Optibase White Paper

Professional Digital Video Networking

Introduction

Rapid technological developments in wide area networking are greatly increasing the availability of broadcast quality digital video transmissions. The switch to high bandwidth digital networks that can support broadcast quality digital video is evident in the professional broadcasting industry and in the corporate sector. This paper will review the new networking technologies that enable digital video transmission. This paper will also review the various formats of digital video that are available and discuss what formats are most appropriate for wide area digital video networking.

Why do we need digital video transmission?

Mention the word video transmission and most people will say ‘TV’, but both in the consumer and corporate sectors, video is being transmitted for many purposes. At present, most video is still transmitted in analog format which is very expensive and therefore limited to specific purposes. The picture is changing with the marriage of computer networking and digital video. The existence of digital video and the broad availability of wide area networks has pushed the telecommunications, entertainment and business sectors to find solutions for transmitting digital video over existing networks. This in turn has opened up entire new applications for digital video networking.

Digital video networking can facilitate business interaction in ways, that until now, were not even considered. One example is in advertising. At present, clients reviewing rushes of TV advertisements have to physically go to the ad company or get a copy of the analog tape. This could be different if the ad company and its clients utilized existing communication networks. Instead of sending a copy of the analog tape to the client by courier, the ad company could send a digital video clip by email. This would save time and travelling expenses. By optimizing their computing infrastructure to transmit digital video, both company and client benefit.

Today, most of the development in digital video transmission is taking place in two different sectors:

- The professional broadcasting sector which includes national and regional TV operators, cable TV operators and video transport.
- The corporate sector which is at the forefront of delivering digital video to the workdesk.

Although very different in nature, these two sectors have something in common: they are both adopting new networking technologies which enable the delivery of broadcast quality digital TV.

The Broadcast TV Market

At present most national and local TV stations still broadcast in analog. The professional broadcasting industry is conservative about adopting new technology but there is growing interest in using existing networks to broadcast digital video. TV broadcasts can be divided into two stages: transporting the live signal from the event to the TV station and distributing the edited footage from the TV station to viewers’ homes. At present there is more activity and development in the first stage, that is, transporting the live signal from the event to the TV station.

Although there is also potential in distributing MPEG digital TV to viewers’ homes, this area is expected to take longer to develop since it requires consumer use of high bandwidth digital networks that are not yet prevalent in most places.

Digital Video Networking in the Corporate Sector

One of the fastest growing areas for digital video transmission is the corporate sector. Corporations use existing networks such as T1/E1, T3, microwave and satellite to transmit video among subsidiaries and regional branches. Corporations are also at the forefront of adopting newer networking technologies such as ATM.

Obstacles to Digital Video Networking

Although both the digital video and the communication infrastructure for transmitting it exist, there are some technological complications. These complications arise from the fact that existing communication networks have been optimized to carry voice and data, not video. The nature of video and the size of video files means that existing telecommunications networks have to meet specific requirements to transmit video successfully.

Video requires large, continuously flowing streams of data to successfully play back clear, moving pictures, and this causes problems.

Bottlenecks are another problem. Most networks are shared media, meaning that many users compete for available bandwidth. When a network becomes busy, all its traffic slows down. A few seconds delay in the delivery of a data packet is not crucial as long as the entire message comes through in one piece. With video, the opposite is true. Because video is time dependent, the broadcast will be distorted if the video transmission has to wait for other traffic to go through first.

Cost: The prices of leasing medium and high bandwidth lines has also been a major stumbling block to the wide implementation of digital video networking. However, it is a matter of time before digital video networking takes off. The market is being driven from two ends: from end users, who would like to enhance the use of their extensive data networks, and from vendors and developers, who are tackling the technical issues and looking for ways to add value to their networking products.

Video File Size: Current networks cannot carry raw digital video which is still too large to be manipulated. An uncompressed 24 bit color video, with 640 x 480 resolution, at 30 frames per second, would require a bandwidth of over 200 Mbps. The goal of digital compression is to massively reduce the amount of data required to store and transmit a digital video file, while retaining its original quality. The following pages of this paper will discuss various formats for compressing digital video.

Bandwidth: The many telecommunication networks available today offer varying bandwidths for carrying data. A regular phone line for example, has a bandwidth of 28.8 Kbits, while a T1 line carries 1.5 Mbit/s of data. The large size of video files means that relatively broad bandwidth networks are needed to transmit them. The size of a video file depends on the bit rate and compression method used. Thus there is a playoff between bandwidth and video quality. The section below discusses video compression formats in greater detail.

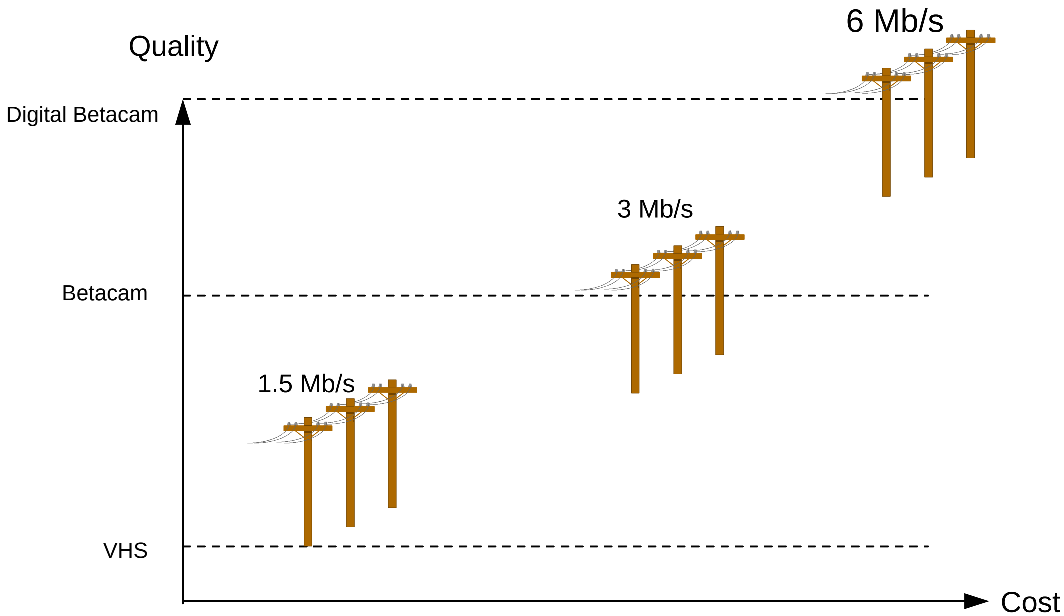
The Digital Video Equation

This section discusses the various types of digital video and reviews what kinds of digital video are most appropriate for different types of networks.

One way of approaching digital video is to view it as an equation made up of the following factors:

- Playback rate
- Storage capacity
- Quality
- Cost

These issues are closely interconnected since playback rates (or bandwidth limitations) affect the compression quality of video. The higher the bandwidth, the better the quality and broader the bandwidth capacity required for an hour of digital video. At the same time, the better the quality the higher the video transmission and production costs. For this reason, the cost of an application, to a large extent, dictates what quality of digital video it can afford. Using the correct digital video compression format can optimize the equation and thus contribute to the development of better digital video applications. An overview of digital video compression formats appears in the following section. The diagram below shows the relation between quality, bandwidth and cost.



The 150 KByte/Sec Threshold

The section below discusses the different compression formats in use today and applications that are limited to a playback rate of 150 Kbyte/s (1.2 Mbit/s).

There are several compression formats suited to this playback rate. The most well known are MPEG-1, Indeo usually used in AVI architecture and Cinepac usually used in Quicktime architecture.

Cinepac and Indeo are CODECs (compression/decompression) solutions that usually only compress 15 frames per second, half of the regular VHS playback rate which is 30 (NTSC) or 25 (PAL) frames per second. These CODECs suffer from other major disadvantages. They are not always real-time compression solutions. In addition, they are not cross-platform. These formats cannot be played back through set-top boxes for display on TV monitors. Because they are not cross-platform (can not play back across different components and systems from different manufacturers or service providers) their accessibility is limited. To sum, Cinepac and Indeo do not meet the quality standards of MPEG, nor are they as widely accepted across the computer and entertainment industry.

Why choose MPEG-1?

The decision to choose MPEG-1 compression over other formats depends on several factors. MPEG-1 is a digital video compression format that was defined by the Moving Pictures Experts Groups which is part of the International Standards Organization. MPEG-1 was defined by industry leaders to provide the best quality at playback rates of up to 150 Kbytes/sec. MPEG-1 compresses full screen full motion NTSC or PAL (30 or 25 frames per seconds). Because it offers better quality, MPEG is suitable for a far broader range of applications than software only compression formats. Most important, MPEG-1 is cross platform.

One of the most important advantages of MPEG-1 is the fact that it is an official ISO standard. This means that MPEG digital video is cross platform, i.e., it can play back across different components and systems from different manufacturers or service providers. MPEG-1 can be played back on TV monitors, video-CD players, CD-i players, CD-ROM drives and PCs. Thus it is the best digital video format for the home and business environment. MPEG is to digital video what VHS is to analog video: the standard that symbolizes broad industry, acceptance, high quality and interoperability.

The High Speed Digital Video Domain

In the previous section we discussed digital video that is limited to a playback rate of 150 Kbytes/sec (~ 1.2 Mbit/s). This section will discuss applications that are not limited by bandwidth and which therefore do not need to sacrifice quality to bandwidth limitations. Because these applications require higher bandwidths and better quality, they are more expensive to produce.

Following the successful adoption of MPEG-1, the Moving Pictures Expert Group decided to extend the range of applications for digital video distribution by defining a standard that would determine compression rates for broader bandwidths. As was mentioned previously, MPEG-1 was designed to provide a video compression solution for applications that are limited by bandwidths. MPEG-2, on the other hand, provides a compression solution for applications that are not limited by bandwidths (3 to 15 Mbit/s). Such a broad compression range means that it is not necessary to sacrifice quality to compression rate limitations.

Because digital video applications are versatile, MPEG-2 is being used as a generic standard with specific definitions (called profiles) for specific groups of applications. The MPEG-2 Main Profile was defined to support digital video transmissions at 3 to 15 Mbit/s over cable, satellite and other broadcast channels. This profile also refers to digital storage media.

MPEG-2 Technicalities

Resolution

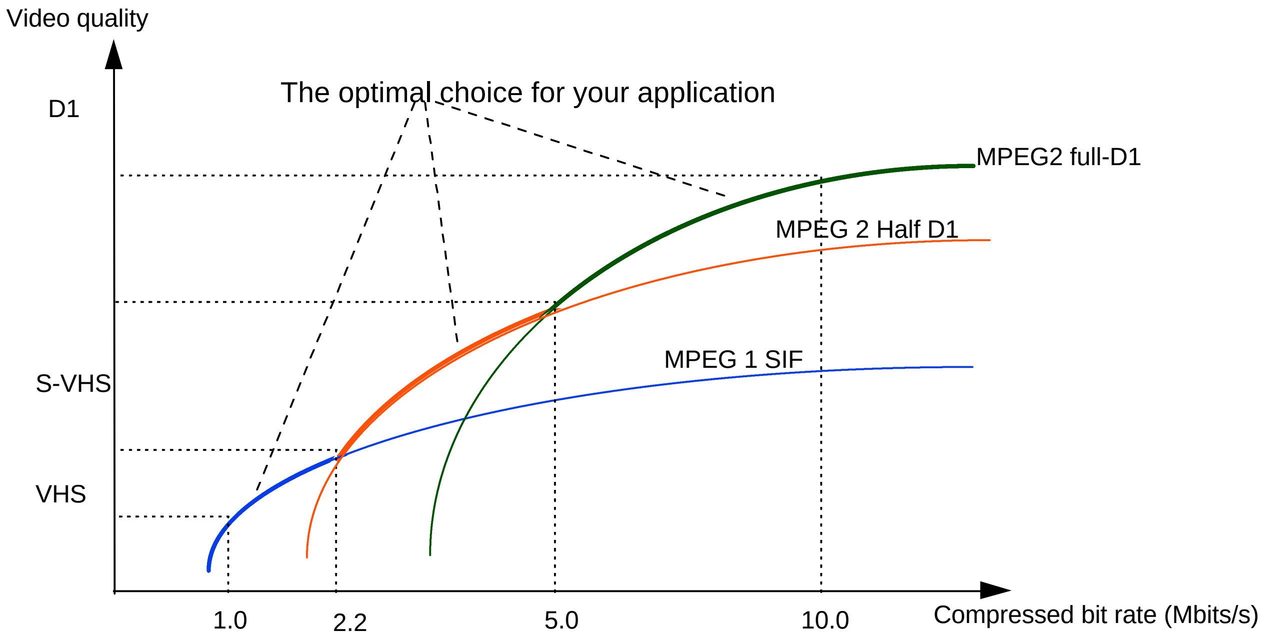
The MPEG standard is a total digital video solution because it optimizes the digital video equation. It allows application developers to create customized trade-offs between playback rate, quality, storage capacity and cost. The input resolution of a digital video stream directly affects compression quality. The section below discusses MPEG input resolutions.

The international recommended digital representation of a CCIR 601 video signal is known as D-1. This recommendation refers to a resolution of 720 x 576 pixels (PAL), (NTSC - 720x480). The MPEG-2 standard recommends that the input resolution of the signal before compression be D-1. Thus no image information is lost before compression. This input is used for high-end digital video applications such as satellite broadcasting networks where quality plays a prominent role in the digital video equation. Other factors such as bandwidth limitation and cost are less significant.

The recommended input resolution for MPEG-1 is SIF which is one quarter of D-1. This means that only one quarter of the original image is compressed. SIF resolution is used in applications such as video games and video kiosks where the dominant production factor is wide distribution and cost.

Another input resolution, covered by the MPEG-2 standard is Half D-1, which is half of the original D-1 source. Although a Half D-1 input resolution means that only half the image is compressed, the loss in quality is barely detectable to the average viewer. Half D-1 compression creates greater flexibility in the video equation. Based on cost and quality needs, content developers can choose between MPEG-1, MPEG-2 Half D-1 or MPEG-2 D-1. An example of this kind of trade off is evident in a survey funded by 4 industry leaders (Pacific Telesis Video Services, AT&T, Bell Atlantic Video Services and NYNEX) who want to set up an interactive television service. Results of the survey found that consumers far preferred MPEG-1 and MPEG-2 to VHS. MPEG-2 Half D-1 video delivered at 3.0 Mbit/s was chosen as the best quality. This bit rate was subsequently adopted as the encoding standard for movies.

The diagram on the following page illustrates the correlation between input resolution, bandwidth, compression rate and video quality.



Setting up a digital video network

Companies can rely on private or public networks. A private network consists of a dedicated line that is leased from the phone company and switching equipment that directs traffic between sites. Another kind of private network is based on microwave or satellite links. These networks are provided by companies that specialize in this type of service.

The feasibility of leasing a private line from a telecommunication company depends on budget, transmission requirements and the distance between sites. Some of the things that need to be taken into consideration are:

- Distance: the longer a link the more expensive it is to lease.

- Data volume: transmitting low volumes of data is usually not cost effective.

Leased lines are used to carry voice, video and data. Companies can also lease lines at a set time every month for a specific purpose such as transmitting the CEO’s speech to regionally dispersed company departments.

There are also private lines such as microwave or satellite links. These types of networks are installed by private companies that specialize in providing these services.

Telecommunication companies can be contacted to discuss the specific requirements needed to transmit video over leased lines. These telcos will be able to provide advice about what kind of line is appropriate, peripheral equipment needed as well as the costs involved.

Network Types

Selecting the digital format for your video will probably be based on your available transmission bandwidth. This section discusses the networks that can be used to transmit digital video. These networks have different bandwidths and therefore are suitable for various applications, depending on video quality requirements and budget restraints.

T1 and E1 Lines

A T1 service is a framed communication protocol that delivers a two-way connection at 1.544 Mbit/s each way. In Europe and other countries outside the U.S., the equivalent of T1 is a service called E1 - a two way connection at 2.048 Mbit/s. T1 and E1 define the physical, electrical and framing requirements of the interface. Therefore the actual transmission media is irrelevant and can be different types of lines such as microwave, optic fiber or copper wire.

Are T1/E1 links prevalent?

T1/E1 links are very prevalent. Historically, phone companies developed the T1 protocol to accommodate high volume voice communications. Today T1/E1 lines constitute a major part of phone companies' networks. Because phone companies invested heavily in T1 networks they are in a position to offer leased T1 lines to corporations and other users.

Where are they located?

The largest and most flexible T1 networks are offered by the public telephone companies (PTTs). Depending on the geographical region involved, one or more telephone companies may preside over a T1 link from the point of origin to the destination. Because of their broad acceptance, T1/E1 lines are also available on other links and networks such as microwave.

What kind of T1/E1 lines are offered by the PTTs?

Most T1/E1 lines provided by PTTs are dedicated T1/E1 lines or lead lines which give customers permanent access to a specific destination through the network. Recently, a new T1/E1 service called Switched T1 was introduced. Switched T1 allows users to switch their destination as needed. Fractional T1/E1 services are also available. These allow users to purchase only a portion of the T1/E1 line that they need. Fractional T1/E1 and Switched T1/E1 services are not as widely prevalent as dedicated T1/E1 services.

What are they used for?

Historically T1 lines were commonly used to transmit voice data. Today, with the existence of sophisticated computerized infrastructures, phone companies use T1/E1 lines to transmit all types of digital data.

Are T1 lines suitable for video transmissions?

T1 lines are good for video transmission because they can carry 1.544 Mbits of data per second. E1 has a bandwidth of 2.048 Mbit. These are sufficient to transmit quality MPEG-1 video. The T1/E1 protocol is defined as constant delay transmission. This means that data is delivered at specific time intervals, a pre-condition for transmitting video on any network. Another reason T1/E1 is good for transmitting video is the fact that there is no mis-sequencing. This means that all data packets are delivered in the correct order.

Companies that want to exchange video data can take advantage of already existing T1 networks without having to incur vast expenditures for specialized video networks. Because T1 lines have a bandwidth of 1.544 Mbits, companies that lease a T1 line and dedicate it to video transmissions can broadcast high quality MPEG-1 digital video at cost efficient prices.

Additional T1/E1 information is available at the WWW's T1 Committee site at http://www.t1.org/

ATM (Asynchronous Transfer Mode)

ATM is a data transmission technology standard suitable for LANs and WANs. ATM supports high speed transmission rates of all kinds of data. Using optic fiber networks, like SONET (Synchronous Optical Network) data distribution over ATM can reach up to 622 Mbit/s. One of the biggest advantages of ATM is that it covers the local and wide area. The technology takes voice and video data, breaks it up into 53-byte cells, and transmits them over high-speed circuits. Intelligent end equipment takes care of putting the data together again.

ATM is suited to real time transmission because of its high bandwidth, its fixed packet transmission method and the ability to dedicate a specific bandwidth to an application. ATM does not specify a particular physical transmission media and therefore supports many different existing protocols through circuit emulation. In the LAN environment, LAN emulation is a popular way to access ATM networks. In LAN emulation, the client is still connected as a standard LAN while the backbone technology is ATM.

Industry experts are endorsing the SONET as the physical transport media for LANs and WANs. The ATM Forum is proposing FDDI (100Mbit/s), Fiber Channel (155 Mbit/s), OC3 SONET (155 Mbit/s) and T3 or E3 (45 Mbit/s). At present most telecoms offer T3 connections. High bandwidth ATM transmission will become prevalent when optic fiber networks are installed and become widely available.

ATM Basics

ATM networks operate in a similar way to frame relay networks. Subscribers select access and port speeds and a sustained information rate (SIR). For example, subscriber traffic can enter an ATM network at 45 Mbit/s with an SIR of 10 Mbit/s. The traffic is guaranteed to travel through the network at 10 Mbit/s but can burst up to 45 Mbit/s when network capacity is available. By definition, ATM delivers six types of service:

- Class A (or CBR) transports traffic that requires low and stable delay, such as voice. Because ATM is a shared service, T3-speed ATM circuits cost less than their leased-line counterparts.

- Class B is a connection oriented service which is timed for transmitting variable bit rate voice and video.

- Class C (VBR) transmits bursty data generated at irregular intervals. For this reason it is unsuitable for voice or video which needs a continuous connection.

- Class D transmits variable rate data that does not require timing relationships between end nodes. This kind of transmission is suited to LAN traffic.

- Class Y is an ABR (available bit rate) service that allows end-users to tell the network how much bandwidth and what type of service they need for any given transmission. The network will confirm or deny the request. ABR services are appropriate for sporadic non-critical traffic whose bandwidth requirements change from one transmission to the next.

- Class X is a UBR (unspecified bit rate) service that offers no bandwidth or delivery guarantees. This low-cost option is ideal for low-priority traffic.

History

ATM was first defined as part of the Broad-ISDN network by the Consultative Committee for International Telegraph and Telephone (CCIT) in 1988. B-ISDN is an extension of ISDN which defines public digital telecommunication networks. Since 1991, the ATM Forum has been meeting to discuss ATM interaction with public WANs and private LANs.

ATM deployment in Wide Area Networks (WANs) will be slow in coming to the size and complexity of these publicly provided networks. At present, ATM networks are more prevalent in the LAN environment. Companies with high bandwidth or multimedia requirements are looking at ATM as a possible solution. Although ATM takes up only a fraction of the total LAN market, this technology is expected to grow in the near future.

Are they good for video transmission?

Yes. ATM is a very good technology for video transmission because of its high bandwidth, its fixed packet transmission method and the ability to dedicate a specific bandwidth to an application.

Additional information is available on the WWW’s ATM forum at: http://www.atmforum.com/

ISDN (Integrated Services Digital Network)

ISDN is an all digital transmission technology that integrates data, voice and video signals. ISDN is innovative in that it delivers the speed, reliability and flexibility of a digital signal to the home or office. The main differences between ISDN and T1/E1 is that ISDN is a switched service with pay-as-you-go rates, unlike a dedicated T1/E1 line. Also, in ISDN, signalling is done on a separate channel so that more bandwidth is available for data transfer.

ISDN uses time division multiplexing (TDM) to divide the available bandwidth into a number of fixed-size time slots called channels. In ISDN, the local loop (the data link between the customer and the local exchange) consists of several logical channels. There are two basic types of channels for ISDN: B and D.

The B Channel: The B channel (bearer channel) carries digital data, as well as digitized voice and video information. The B channel, which operates at a data rate of 64 kbps, can be used for both circuit-switched and packet-switched applications.

The Delta Channel: The Delta channel (signalling channel) provides signalling and control for each ISDN line installed. Because signalling messages over the Delta channel rarely uses all its available bandwidth, the Delta channel can sometimes be used to carry data. When the Delta channel does carry data, signalling messages always have priority. The Delta channel carries 16 kbps.

There are three main types of ISDN services available:

- ISDN Basic Access, also known as ISDN2, 2B+D or ISDN BRI.
- ISDN Primary access, also known as ISDN30, 30B+D or ISDN PRI.
- Multiple Rate Interface (MRI): MRI consists of multiple 128 Kbit/s B channels and one 16 Kbit/s D channel-more than four times faster than a 28.8-kbit/s modem.

ISDN Basic Access:

The ISDN Basic Access service is carried from the telephone exchange along a traditional twisted pair copper cable. The B Access service is usually presented as two wires with an RJ-45 interface. This single pair of wires carries two Bearer (B) channels and one Delta (D) channel. These three channels make up an ISDN basic rate line. The B channels carry communication at a rate of 64 kbit/s. The D channel carries all the control information to the digital exchange including dial up information. So passing back and forward along your single ISDN Basic Access line are two 64 kbit/s B channel data streams and one 16 kbit/s D channel data stream. The only restriction with ISDN Basic Access is the distance between the local telephone exchange and subscriber, which is limited to 5.5 kilometres.

ISDN Primary Access:

ISDN Primary Access uses a single coaxial or fibre optic cable to carry all the data. ISDN Primary Access is usually presented as a 4-wire trunk circuit that connects the customer's equipment (such as an ISDN bridge/router) to the local exchange. The PRI presentation is usually DSX-1 in the U.S., and 75-ohm G.703 (BNC) or 120-ohm G.703 (RJ-45) in other parts of the world.

The ISDN Primary Access line carries 30 64 kbit/s B channels and one 16 kbit/s D channel. This allows 1.544 (T1) or 2.048 Mbit/s (E1) of data to be transferred along a single cable in either direction. ISDN Primary Access is used mainly to connect private telephone switchboards (PABX's) to the public digital telephone network. It can also be configured as an ISDN6 line which offers significant savings over three separate ISDN Basic Access lines.

Connecting between a PC and the ISDN line

The ISDN standard defines several different types of devices that can be connected to the network, as well as the interfaces between devices. Each interface, called a reference point, requires a communications protocol. Because ISDN was originally developed for telephony applications, networking equipment such as an ISDN bridge/router does not easily fit these definitions.

Terminal Equipment Types

End-user devices such as digital or analog telephones, X.25 DTEs, or bridge/routers are called terminal equipment. There are two types of terminal equipment.

- Devices that use ISDN protocols and directly support ISDN. These services are called Terminal Equipment Type 1 (TE1).

- Non-ISDN devices. These are called Terminal Equipment Type 2 (TE2), and require a terminal adapter (TA) and software that controls the TA so that it can communicate with the ISDN network.

For example, a bridge/ router with a standard synchronous serial line interface is a TE2, while a bridge/ router with a Basic Rate Interface is a TE1.

Network Termination Types

There are also two types of network terminations. Network Termination Type 1 (NT1) is a network termination device which is usually the local carrier's network termination unit at the customer's site. This is the device to which all networking equipment is connected. The NT1 terminates the physical connection between the customer site and the local exchange and connects the four-wire customer wiring to the conventional two-wire local loop. The NT1's responsibilities include: line performance monitoring, timing, physical signalling protocol conversion, power transfer, and multiplexing the B and D channels.

Network Termination Type 2 (NT2) equipment provides customer site switching, multiplexing, and concentration of multiple ISDN lines. The NT2 is a more intelligent piece of equipment and can include voice and data switching devices such as PBXs. NT1 and NT2 devices may be combined into a single physical device called NT12. This device handles the physical, data link and network layer functions.

ISDN Reference Points

ISDN reference points specify the communication between different devices in the ISDN infrastructure. ISDN defines four protocol reference points: R, S ,T, and U. Each reference point uses a different protocol.

- The R reference point is located between non-ISDN terminal equipment (TE2) and a terminal adapter (TA). There are no specific standards for the R reference point. The TA manufacturer will specify how the TE2 and TA communicate with each other. Usually, this protocol is either RS-232 or V.35.

- The S reference point is located between the ISDN user equipment (TE1 or TA) and the network termination equipment (NT1 or NT2).

- The T reference point is located between the customer site switching equipment (NT2) and the local loop termination (NT1).

- The U reference point is located between the NT1 and the local exchange. This protocol is defined by the ISDN provider.

Protocols

Many networking equipment companies use the Point-to-Point Protocol (PPP) protocol. The PPP is a standard data link protocol that enables compatibility between different manufacturers' networking equipment. PPP is actually a whole set of specifications that cover different aspects of WAN communication, such as data integrity, bandwidth and security.

Are ISDN lines prevalent?

In most countries, there is broad access to ISDN services at attractive prices.

Who runs them?

ISDN lines are offered by telecommunication companies.

Are they good for MPEG video transmission?

ISDN transmission uses circuit switching. This means that connections are dedicated for the duration of a call and there is very little delay on the line. (The other transmission method is packet switching where data is divided into packets and switched over the public network or LAN. Packet switching is not suitable for video transmissions because packets can be delayed or dropped when the network gets congested. This can corrupt video data.)

PRI ISDN which has a bandwidth of 1.5 Mbit/s or 2 Mbit/s can be used to transmit MPEG-1 SIF and QSIF video. It is also possible to use an inverse multiplexer to split up a high speed video stream and transmit it over several BRI lines. PRI is attractive because it allows dial-up access to any site with a PRI connection. A main benefit of ISDN is that it can be used simultaneously for voice, data, and video.

Additional information about ISDN is available on the WWW at: http://199.103.128.206/isdn/

Microwave

A Microwave link is a transmission link that does not require any physical media for transportation. A microwave link consists of two antennas that beam electromagnetic waves directly at each other. The antennas require line of site paths. The maximum range of one microwave link is 90km. A much longer range can be attained by placing several antennas that have a line of site between them. Microwave links broadcast frequencies ranging from 2-25 gigahertz. Microwave links are an alternative to copper or optical cable systems. They are relatively easy to set up with equipment supplied by private transmission service companies. Depending on the country, it is usually necessary to apply to the telecommunications authority for a transmission frequency. Microwave links are cheaper than physical cable links because they bypass traditional transmission service providers and they are relatively inexpensive to install. They can carry between 8 and 34 Mbps.

Are they prevalent?

In Europe and the US microwave licenses are easily obtained and very widely used.

Who runs them?

Microwave links are privately owned. The equipment needed to install a microwave link can be bought by companies that specialize in microwave links. In order to use a specific microwave bandwidth, it is usually necessary to receive a licence or permission from the ministry of telecommunications.

Are they good for MPEG video transmissions?

Microwave bandwidth is very suitable for high quality MPEG-2 digital video. They are privately owned and therefore can be controlled totally by the service provider. Microwave transmissions are constant delay and therefore deliver video data in one stream.

Satellite

Satellite systems transmit signals from earth based tranceivers (transmitter/receiver) to space satellites. Ground stations antennas aimed at the satellite transmit hundreds of multiplexed channels to and from the satellite. Satellite transmissions are single to multi-point transmissions, that is, the signal is beamed from one to many points. Satellites are used for phone, television and data transmissions. When transmitting over satellite, users pay for the bandwidth used. Satellite is widely available but expensive. The advantage of digital video is that more digital channels than analog channels can be transmitted over a single link.

Satellite is particularly well-suited for data that's graphics-heavy. It's also more cost-effective than T1 for running business applications involving weekly or daily downloads of large files.

ADSL (Asymmetrical Digital Subscriber Line)

Asymmetric Digital Subscriber Line (ADSL), a new modem technology, converts existing twisted-pair telephone lines into access paths for multimedia and high speed data communications. The acronym ADSL, refers to ADSL modems and ADSL lines. ADSL modems are located on either end of a twisted-pair copper line, usually a telephone line, that provides asymmetric (one-way) transmission of data, up to 8 Mbps downstream (to the customer) and up to 800 kbps upstream, depending upon line length and the capabilities of the particular modem.

ADSL modems supply three separate frequency channels over the same line:

- One channel carries telephone conversations.
- The second carries a 16- to 640-kbit/s data signal upstream from a user to the Internet.
- The third channel is a high-speed downstream connection running anywhere from T1 (1.544 Mbit/s) to 8 Mbit/s.

ADSL also provides for a 16 - 64 Kbit/s data channel for data and menu signals in the opposite direction. ADSL is used mainly to proved high speed links to consumer homes over existing telephone lines for multimedia and internet access. To upgrade to ADSL, telecom operators need to install ADSL equipment at both the the subscriber and the central offices.

Some ADSL modems offer a minimum configuration of 1.5 or 2.0 Mbps in one direction a 16 kbps duplex channel. Others provide rates of 6.1 Mbps and 64 kbps duplex. Data rates depend on a number of factors, including the length of the copper line, its wire gauge, the presence of bridged taps, and cross-coupled interference.

ADSL lines are good for video transmissions because of their broad bandwidth and because they incorporate forward error correction that dramatically reduces errors caused by impulse noise. Error correction on a symbol by symbol basis also reduces errors caused by continuous in a line.

ADSL Technology

To create multiple channels, ADSL modems use two methods to divide the available bandwidth of a telephone line: Frequency Division Multiplexing (FDM) or Echo Cancellation.

- FDM assigns one band for upstream data and another band for downstream data. The downstream path is divided by time division multiplexing into one or more high speed channels and one or more low speed channels. The upstream path is also multiplexed into corresponding low speed channels.
- In Echo Cancellation, the upstream band overlaps the downstream band. The two are separated by means of local echo cancellation.

An ADSL modem prepares the data stream for transmission by multiplexing downstream channels, duplex channels, and maintenance channels together into blocks. An error correction code is attached to each block. The receiver then corrects errors that occur during transmission up to the limits implied by the code and the block length.

Availablitiy

ADSL technology is relatively new and services therefore are not widely available. ADSL modems have been tested successfully by about 30 telephone companies, and hundreds of lines have been installed in various technology trials in North America and Europe. Several telephone companies plan market trials using ADSL for video on demand, personal shopping, interactive games, and educational programming.

Additional information about ADSL is available on the WWW’s ADSL Forum at: http://www.adsl.com/

The table below shows various types of networks, their bandwidth limitations and the MPEG resolution most appropriate.

Distribution Media	Bandwidth Limitation	MPEG-1	MPEG-2 Half D-1	MPEG-2 Full D-1
ISDN	2.048 Mbit/s	✓	✗	✗
E1	2.048 Mbit/s	✓	✗	✗
T1	1.544 Mbit/s	✓	✗	✗
ADSL	8 Mbit/s	✓	✓	✓
Ethernet (multi-channel)	10 Mbit/s	✓	✗	✗
Microwave	32 Mbit/s	✓	✓	✓
ATM (multi-channel)	155 Mbit/s	✓	✓	✓
Satellite Broadcasts (multi-channel)	No practical limit	✓	✓	✓

Digital Video Networking Applications

Below are some applications that realize the advantages of digital video networking.

- **Remote Security Monitoring:** Digital video networking enables the transmission of more than one video stream from a remote site to a control room. In the control room, an operator monitors the incoming video stream. Depending on the content, the video can be stored to hard disk for later review or not.

- **Satellite entertainment networks**: broadcasting compressed digital programming contributes to transponder cost savings and the ability to provide separate programming and advertising feeds as well as better quality.

- **Distance Learning:** Distance learning is developing rapidly, especially on university campuses and in peripheral areas where digital video courses are broadcast to remote areas.

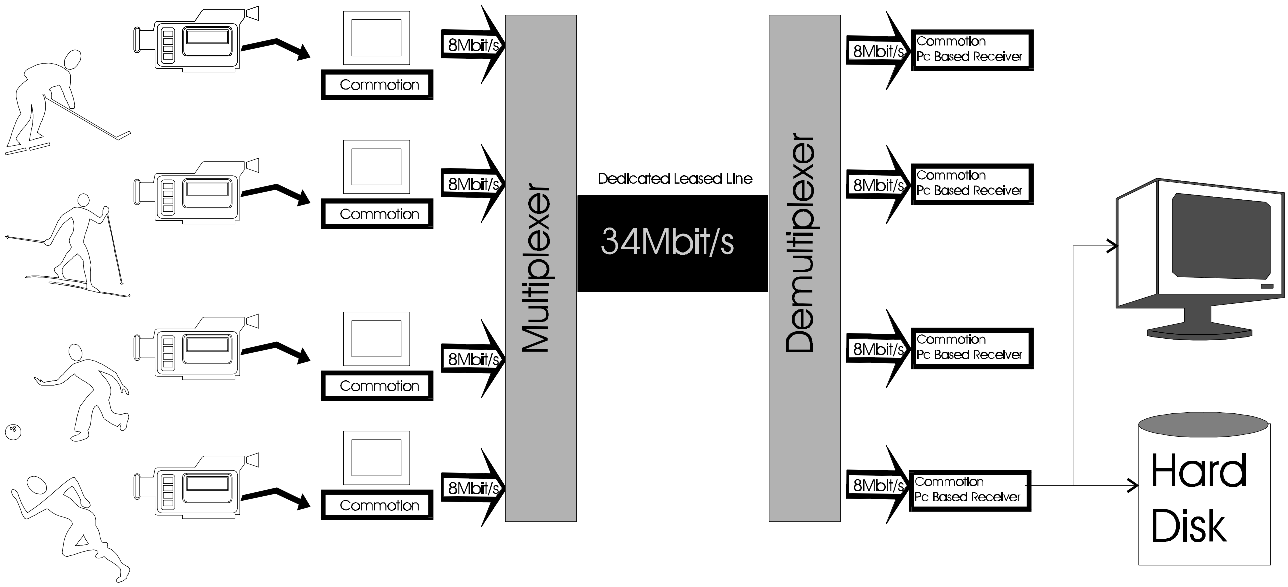
- **Video Archiving**: Digital video archives vastly improve the ability to access video material rapidly. Digital files are stored on a central video server. Multiple users can access video files based on keywords or dates and view them at their desktops. As opposed to analog video archives, the quality of archived digital video does not deteriorate. Rapid retrieval of video material on a network is especially important in advertising companies, TV stations and production houses.

- **News on Demand**: Digital video programming is distributed to individual work stations from a single central feed.

- **Cable TV**: A digital cable TV channel can broadcast between six and eight channels as opposed to only three for regular analog channels. Digital ad insertion systems which retrieve and broadcast video files from a central video server are replacing vast mechanical systems made up of dozens of VCR machines that are fed by mechanical arm.

- **Video Transport**: Transporting digital video video from point A to point B is becoming more popular as a means of transmitting several live feeds from multiple points to a service provider who edits the footage and broadcasts it to viewers' homes.

The following diagram illustrates live digital video transport from point A to B. At one end, four sports events are recorded. The live feeds are encoded to MPEG-2 and then multiplexed to one signal. The signal is transmitted via satellite or microwave to the receiving end. At the receiving end, the signal is demultiplexed and decoded to its original analog form. At this point the video signals will be edited, stored to tape or distributed to viewers' homes.



Conclusion

As this paper shows, there is a growing convergence between computers and telecommunications. In the past, new services introduced by the telecoms were technology driven. Today, as PCs and software become more sophisticated, the pressure for better and faster services is coming from the computer world. This pressure means that new and experimental transmission technologies such as ATM and ADSL will become more widely available and cost effective.