What's New in Computers

Video-on-Demand

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This article presents an introduction to multimedia and describes one of its popular applications, video-on-demand.

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What is Multimedia?

Traditionally, information services have been available to us in different ways. Educational material such as books, journals and newspapers are publishcd and delivered mainly in printed form. Entertainment through television and radio broadcasts is produced and delivered primarily in analog form. Both these domains have undergone radical changes in recent years due to advances in computing and communication technologies. Innovations in digital signal processing, mass storage, and optical communication networks have enabled the integration of diverse types of media such as text, audio, video and graphics to be utilized in digital form. This integration is commonly referred to as *multimedia.* A system with the capability to capture, digitize, compress, store, retrieve, decompress and present multimedia information is called a *multimedia system. Figure 1* illustrates the main functional blocks of a simple multimedia system. Examples of multimedia systems include distance learning, home shopping, video-on-demand, video conferencing and information kiosks.

Characteristics of Multimedia

Media such as audio and video are called *continuous media,* because they consist of a sequence of media units (audio samples or video frames) that make sense only when presented in the same time sequence in which they were recorded. The design of information services to support continuous media differs significantly from services that allow only textual or numerical

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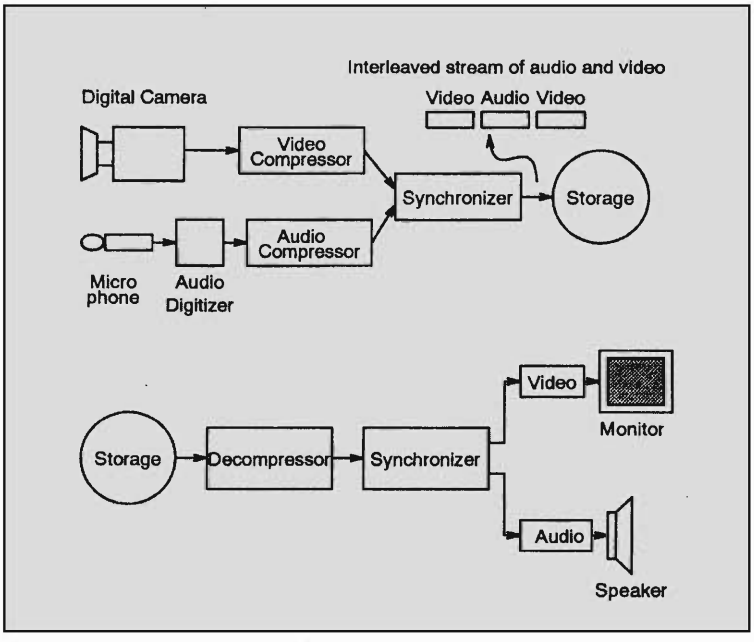

Figure 1 Capabilities of a multimedia system.

data, due to three fundamental characteristics of continuous media:

- *Storage and retrieval of continuous media are real-time operations.* Media capture devices (digital cameras and audio digitizers) generate a continuous stream of media units that must be stored in real time. During retrieval, the units of a continuous media stream are presented in the same time sequence in which they were captured. Any deviations from the timing sequence might result in perceptible glitches in audio and video presentations.

In spite of the stringent real time constraints and large storage and communication bandwidth requirements, multimedia applications are gaining popularity day by day.

- *Related media streams have to be temporally coordinated.* Several applications require the synchronization of more than one type of medium at the time of presentation. For example, a movie presentation requires the audio and video streams to be synchronized. This is also known as *lip synchronization.*

- *Continuous media have very high data transfer rates and large*

storage space requirements. Uncompressed digital audio and video have very high transfer rates and require large storage space. For example, the data rate for CD-ROM quality audio is 1.4 mega bits per second (Mbps; mega = 10^6). Several compression schemes have been developed to reduce the data size for the purposes of storage and transmission. MPEG (Motion Picture Experts Group) is an example of an international standard for digital video and audio compression.

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What is Video-On-Demand?

The conventional mode of operation of television and cable television is the *broadcast* mode. In this mode, viewers have little flexibility in

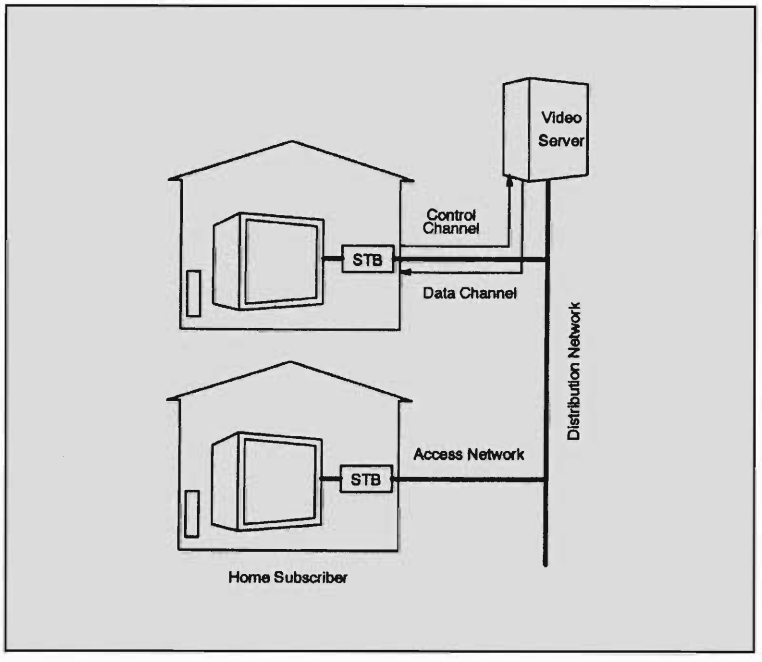
- Selecting programs (limited by the number of channels available),
- Scheduling the viewing time of programs, and
- Controlling the programs they view (viewers cannot skip parts of a program they find boring).

In contrast, an *on-demand* service provides its subscribers the ultimate flexibility in selecting programs when they wish, besides interactive control functions such as pause, resume, fast-forward, and rewind. The video rental service is in some sense an on-demand service. The electronic equivalent of the video rental service, that provides its subscribers on-demand access to a large collection of videos stored in high capacity servers over a broadband network is called a *video-on-demand* (VOD) system. Today's technology permits operators of telecommunication networks

Video Compression

The basic principle in audio and video compression is the elimination of redundant information. For example, in video, large portions of a scene remain unchanged from frame to frame. Video compression schemes exploit this fact by storing the differences (i.e., changes in positions of objects in a scene) between similar frames instead of the frames themselves. The more similar fhe frames the more compact the result. The maximum compression possible by MPEG-1 is about 200:1, but 50:1 is more typical. Newer compression methods have produced nearly 500:1 compression of video.

Figure 2 Components of a VOD system.



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(traditional telephone and cable TV operators) to provide a VOD service at a price competitive with the video rental service, without the need for the customer to travel.

Elements of a VOD System

Figure 2 illustrates the major elements of a VOD system. The three main components are: a video storage server, a network subsystem and customer premises equipment.

Video server: The video server consists of the storage and control required to store a large number of videos in compressed format and play back on request. It differs from traditional file servers in that it has to perform a number of functions such as

- *supporting continuous media storage and retrieval* – multimedia data is read or written by the server as a continuous stream of media blocks.
- *admission control* – the server checks if it has enough space and bandwidth to accommodate a new user session.

- *real-time request handling* – the server must ensure that each read or write request is completed within a time limit (request deadline).
- *guaranteed stream transmission* – to maintain a continuous display at the user's end, the server must transmit data at a steady rate.
- *stream encryption* – data streams transmitted over the network are scrambled or encrypted to prevent unauthorized access to the VOD service.
- *access control functions* – permits viewers to skip or replay portions of programs they watch.

A video server's functions are highly demanding in terms of storage space and transfer rate. For example, a two hour, MPEG-2 compressed movie (at an average transfer rate of 3 mega bits per second (Mbps)) requires 2.7 giga bytes (GB) (giga = 10^9) of storage. To store 500 such movies a video server would need 1.35 tera bytes (TB) (tera = 10^{12}) of storage. Because of these huge storage requirements, a video server is usually constructed as a hierarchy of storage media that includes semiconductor memory, secondary storage devices such as hard disks and tertiary storage devices such as optical jukeboxes. Of these the hard disks and optical jukeboxes form the bulk of the storage system. The easy availability of high performance hard disks permits the construction of large video servers based on an array of disks.

Space requirement

Assuming a data rate of 3 mega bits per second for TV quality video, the space required to store a one hour programme is $3 * 10^6 * 60 * 60 = 1.08 * 10^{10}$ bits; which is a lot of investment in terms of storage space.

In the normal mode of operation, admission control is done at the start of each customer session to determine if a new request can be serviced by the available resources in the system. If the new customer is admitted, media blocks of the requested video are retrieved from the storage system, temporarily buffered in memory and transmitted to the customer over the network. To guarantee uninterrupted playback the server must allocate storage bandwidth, buffer space and processing bandwidth.

Network subsystem: The network subsystem provides the interconnection of the various network elements in a VOD

system. Broadband networks enable video servers to communicate with the *set-top box* (STB) in the subscriber's home. These networks are *asymmetrical* in nature, with high bandwidth capacity from the video server to the set-top box (the downstream or data channel) and lower bandwidth for signalling from the set-top box to the video server (the upstream or control channel). Typically the bandwidth downstream is 1.5 Mbps (for one MPEG-1 stream) and upstream is 1.5 Kbps per user session.

Distribution networks carry video streams from the video servers to distribution points or head-end equipment by using a high speed transmission scheme such as *asynchronous transfer mode* (ATM) or synchronous optical network (SONET) which can provide output rates reaching 2.5 GBps. Access networks transport video from the head-end to set-top boxes by one of several alternative architectures: asymmetric digital subscribers loop (ADSL), hybrid fiber coax (HFC), or fiber in the loop (FITL). HFC is currently the popular architecture for the access network.

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The network's greater downstream bandwidth carries compressed audio and video streams, while the lower upstream channel carries the control signals from users to the video server. In addition, there are bi-directional control channels between the video server and the distribution and access networks to establish user sessions and reserve bandwidth for the downstream. The network ensures the real-time delivery of video streams at a constant rate (*isochronous* mode of operation), and the synchronization of related audio and video streams at the destination.

Customer Premises Equipment: The customer premises equipment consists of a set-top box (STB), a television monitor and a remote control. The STB is the bridge between the subscriber's display devices, peripherals, and input devices (such as a hand held infrared remote controller) and a communication channel in the access network. The channel connects the STB to

video or other information providers. The STB receives the incoming signal, demodulates it to recover the compressed digital video stream, decodes the stream and finally converts it to analog form and presents it to a TV monitor. The STB also has hardware blocks for remote control management, creation of necessary user interaction menus on the monitor and the sending of control information to the video server. Security and encryption are two other functions of an STB that prevent unauthorized access to services and ensure that subscribers are fairly charged. Future STB's might include a *personality module* that stores the subscriber's viewing profile, searches for and locates information that matches the subscriber's interests and schedules presentations at the subscriber's preferred viewing times.

Current technology trends indicate that by the turn of this century, what we see today as computer, television and telephone will all be wrapped into a single unit called a *teleputer*.

Basic Operation of a VOD Session

A typical VOD session consists of the following steps:

- *Connection establishment.* Initially, the set-top box is connected to a service gateway in the access network. From the gateway the user receives a list of accessible service operators.
- *Service selection.* The user selects a service operator from the list and the STB signals the selection to the gateway, which in turn selects the corresponding video server.
- *Path set-up.* Using the routing information in the service gateway, a path (downstream channel) is set up between the video server and the STB.
- *Program selection.* Once a video server is connected to the STB, a list of programmes offered by the server is downloaded to the STB. The browsing is done locally at the STB and requires no interactivity with the server. The user browses through the list and communicates his/her request to the video server via signalling.
- *User admission.* The video server on receiving the request determines if the new user can be serviced with the available resources. If sufficient bandwidth and storage capacity are avail-

VOD trial sites

One of Europe's largest trial systems began operation this January at Stuttgart, Germany and hopes to reach 4000 household and business subscribers. In the US, trial systems have been in operation for nearly a year now in Orlando, Omaha, Redmond, Fairfax County and San Jose. In England, VOD trials are underway in Colchester and Cambridge.

able, the server starts transmitting the requested programme through appropriate actions in the network. Otherwise, the user request is queued up or cancelled.

- *Interactive program viewing.* The STB receives the programme from the network, decodes it and presents it to the viewer. Depending on the degree of interactivity supported by the video server and STB, the viewer can do some or all control functions such as pause, resume, fast-forward and rewind.
- *Session close.* The end of session is signalled by the STB to the video server, and resources allocated in the server and network are released.

Conclusion

Digitization of diverse types of media such as text, audio, video and graphics has led to the development of a wide range of highly interactive multimedia services. The high level of interactivity is the key to the success of these services, in spite of the fact that multimedia data have unusually large storage space and communication bandwidth requirements. Adding interactivity to conventional broadcast television provides otherwise passive viewers the flexibility to choose programmes that match their interests and view them at times they wish. Present day computing and communication facilities allow interactive television services to be offered on a large scale and there are already several trial systems in operation in the US and Europe. Current technology trends indicate that by the turn of this century, what we see today as computer, television and telephone will all be wrapped into a single unit called a *teleputer*.

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Suggested Reading

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