EXHIBIT 2

A store-and-forward architecture for video-on-demand service

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Abstract
A store-and-forward architecture is presented that can provide video-on-demand (VOD) as well as other database distribution services. It assumes a B-ISDN network to be in place. The four major elements in this architecture are the information warehouse (IWH), where video material is archived; the central office (CO) server, which contains a processor responsible for service management and a video buffer that interacts directly with network customers; and the customer premise equipment. A requested video program is provided in a real-time fashion from the CO server to the customer. At the information warehouse the video program is retrieved from the archival storage in blocks, and with transfer rates much faster than real-time. Subsequently, it is sent in a bursty mode to the CO servers via high speed trunks

Index Terms
Available to subscribers and IEEE members.

References
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Citing Documents
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A STORE-AND-FORWARD ARCHITECTURE FOR VIDEO-ON-DEMAND SERVICE

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Abstract

This paper presents a store-and-forward architecture that can provide video-on-demand (VOD), as well as other data-base distribution services. It assumes a B-ISDN network to be in place. The four major elements in this architecture are the Information Warehouse (IWH) where video material is archived; the central office (CO) server which contains a processor responsible for the service management, and a video buffer that interacts directly with network customers; and finally the customer premise equipment. A requested video program is provided in a real-time fashion from the CO server to the customer. However, at the information warehouse, the video program is retrieved from the archival storage in blocks, and with transfer rates much faster than real-time. Subsequently, it is sent in a bursty mode to the CO servers via high speed trunks.

1. INTRODUCTION

With the emergence of B-ISDN, large information networking bandwidths would become available to the end-user population. We expect that this bandwidth availability will lead to the creation and deployment of broadband information services from a variety of information providers. Video-On-Demand appears to be an important representative of such future services because of the increasing popularity of customer choice in entertainment offerings (e.g., video rental stores).

As evidenced by the success of present voice information-providing services (such as those associated with the dialing codes 900, 976, etc.), it is advantageous, to both customers and information providers, to have a "partnership" with the network providers. The local telephone companies for instance, today provide the billing function as well as the distribution functions for these information providers. This includes CO allocation, switching, line hunting, etc. Similarly, local cable TV companies, while supplying customers with programs from a variety of providers, handle the information packaging, transport and billing.

Given that video in one form or another is the most bandwidth consuming medium, its contribution to the total network traffic will be significant. Also, due to the variety of possible end-to-end services, users and information service vendors will benefit from information navigational aids and service administration. Therefore it is prudent to design video distribution schemes that rely on a vendor/network partnership. This implies that some additional functions beyond transport may have to be allocated to the network to achieve overall service efficiency and economy. Among these could be information kiosk functions and billing, facilitation and support of the retrieval process and of the scheduling of information delivery, broadcasting and multicasting, user control features support, and help for the end-user in information presentation management.

In this paper we present an architecture for the distribution of information. The primary application for this architecture is Video-On-Demand service. However, it can support other, customer-specific, information services, for instance: various data-base material retrieval services, electronic magazines, educational programs, etc. This architecture also supports multicast and broadcast services.

The basis for this architecture is *Information Vendor/Network* cooperation in video distribution and a *Store-And-Forward* technique employed by an ATM/SONET public network.

The advantages of the proposed video distribution architecture reside in the possibilities to optimize the service by better management of the information retrieval and network traffic. It also allows improvement in the information vendor's and the network's resource sharing.

Section 2 deals with service scenarios. In section 3 we describe the system architecture. Sections 4-6 provide greater detail on the architectural components: the Customer Premise Equipment (CPE), the Information Storage, and the Network.

2. SERVICE SCENARIOS

The deployment of an infrastructure for B-ISDN services provides the opportunity for offering additional video services beyond simple broadcasting of a limited number of entertainment programs. One of the most popular, and

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well documented, proposed offerings is that of Video-On Demand (VOD) services, [1-6]. In this paper we consider three grades of VOD service:

1) **Pay-per-view** (PPV) service in which customers can "tune in" to scheduled pre-determined programs. Those subscribers who choose a particular program will receive it by way of broadcasting, meaning that the subscriber has no control (PLAY, STOP, REWIND, etc.) of the program.

2) **Quasi-VOD** service in which customers are grouped by requests and receive service after some delay. For some quasi-on-demand scenarios, only those programs that reach a threshold level of requests are broadcast by the service provider, [5].

3) **True-VOD** service. This grade of service is equivalent, in terms of user control, to the VCR playback of rental programs. The subscriber is provided with play, pause, fast forward/reverse, and search modes. The advantages of this service over the VCR-like service are numerous. There is no need to pick up or return video tapes, selection variety and availability are significantly improved, and the service charge could be related to actual viewing time, rather than just per program. In addition, the program material available would likely be much broader in scope. It could include movies, instructional material, short programs like: "video hits", tele-shopping, educational programs, encyclopedia entries, etc. Some of these offerings could be of an interactive nature as well.

Most of the discussion in this paper concerns the True-VOD service since it is the most general and most demanding. However, the proposed service architecture is applicable to all service grades, and furthermore, the resource sharing advantages are more dramatic for the broadcast-oriented offerings.

3. STORE-AND-FORWARD SERVICE ARCHITECTURE

Fig.1 illustrates the overall service architecture for supporting the VOD service.

The components of the architecture are Information Warehouses (IWH), Central Office (CO) service circuits, and the customer premise equipment. The Information Warehouses are geographically distributed entities responsible for long, and medium-term information storage. They are also capable of dispensing information in parts, or in total, via high speed dedicated lines that connect them to the network central offices.

Video and other information programs owned by vendors are stored in IWHs using various storage media: optical, magnetic, and electronic, and with a hirarchy of access mechanisms: non-random access for archival material, video juke-boxes for medium speed access, magnetic disk drives for on-line popular material, etc. The information is stored digitally, in a compressed form.

An uncompressed NTSC video program, digitized at a rate of about 100 Mb/s, would take nearly 100 Gigabytes of storage for two hours worth of material. The same material compressed to the 1.5 Mb/s rate requires only 1.5 Gigabytes storage capacity. Since information vendors will have to store large amounts of material, and in view of the

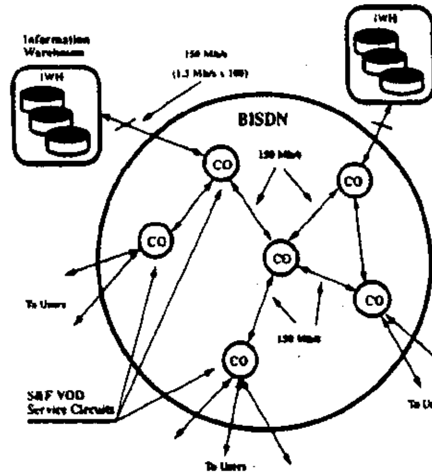

Fig.1. Video-On-Demand: Service Architecture

latest developments in video coding algorithms at rates around 1-2 Mb/s, we assume that the source material is stored in a compressed form, tailored to the DS-1 (1.544 Mb/s) rate.

Other than for the addition of the IWH, Fig.1 represent a typical Local Access and Transport Area (LATA) network in a B-ISDN environment. For the VOD service, subscribers place requests with their local CO via user interfaces, using an upstream control channel. In turn, the CO places a request with an appropriate IWH.

The IWHs are connected to the network via high capacity STS-3 (155 Mb/s) or STS-12 (622 Mb/s) lines. Therefore, the information trunking between the IWH and the customer's CO can be done faster than real-time (i.e. 1.5 Mb/s), and the requested programs can be delivered in segments. In order to take full advantage of this "speed-up" factor, the transfer rate of the stored material to the network should be equal to the network transmission rate, i.e. around 150 Mb/s. The retrieval of the video segments is managed by an ambassador service processor IWH-SP. The ambassador processor, while possibly being located on the vendor's premise, cooperates with the network and possesses relevant knowledge of the network state. This knowledge allows the processor to effectively schedule the information transport to requesting CO's, taking into consideration the time budget of each request and the traffic conditions in different parts of the network.

At the user's local CO, the information is buffered, the data-rate is then converted to the video coding rate (i.e. DS-1), and then possibly decoded to the original video signal form (e.g. analog). The video signal is then transported to the user in the form which corresponds to the local access switching and transmission parameters and the user's CPE capabilities. In this paper we assume that all users posess terminal equipment which accepts either compressed or non-compressed signals. The DS-1 video decoder may therefore be located at the CPE or be a part of a service circuit pool at the CO. In either case, the matching of video rates would be done at the CO and the channel from the CO to the subscriber is real-time.

This architecture takes advantage of the high transfer rates of currently available, and future, storage systems and of high-speed trunks, to provide the rate speed-up and consequently vendor and network resource sharing through time-multiplexing. The store-and-forward mechanism, by being more general than a real-time transfer system, allows alternative (to real time) information delivery schemes. Thus, better utilization of the network resources and improvement in the overall service economics are among the advantages of this architecture. The flexibility of the proposed technique allows one to employ, if necessary, higher layer protocols for error and/or cell loss control. By distributing the complexity of the supporting hardware and software infrastructure, the reliability of the service can be improved.

For PPV and Quasi-VOD service scenarios, only a single copy of the material has to be delivered to the CO, buffered, and then broadcast, or replayed to customers with different starting times.

The next three sections describe, in more detail, the components of this proposed architecture starting from the user's end, then the information service provider equipment, and finally the network which bridges between them.

4. CUSTOMER PREMISE EQUIPMENT

The Customer Premise Equipment (CPE) for the proposed Video-On-Demand service is depicted in Fig.2.

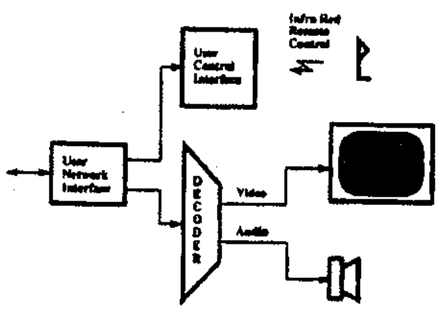

Fig.2 Video-On-Demand Customer Premise Equipment

The customer's downstream signal includes the DS-1 video signal, whereas the upstream signal contains the low speed control information. The decoder shown in the figure as part of the CPE may alternatively reside in the Central Office and be part of a shared resource pool. In that configuration the downstream video signal may be transmitted to the User Network Interface (UNI) in various formats (analog, STS-1, etc.) depending on the loop architecture and the CPE.

Users are able to browse through information menus and control the material presentation with functionality similar to the control of a VCR or a disk player.

5. INFORMATION WAREHOUSE

An architectural block diagram of the proposed information warehouse is shown in Fig.3.

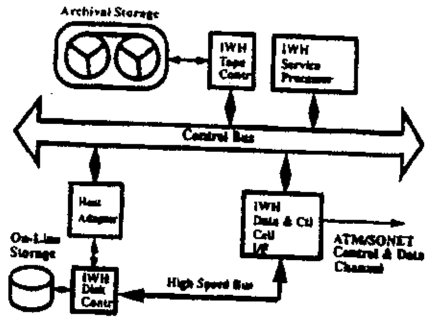

Fig.3 Information Warehouse Architecture

The on-line data is moved from the archival medium to the fast access storage medium, magnetic disks, for example. Control messages are communicated from the CO to the IWH-SP via the ATM/SONET interface, and the control bus. The data is retrieved via a high speed bus and transmitted through the network at rates exceeding the real time rate by approximately a hundred times. It is possible to provide a data rate throttling mechanizm by changing the ATM cell rate at the ATM/SONET interface. This is realized by the IWH Processor under the command of the vendor's serving CO.

Video programs are encoded from source material into a digital compressed format and recorded for archival purposes on a mass storage medium. The encoding procedure consists of various operations on the original sequence of images, or frames, so as to reduce the information rate required to transmit these frames. The video compression technique assumed in this paper is based on standardization activity of the Moving Picture Experts Group (MPEG) which has produced recommendations for video coding at rates around 1-2 Mb/s [7]. This scheme is designed for VCR-like picture quality. The audio information is multiplexed into the DS-1 stream and is separated in the decoder. According to this standard, the encoded bit-stream contains groups of frames that start with an intraframe coded frame, where only spatial redundancies are treated for bit-rate reduction, and then a sequence of predicted and interpolated frames, where both spatial and temporal compensation are used for a higher level of compression. Under the MPEG standard the number of coded frames in a group of frames may be variable. For the purpose of fine granularity in the random access, for example, each group of frames can represent half a second of video i.e. consist of 15 frames, starting with the intraframe information and followed by a sequence of interpolated and predicted frames. To reconstruct the original video signal, groups frames must be accessed sequencially. However, some operations (e.g. forward and reverse searches) can be implemented by retreiving the intraframes only.

Upon request of a particular segment of a video program, it is read from storage at a higher than real time transfer rate. The segment size may range, depending on network traffic, service type, and CO buffer limitations, from several seconds to a whole program, and is determined by the CO Service Processor.

For example, a 20 second video segment comprises 30 Megabits at a compressed video rate of 1.5 Mb/s. However, this segment may be delivered in an interval of 0.2 second at the 150 Mb/s transfer rate. The segment is read from the storage and transmitted via the network interface in an ATM cell format to the requesting CO server. This speed-up in transfer rates allows, in effect, several different segments to be transmitted simultaneously from the IWH to several CO's. In addition, each segment may be broadcast to several CO's, specifically for PPV and Quasi-VOD services.

It is the IWH Service Processor which receives the various requests, selects the appropriate program segments from the storage devices, and schedules the segment's transmission.

The mass storage technology has to meet several requirements within the context of the VOD services discussed in this paper. It is assumed that each IWH contains several thousand video programs, with lengths ranging from a few minutes to several hours. Some of the programs may require dedicated drives, due to heavy demand at the time, so as to guarantee random access with only a few millisecond access times to those programs. However, most other programs might be handled in a 'jukebox' fashion using, for instance, optical disks. This arrangement implies several seconds access to the disks, and milliseconds access times within a particular medium. High-capacity optical or magnetic tape may also be used for the archival storage in the IWH, Fig.3.

Magnetic disk recording technology (e.g., Winchester disk drives) is the most mature technology for on-line playback (storage to network) purposes. It has access times of a few to 10's of milliseconds, and can reach 100's Mb/s transfer rates using parallel head systems or arrays of disk drives. Since this media is not removable, the allocation of, roughly, a disk drive per two hours program is implied. However, the number of programs that have to be kept on-line at any given time is limited.

Magneto-optic recording systems are being developed using laser and detector arrays on a single head, with 100's of Mb/s transfer rates [8]. For Gbit/s transfer rates, which would be required for VOD using HDTV quality programs, multiple head systems will have to be developed. This technology, though still in the early development stages, combines high transfer rates, fast access times, and removability.

6. CENTRAL OFFICE VOD SERVICE CIRCUITS

In the proposed architecture, the BISDN Central Office plays a facilitating role in the service management. The first CO function is that of an Information Kiosk. This allows the customer a one-stop-shopping scenario for information. The navigational aids, and lists of available material, could be presented in some convenient way to the customer. Some services may have subscription policies while others may be unsubscribed, as is practiced in voice information providing services on the public telephone network today.

Fig.4 depicts the architecture of the CO with Store-and-Forward Video-On-Demand service circuits.

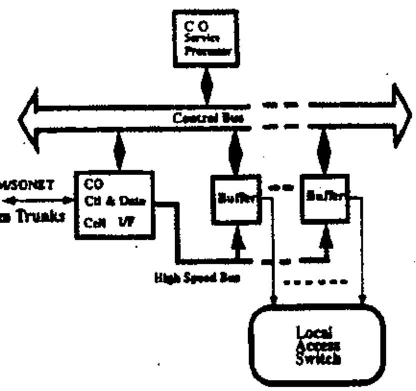

Fig.4. Central Office with Video On Demand Store-And-Forward Service Circuits

The CO Service Processor (CO-SP), the ATM/SONET interface, and the CO buffers communicate control messages via the control bus while the video data which is received from the trunks is transferred to the buffer by way of the High Speed bus.

The CO-SP performs the information kiosk and material browsing functions. It runs the video data transfer protocol, composes the requests for data to the IWH corresponding to customer requests, and supports the user control interface and material presentation management functions.

6.1 VOD Service Example

When a request for VOD service is received at the customer's local CO, the browsing stage of the service begins. The browsing scenario is dependent on the types of material offered in the framework of the service. The user interface is used to control material browsing and selection.

After the selection has been made by the customer, the CO chooses an appropriate warehouse and places the request for the material with its ambassador processor IWH-SP.

It also allocates the necessary internal buffer space to support the service. In the case of true video on demand, the buffer is dedicated to the customer for the duration of the service. For the PPV and Q-VOD grades of service, the buffer space is shared by groups of customers.

The most demanding scenario to realize is true VOD, implying a premium price to the customer. In this scenario the user's CPE generates the control messages which are interpreted by the CO-SP. The control functions may be as follows:

VOD, PLAY, STOP, PAUSE, FAST-FWD, FAST-REV, FWD-SEARCH, REV-SEARCH

The *VOD* command initiates the service. Upon the *PLAY* command, the CO-SP, via the ambassador processor IWH-SP, retrieves a segment of video corresponding to the allocated buffer size. This segment is delivered via a high speed short burst to the CO and stored in the buffer. The segment is read out to the customer at the DS-1 rate provided that the decoder is at the CPE. For customers without the decoders or with some other type of video receivers the transcoding of the video and audio signals is done by the CO service circuits.

As the user views the material, the CO server fetches the next segment while the current one is being watched. When the *STOP* command is received by the CO-SP, the readout from the buffer is halted and the viewer is provided a blank screen with the word 'stop' displayed. During the pause command, the server continuously replays the next intraframe, or, if the decoder is located at the CO, the last reconstructed frame.

Should the user issue a *FAST-REV* (rewind) command by indicating the desired position in the material via his user interface, the server will then fetch the corresponding segment from the IWH. A similar action takes place during the *FAST-FWD* command. Forward search and reverse search are accomplished by retreiving and playing out only the intraframes out of each group of frames in the recorded program.

7. CONCLUSIONS

We have described an architecture for an information distribution service, suitable, among other applications, for various scenarios of the Video-On-Demand service.

This architecture is designed to provide an infrastructure for information networking by facilitating information storage and management in the network nodes. In the paper we illustrated just one particular application that can be supported by the architecture, namely, Video On Demand. The processing power and medium-term storage (disks) as well as short-term buffering (solid-state memory) introduced in the central offices can be used for supporting other functions in information networking, such as information presentation, filtering, multimedia messaging, etc.

As it applies to a mass information providing service, such as Video On Demand, the flexibility of the proposed architecture allows adaptation of the distribution scheme to a variety of requirements that may be desired by the various information vendors as to the information retrieval and transport protocols. Due to the vendor/network partnership and cooperation in the information distribution, the information shopping and billing processes could be greatly simplified and may prove to be more economical.

In order to make the service realizable and economical, many issues still have to be addressed.

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