Video Communication Networks

Introduction:

Paul Baran from the RAND Corporation first proposed the notion of a distributed communication network in 1964. His aim was to develop a decentralized communication system that could survive the impact of a nuclear attack. This proposal employed a new approach to data communication based on packet switching.

Construction of a communication network based on packet switching was initiated by the Department of Defense through the Advanced Research Projects Agency (ARPA). This agency commissioned the ARPANET, later known as the Internet, in 1969.

Internet 2 is an independent project coordinated by academic institutions whose goal is to accelerate the development of the Internet. This goal is addressed by deploying advanced network applications and technologies. Much of the effort of Internet 2 members has focused on the Abilene network. Abilene is a high-performance backbone network formed by partnership between Internet 2 and industry in 1999. Initially, Abilene provided communication at OC-48 (2.5 Gbps). Currently, the Abilene backbone has been upgraded to OC-192 (10 Mbps).

Improvements in communication networks' infrastructure are aimed at improving data communications and expanding applications. Efforts are underway to increase the communication bandwidth and support real-time services such as audio and video communications. The tremendous bandwidth required by video communications makes it among the most challenging of the applications envisioned in the next generation networks.

In the future, video communication networks will be used for a variety of applications including digital television, video streaming, video-on-demand, and video conferencing. An illustration of video communication services is depicted in Fig. 1. In this chapter, we will explore the current techniques used for video communications over data networks.

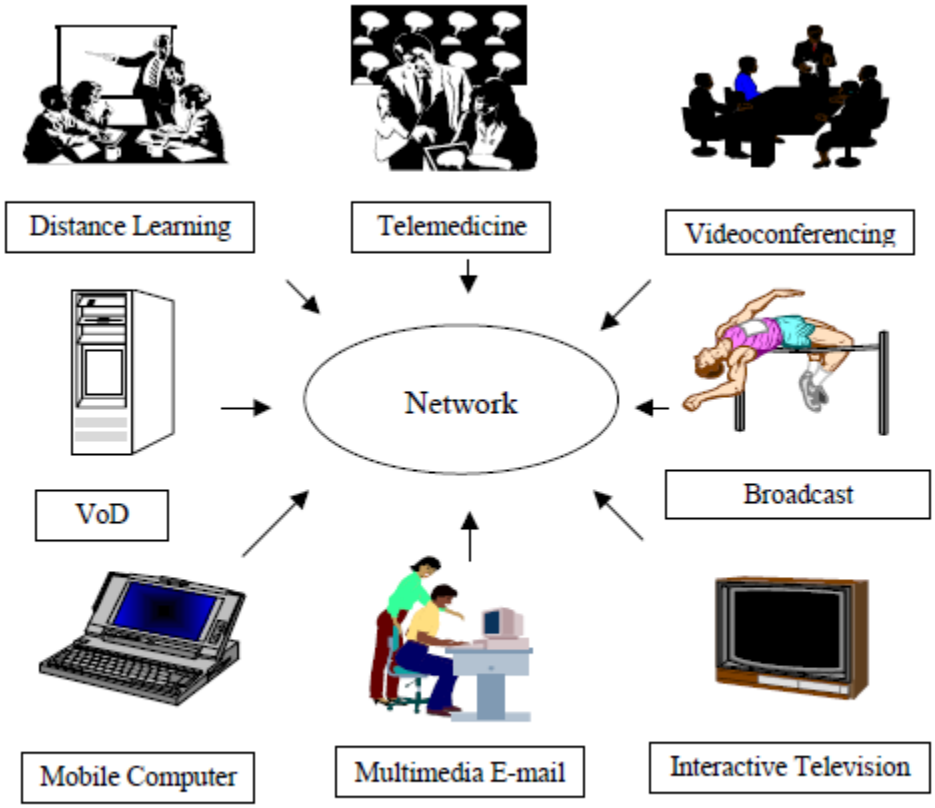

Figure 1: Video Communication Services

Briefly Explanations of Video Communication Networks

A wide array of communication networks has proliferated over the past few decades. The goal of many communication networks is to provide as much communication bandwidth as possible while controlling the infrastructure costs. Efforts to provide inexpensive communication mediums have focused on exploiting the infrastructure of existing communication systems.

For example, the hybrid of fiber optics and coaxial cable used in the cable television system has been adapted for data communications. Similarly, the web of copper wiring used in the telephone system has also been utilized for digital transmission. Moreover, the traditional use of 'air' as a conduit in wireless systems- radio and television, cellular telephony, etc.-has recently been extended to accommodate high-bandwidth data communications.

Some applications require high-bandwidth communication networks that do not compromise transmission quality to reduce infrastructure costs. Examples of applications that impose severe bandwidth demands are communication backbones for wide and metropolitan area networks. On occasion, high volume traffic in local area networks will also require a high-bandwidth communication infrastructure. Communication networks that need extremely high-bandwidth generally rely on fiber optics as the communication medium. A common deployment of high-bandwidth communication networks is based on Asynchronous Transfer Mode (ATM) networks. ATM networks are extremely fast networks that are usually, although not necessarily, implemented using fiber optics. In some networks, ATM provides a protocol stack that characterizes the entire communication network. In most instances, however, ATM serves to represent the lower- level layers in a communication network such as the Internet.

A general design philosophy adopted is to provide very high-bandwidth communication for the networks' backbone and exploit existing infrastructure to connect individual users. This methodology is rooted in economics: the investment costs in installation of a powerful backbone will serve all customers and can be easily recovered. Deployment costs of high-bandwidth communication lines to each individual user, on the other hand, are excessive and therefore avoided. Indeed, tremendously powerful

communication backbones have been implemented in the past few decades and are continuously evolving. Practically, one of the main difficulties presented today is the local distribution problem: how to efficiently connect individual customers to the communication networks' backbone? This problem is also colloquially referred to as the "the last mile problem." Various solutions have been proposed by the cable television, telephone, and wireless industries. Cable television and wireless communication systems are inherently broadcast systems which may pose some limitations for many communication network applications. Telephone systems are based on point-to-point communications which may be exploited for linking the backbone to customers' homes.

In this section, an overview of some of the main communication networks and their utility for multimedia communication applications is presented. The cable television network-known as the Hybrid Fiber-Coax (HFC) network-is discussed in Section 1.1. Adaptation of wireline telephone networks to computer networking through the Digital Subscriber Loop (DSL) protocol is presented in Section 1.2. The evolution of various wireless networks to high-bandwidth communication applications is sketched in Section 1.3. The widest bandwidth communication conduit is provided by fiber optics which are discussed in Section 1.4. A brief presentation of digital communications based on Integrated Services Digital Networks (ISDN) is provided in Section 1.5. Finally, the use of Asynchronous Transfer Mode (ATM) networks for multimedia communications is discussed in Section 1.6. For brevity, this presentation will be restricted exclusively to video communications based on the MPEG-2 compression standard.

1.1 Hybrid Fiber-Coax Networks (HFC)

Cable television providers have installed an extensive communication network for delivery of television channels to the home. The main communication conduit used by the cable television industry is the coaxial cable. Coaxial cables are usually deployed between homes and a central point known as an optical node. Several optical nodes are connected via optical fibers to a head end. The cable television network is thus a mixture of both fiber optics and coaxial cable known as a Hybrid Fiber Coax (HFC) network.

Communication networks deployed over existing cable television systems must accommodate both data communications and television broadcasting. Cable television systems rely on the unused frequency in the 5-42 MHz band for upstream channels. Normal cable television channels in the 54-550 MHz region are maintained. Downstream channels are allocated in the frequency range available above 550 MHz.[11]

In reality, however, existing cable television systems cannot afford to devote 50 channels exclusively to a limited number of customers not exceeding 500 homes. Most current cable television providers do not guarantee data communication rates above 700 Kbps. At these rates, video communications using the MPEG-2 compression standard could not be conducted.

1.2 Digital Subscriber Loop (DSL)

A long tradition has evolved in an effort to use the public switched telephone network (PSTN) for data communications.12 The main advantage of PSTN is that it is widely accessible to virtually all homes. Modem technology for dial-up service over PSTN have improved and can reach rates of up to 56 Kbps. A communication standard-H.324-has been developed for multimedia communications over PSTN. Video communications, however, requires much wider bandwidth using most compression standards.

1.3 Wireless Networks

Historically, wireless networks date to ancient civilization. Fire signals were used for messaging between hilltops. Modern wireless communications dates back to the Italian physicist Gugliemo Marconi who, in 1901, used a wireless telegraph with Morse code to establish communication to a ship.

Another form of wireless networks is provided by satellite communications. Video broadcasting over satellites has been conducted for many years. Both analog and digital video broadcasting have been used over satellite networks. More recent efforts have attempted to use satellites for real-time video communications. Limited success of this endeavor is due to the large number of satellites that are required to be launched into low orbit in order to reduce the communication delay.

1.4 Fiber Optics

There are two main methods provided by the telephone industry for local distribution using fiber optics: Fiber To The Curb (FTTC) and Fiber To The Home (FTTH). FTTC requires the installation of optical fibers from the end office to central locations such as residential neighborhoods. These central locations are equipped with a device known as an Optical Network Unit (ONU). The ONU is the termination point of multiple copper local loops connected within the immediate vicinity. The local loops between users and the ONU are sufficiently short that it is now possible to provide much higher communication bandwidth. For example, full-duplex T1 or T2 communication networks can be run over the copper wires for transmission of MPEG-2 video channels.

1.5 Integrated Services Digital Network (ISDN)

The Integrated Services Digital Network (ISDN) is the first public digital network. It was designed to support a large variety of date types including data, voice, and video. It is based on circuit-switched syn-

chronous communication. ISDN uses B channels for basic traffic and D channels for return signaling. Each B channel provides data rate of 64 Kbps and each D channel is 16 Kbps. Multiples of B channels are used to accommodate p □□64 Kbps. The Basic Rate Interface (BRI) provides 2B+D channel which can be used for signal delivery at the rate of 128 Kbps. At this level, high-quality video communication cannot be supported. Wider bandwidth communications based on ISDN is available by using the Primary Rate Interface (PRI). PRI communications can rely on up to 24 B channels for transmission at rates of 1.5 Mbps.20 H.320 provides a communication system standard for audiovisual conferencing over ISDN. The vast majority of video conferencing and video telephony systems currently used rely on H.320.

1.6 ATM Networks

Asynchronous Transfer Mode (ATM), also known as cell relay, is a method for information transmission in small fixed-size packets called cells based on asynchronous time-division multiplexing. ATM technology was proposed as the underlying foundation for the Broadband Integrated Services Digital Network (B-ISDN). B-ISDN is an ambitious very high data rate network that will replace the existing telephone system and all specialized networks with a single integrated network for information transfer applications such as video on demand (VoD), broadcast television, and multimedia communication. These lofty goals not withstanding, ATM technology has found an important niche in providing the bandwidth required for the interconnection of existing local area networks (LAN); e.g.Ethernet.