

In order to ensure that the deployment of ITS systems continues without stagnating, there are prudent steps that can be taken to overcome these barriers. The first of these is procuring equipment with an inherent architecture that allows it to use either broadband analog technology or digital technology. In doing so, as the price of digital decreases over time, the DOT can gracefully migrate to digital video functionality with modular additions or changes to the equipment. The second approach is to limit the procurement of digital video technology over the short term to the Traffic Control Centers, by digitizing video only where necessary (i.e., where the video signals are required for transmission over leased lines, over the public telephone network, etc.).

## **7 Appendix A**

There are currently many different standards for digitizing (encoding and compressing) analog video signals for efficient transmission, storage, and playback. The current competing standards were originally designed specifically for various applications - from CD-ROM playback to still image compression to narrow band compression for video conferencing. However, these various application specific encoding techniques have or are being updated and enhanced in the hopes of being the dominant standard for digitizing video signals. To date, MPEG-2 seems to be the emerging winner in ITS due to influences of other industries which have accepted it as the standard (e.g. media and computing). However, there are niche applications that still require the other technologies.

The following are the digital video compression technologies that will be discussed in the subsequent sections:

- 1) MPEG (Motion Picture Experts Group) Family of standards
- 2) JPEG (Joint Photographic Experts Group)
- 3) ITU-T's Video Conferencing Set of Standards (specifically H.261 & H.263)
- 4) Other emerging compression technologies (e.g. Wavelet, and Fractal)

The descriptions of the various compression technologies are based on the available resources on the Internet.

### **7.1 MPEG**

The MPEG family of encoding standards began with MPEG-1 that was originally developed for CD-ROM video playback. As Compressed Digital Video developed, so did the MPEG standards. MPEG2 was developed for broadcast quality compressed video. The following are brief descriptions of the MPEG standards.

#### **7.1.1 MPEG 1**

MPEG-1 is used primarily for CD-ROM video playback. MPEG-1 (named for the Motion Picture Experts Group) uses the lossy compression techniques involved in JPEG with the addition of inter-frame motion prediction. CD-ROM drives require images to be highly compressed in order to approach real-time playback speeds. MPEG-1 compression ratio range up to 200:1, creating small consumer quality data files for compact storage and distribution. MPEG-1 supports data rates of 0.4-1.5 Megabits/second, so it can be transmitted through narrow bandwidth networks. MPEG-1 video resolution is limited to 1/4 of TV-resolution. Many MPEG-1 players use pixel replication to increase the displayed image size, but the resolution is not improved.

Interactivity was not a key design criteria with MPEG-1. In order to achieve fast playback at low cost, the standard is asymmetric, requiring much more compute power during compression than decompression. In fact, software playback of MPEG-1 can be accomplished with very fast processors. MPEG-1 has found its niche with one author, many viewer applications where the information is not very time-sensitive, image quality is not critical, and playback and distribution costs are a major factor. MPEG-1 uses Discrete Cosine Transforms (DCT) for compression.

#### **7.1.2 MPEG-2**

MPEG-2 was designed to build on the MPEG-1 standard and be used in high bandwidth applications such as satellite delivery. It delivers 60 field per second video at full CCIR 601 resolution. Therefore, MPEG-2 requires special high-bandwidth hardware for compression and playback.

Corporate markets accustomed to JPEG quality are looking to deploy distributed stored video applications. MPEG-1, with its low resolution and consumer quality, doesn't meet corporate standards, so companies are moving to MPEG-2. MPEG-2 has high resolution for corporate quality and requires data rates of 4-8 Megabits/second. Since infrastructure costs (like storage and network bandwidth) have fallen, these bandwidths are becoming available, encouraging multimedia applications.

### **7.1.3 MPEG-4**

Unlike in MPEG1 and MPEG2, where the scope and technology were quite well known when the project started, MPEG4 was born in a period of quickly changing conditions. These developments made it more difficult to have a clear view of MPEG4 scope. The current standard is still under development.

## **7.2 JPEG and Motion JPEG**

### **7.2.1 JPEG**

The Joint Photographic Experts Group for still image compression originally created the JPEG standard. JPEG combines lossless compression with optional lossy compression to provide excellent image quality with good compression ratios. Compression ratios range from 3:1 for a lossless still image to 100:1 for a lossy image.

JPEG was adopted for real-time video because there are no difficult motion prediction calculations. Compression and decompression times for JPEG are symmetrical, taking the same amount of compute power and time enabling real-time interactive applications. Consecutive JPEG images are captured and displayed at up to 30+ frames/second (full-motion). Since each frame is captured as a stand-alone entity, JPEG provides excellent frame integrity for frame-by-frame analysis and editing.

### **7.2.2 Motion JPEG**

Hardware products provide real-time JPEG compression and decompression of video images. In simple terms, M-JPEG treats a video stream as a series of still photos, compressing each individually with no interframe compression. JPEG processing can also be accomplished with software, but the intense computation is not real time and taxes even the fastest central processing units (CPUs) available today. With hardware compression and decompression, the CPU remains free to run application software.

JPEG's ability to do real-time data acquisition and distribution makes it ideal for time-sensitive corporate and government applications. JPEG supports corporate quality video over a network at data rates ranging from 1.5 to 12 Megabits per second.

JPEG's high quality, interactivity, versatility and stability as an industry standard make it very attractive as a foundation for a wide variety of video applications and products. Hardware JPEG users can rely on the same products for display, encoding, decoding and video conferencing, in contrast to single purpose MPEG encoders and decoders. However, M-JPEG itself is not standard-based and faces long term risk in its present incarnation because of a lack of interoperability between the products of different vendors.

## **7.3 ITU-T (H.261 & H.263)**

The ITU-T standards for video compression are primarily aimed at video conferencing applications.

### **7.3.1 H.261**

H.261 is a video encoding standard published by the ITU (International Telecom Union) in 1990. It was designed for data rates which are multiples of 64Kbit/s, and is sometimes called p x 64Kbit/s (p is in the

range 1-30). These data rates suit ISDN lines, for which this video codec was designed. Currently, H.261 is the most widely used international video compression standard for video telephony on ISDN telephone lines. The standard describes the video coding and decoding methods for the moving picture component of an audiovisual service at the rates of  $p \times 64$  Kbps where  $p$  is in the range of 1 to 30. The standard is most suitable for applications using circuit switched networks as their transmission channels. This is understandable as ISDN with both basic and primary rate access was the communication channel considered within the framework of the standard. H.261 is usually used in conjunction with other control and framing standards such as H.221, H.230, H.242, and H.230.

### **7.3.2 H.263**

H.263 is a provisional ITU-T standard designed for low bit rate communication. While early drafts specified data rates less than 64 Kbps, this limitation has since been removed. It is expected that the standard will be used for a wide range of bit rates, not just low bit rate applications.

H.263 is one of the better methods available today, when it comes to video compression efficiency. The coding algorithm of H.263 is similar to that used by H.261, however with some improvements and changes to improve performance and error recovery.

The following are some key features that H.263 offers over H.261:

- Half pixel precision is used for motion compensation whereas H.261 used full pixel precision and a loop filter.
- Some parts of the hierarchical structure of the data stream are now optional, so the codec can be configured for a lower data rate or better error recovery.
- There are now four optional negotiable options included to improve performance: Unrestricted Motion Vectors, Syntax-based arithmetic coding, Advance prediction, and forward and backward frame prediction similar to MPEG called P-B frames. When using the advanced negotiable options in H.263 one can often achieve the same quality as H.261 with less than half the number of bits.

## **7.4 Other Compression Technologies**

There are other compression technologies being developed to provide higher compression rates which do not use discrete cosine transform as the basis of their compression methodology. The following are two examples. Their base technology differences are significant and therefore will have little possibility of inter-networking with DCT based standards.

### **7.4.1 Fractal based Compression Technologies**

Fractal compression is based on the patented work of Dr. Michael Barnsley. Fractal compression offers the advantage of being resolution independent. In theory, one can scale up an image without loss of resolution.

Fractal image compression is based on the idea that any real-world world image contains affine redundancy, or self-similarity, and that this redundancy can be exploited to compress images. Fractal functions are self-repeating and may be used to express any repeating sequence or redundant or self-similar pattern. Fractal compression achieves its compression by representing blocks of video as mathematical (fractal) equations rather than a specific pattern in a look-up table. Fractal compression is highly asymmetric because determining the proper mathematical equation during encoding is very intensive. However, decoding is an image for display is very fast. There is significant promise in this technology but its adoption is still low.

### ***7.4.2 Wavelet based Compression Technologies***

Wavelets are mathematical functions that cut up data into different frequency components, and then study each component with a resolution matched to its scale. They have advantages over traditional Fourier or Discrete Cosine Transform methods in analyzing physical situations where the signal contains discontinuities and sharp spikes. Wavelets were developed independently in the fields of mathematics, quantum physics, electrical engineering, and seismic geology. Interchanges between these fields during the last ten years have led to many new wavelet applications such as image compression, turbulence, human vision, radar, and earthquake prediction.

The fundamental idea behind wavelets is to analyze according to scale. In short wavelet technology will compress images to preserve high frequency information (i.e. edges, fine detail, etc.) by using a lower level of compression, while compressing the lower frequency content to a greater degree. In more technical terms, wavelet analysis procedure adopts a wavelet prototype function, called an analyzing wavelet or mother wavelet. Temporal analysis is performed with a contracted, high frequency version of the prototype wavelet, while frequency analysis is performed with a dilated, low frequency version of the same wavelet. Because the original signal or function can be represented in terms of a wavelet expansion (using coefficients in a linear combination of the wavelet functions), data operations can be performed using just the corresponding wavelet coefficients. And if one further chooses the best wavelets adapted to one's data, or truncate the coefficients below a threshold, the data is sparsely represented. This sparse coding makes wavelets an excellent tool in the field of data compression. Wavelet compression is symmetric with quick compression and decompressions.