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Broadband Intelligent Network Architecture for Multimedia-on-Demand Service

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This paper proposes a broadband ISDN (B-ISDN) oriented intelligent network (IN) architecture for a multimedia-on-demand (MOD) service. It demonstrates that IN architecture is effective for MOD service control. Then, this paper proposes an IN call model for B-ISDN, which is an essential model for defining an open interface in the IN architecture. The proposed call model can be applied not only to MOD service control, but to control of more advanced B-ISDN multimedia services. Also, an example of MOD service control based on the proposed IN architecture is given.

1. Introduction

Various multimedia services are expected to be offered following the deployment of broadband ISDN (B-ISDN) technologies such as ATM switching and optical transmission systems. Multimedia-on-demand (MOD) services, which provide users with multimedia information on an on-demand basis, are considered to be especially practical to implement. Video-on-demand (VOD) services such as movie-on-demand is one of the most primitive MOD services. Providing MOD services rapidly and efficiently requires a new service control architecture based on B-ISDN because existing architectures were developed mainly for the plain old telephone service (POTS) and narrowband ISDN services.

This paper proposes a B-ISDN oriented intelligent network (IN) architecture for a multimedia-on-demand (MOD) service. In the IN architecture, services are executed by interworking between a service control node and a switching node. Therefore, function allocation and an interface between these nodes should be specified to develop the IN architecture. A call model is an essential model for defining such an interface. In this paper, the requirements and a general model of an MOD service from the service control viewpoint are described. Next, we explain how the IN architecture is effective for MOD service control. A new call model is then proposed. The proposed call model can be applied not only to MOD service control but to control of the evolution of B-ISDN multimedia services. Lastly, a VOD service with commercial messages is described as a control example based on the proposed IN architecture.

2. Basic concepts of MOD service control

2.1 Requirements

Compared with conventional broadcast services such as CATV, which has a set programming schedule, an MOD service enables users to independently select and receive multimedia information whenever they like. This requires a service control function to connect users to the multimedia information source on an on-demand basis. To support a service control function for a networked MOD service, the following fundamental requirements must be satisfied:

1) Support for evolutionary B-ISDN signaling capability

The service control architecture must allow for future, complex multimedia services. Signaling capability is one of the most important elements of service control. B-ISDN signaling is evolutionary; that is, the ITU-T standardizes B-ISDN signaling in stages.[1] For example, signaling capability set 1 (SCS-1) offers specifications for a single point-to-point connection; and the next capability set, SCS-2, supports multiconnection and multipoint (or multiparty) connections. Therefore, a service control architecture must follow B-ISDN signaling design standards.

2) Support for interoperability and equal access

In a multicarrier, multivendor, and multiprovider environment, every organization provides its own functions (i.e., services and resources). To enable users and information providers (IPs) to access these functions from anywhere in the network, the functions must be interoperable. Also, in a multiprovider environment, equal access is indispensable. That is, the service control function must give users equal access to every IP.

3) Support for customization

Customization of MOD services by IPs must be made an easy task for IPs. For example, a certain IP may wish to provide a home shopping service by enhancing an already existing MOD service (e.g., a movie-on-demand service). This requires an open interface to the IPs and localization of a customized component of the service control function.

2.2 MOD service control model

Before describing a network architecture that satisfies the above requirements, we will describe a fundamental MOD service control model which abstractly defines the functions required to provide an MOD service. **Figure 1** is a diagram of our MOD service control model. This model consists of three functions.

The user function receives multimedia information from the information source function via the network function. The user function has a signaling function for communicating with the network and information source functions to request and control the information (e.g., search and retrieval). A decoding function is needed to decode information which is sent in a coded form. The user function also provides a human interface and a temporary information storage for personal use.

The network function sends multimedia data from the information source to a user by using switching and transmission functions. To connect a user to an information source on a user-demand basis, a call and connection control function is needed to establish and terminate connections dynamically. A signaling function is also needed to support call and connection control. The information source function is distributed (e.g., each IP has all of the information source functions and these functions are connected to a network), thus an information source listing and navigation function is needed to enable users to select an information source (e.g., an IP). When a user requests an MOD service from an information source, a user authorization function analyzes whether the user is permitted to use the MOD service and access the information source. An accounting function calculates user charges based on network accounting data such as the connection holding time and information rate.

The information source function supports an

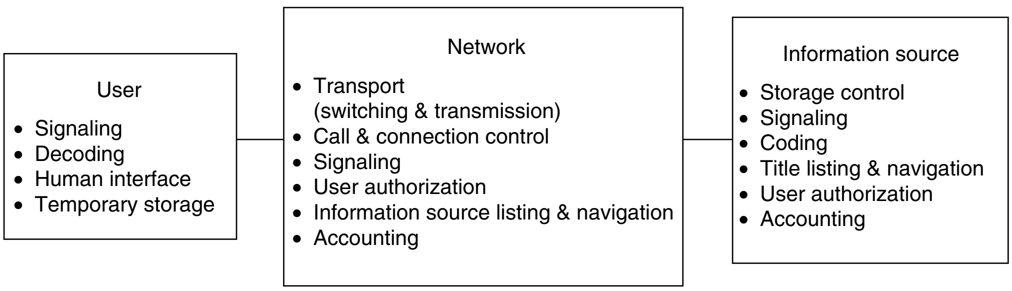


Fig.1– MOD service control model.

information storage and sends the multimedia information requested by the users. A storage control function supports basic information control such as search, retrieval, and storing. Users' requests and control signals (via the network function) are processed by a signaling function. A coding function is needed to compress video information. A title listing and navigation function enables users to select information titles such as movie titles. When a user requests a certain information title, a user authorization function analyzes whether the user is permitted to access the information. An accounting function calculates the user charge based on the information source's accounting data, for example, charges for providing information.

3. Network architecture for an MOD service

3.1 Basic concept

To construct a network for an MOD service based on the requirements and MOD service control model described in Chapter 2, we first need to develop a network architecture based on the model. We should also consider that B-ISDN offers us a good opportunity to introduce new ideas. In this chapter, some network architecture alternatives are considered.

3.1.1 Network architecture alternatives

Figure 2 shows four typical network architectures.

In the PVC architecture, a service controller incorporating an operations system controls an ATM switching system in a PVC setup manner. Control interfaces between the service controller and a subscriber access network or an IP's server are separated from the ATM UNI and are proprietary. For example, these interfaces will be implemented by LAN or WAN. An ATM switching system is controlled via a network management interface such as the common management information protocol (CMIP).

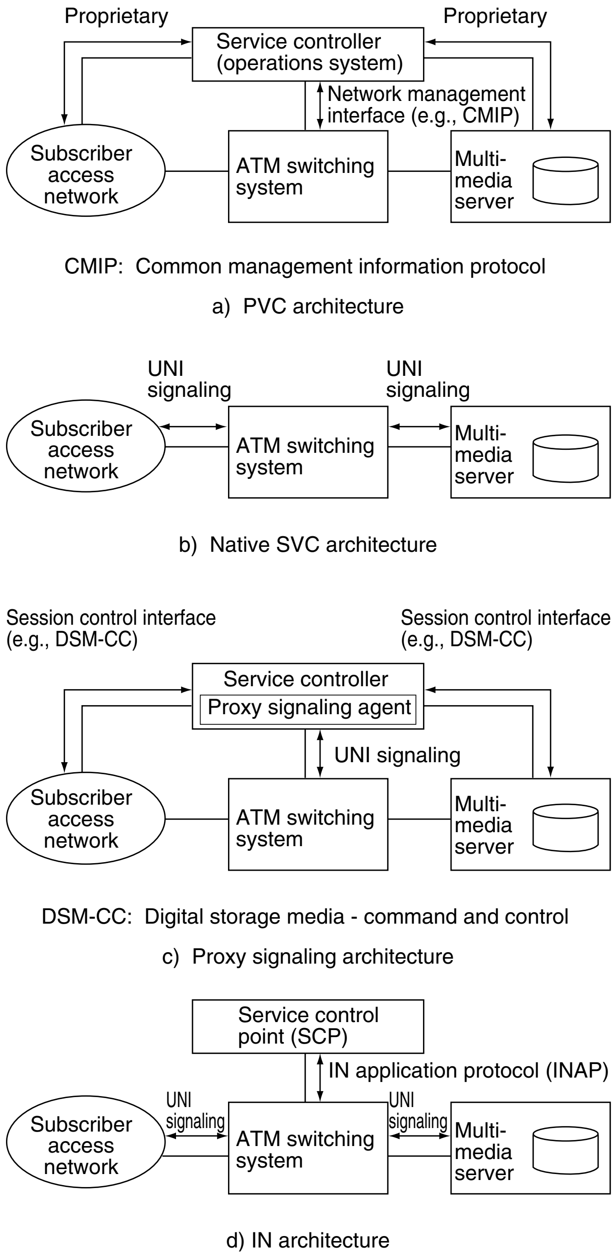


Fig.2– Network architectures for a MOD service.

The native SVC architecture is based on the conventional call setup method; that is, a user dials an IP's number. Call processing in an ATM switching system then analyzes the call information and establishes a connection between the user and an IP. The control interface uses an ATM UNI control plane such as Q.2931 signaling.

The proxy signaling architecture is a kind of SVC architecture and is currently being studied at the ATM Forum.[2] Originally, proxy signaling is used for terminals and subscriber access networks such as CATV networks which do not support a UNI signaling function. That is, a proxy signaling agent (PSA) acts as an agent of terminals (or access networks) for UNI signaling. PSA is located in a service controller. This capability is applied to a VOD system in the ATM Forum's specification. The interface between a PSA and terminals (or access networks) is called the session control interface; the digital storage media-command and control (DSM-CC) will typically be used for this interface.

In the IN architecture, a service control point (SCP) controls an ATM switching system by the IN application protocol (INAP).[3] Interfaces between an ATM switching system and a subscriber access network or an IP's server use an ATM control plane, as is the case for the native SVC architecture.

3.1.2 Considerations

The PVC architecture has the advantage that it can be rapidly implemented using existing facilities such as a CATV network and LAN. However, the real-time performance will be rather low because it uses network management technologies. Moreover, proprietary interfaces based on LANs or WANs will limit network scale. Thus this approach is considered to be suitable only for the initial stage of an MOD service.

Although the native SVC architecture can simplify the network configuration, the service control flexibility is insufficient. For example, a nationwide IP will have several server centers. Therefore, user requests should be distributed automatically to each center according to the traffic conditions. In the native SVC architecture, it is not easy to flexibly implement such an information source listing and navigation function.

The proxy signaling architecture will resolve the performance issue of the PVC architecture and improve the information source listing and navigation function of the native SVC architecture. Also, because terminals or access networks need not support a UNI signaling function, the user's equipment cost can be reduced, which is considered to be a very important requirement for rapid introduction and growth of a VOD service. On the other hand, current session control interfaces such as DSM-CC are rather specific to video services, so the interface should be enhanced or changed to enable multimedia service control.

The IN architecture will flexibly resolve the navigation issue. A logical number, for example, the number of a toll-free phone service, which can be provided by the IN architecture, hides the distribution among centers from the users. Hiding the distribution is also important for equal access. Moreover, the IN architecture provides a generic platform for MOD service customization, flexible accounting, and authorization for a large-scale network.

Both the proxy signaling architecture and the IN architecture can satisfy the requirements described in Section 2.1. In this paper, however, we focus on the IN architecture because of significant issues regarding its development for B-ISDN. In the IN architecture, the network function in the MOD service control model is divided into the service control function (SCF) and the service switching function (SSF)/call control function (CCF). The MOD service is provided as an IN supplementary service.

3.2 Network configuration

This section describes a network configuration for an MOD service based on the IN architecture. Because the standardization of B-ISDN signaling capability is being done stepwise, we propose a two-step network construction.

3.2.1 Step 1

As described in Section 2.1, the service control architecture must enable evolution and must flexibly follow the current stage of B-ISDN signaling capability. The B-ISDN signaling capability is one of the most influential factors in the IN architecture. SCS-1 is sufficient for an initial MOD service such as a movie-on-demand service which needs only single point-to-point connections.

Enhanced MOD services, however, would need more complex connection control for multiconnection support. For example, a home shopping service would need a video connection for a video catalog and a data connection for an order form. This requires SCS-2, which supports both multiconnection and point-to-multipoint connection control. Early MOD services are likely to trigger a rapid introduction of a variety of enhanced MOD services. The IN service control architecture, therefore, needs to be based on SCS-2 even in its first implementation. However, it must still support SCS-1 as a subset of SCS-2 for simple point-to-point MOD services.

Figure 3 shows a Step 1 network configuration. In the early stages of the MOD service's growth, existing CATV networks will be used as the subscriber access network because of their cost-effectiveness. The CATV network is connected to the ATM switching system via a cable head end system. The cable head end system supports B-ISDN UNI signaling termination and converts ATM cells into an information stream for the CATV network. The cable head end system also broadcasts conventional CATV programs. Mass storage multimedia servers will be connected to the ATM switching system and will send the requested multimedia information to the subscriber's terminal (e.g., an enhanced set top box or a personal computer). The service control point (SCP) will control basic call processing (SSF/CCF) in the ATM switching system and the multimedia servers. For Step 1, the conventional signaling system No. 7 (SS7) network will be used as the signaling network for cost-effectiveness. The network management system manages each network element via the data communication network, which supports the X.25 protocol.

3.2.2 Step 2

For Step 2, the network configuration will be more sophisticated. The IN service control supports connection control that is more complex than that supported in SCS-2; for example, it supports control of multipoint-to-point and multipoint-to-multipoint connections. Thus more sophisticated concurrent information reception from multiple servers and multimedia conferencing can be provided as IN supplementary services.

Figure 4 shows the Step 2 network configuration. Optical subscriber loops will be widely used, and private networks will be accommodated. The subscriber's terminals are enhanced (e.g., a workstation and a multimedia conferencing terminal) and support the B-ISDN UNI signaling termination function. The main differences from the network in Step 1 are an ATM signaling net-

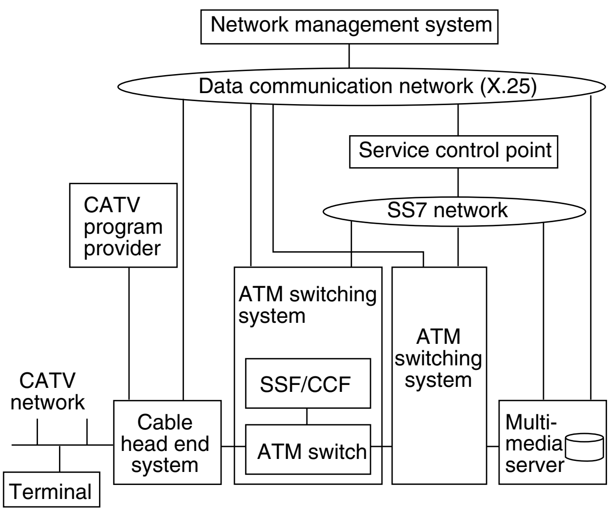


Fig.3– Network configuration for a MOD service (Step 1).

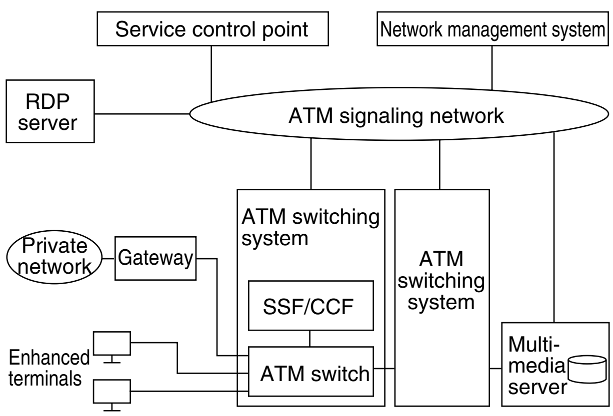


Fig.4– Network configuration for a MOD service (Step 2).

work and a real-time distributed processing (RDP) function. The ATM signaling network provides high-speed communications between network nodes. The RDP provides network-wide distribution transparency. The RDP is used for dynamic SCP selection. That is, when a user requests an IN supplementary service, an SCP supporting the requested service is selected. If multiple SCPs support the requested service, the SCP with the lightest processing load is selected. Ultimately, the RDP is used for mobile multimedia personal communication.

4. IN call model for B-ISDN

To implement an MOD service as an IN supplementary service, the IN architecture must incorporate B-ISDN capability. However, current IN research, including standardization activities at ITU-T, mainly focuses on service control for POTS and narrowband ISDN services, indicating that B-ISDN service control is presently insufficient. When developing the IN architecture incorporating B-ISDN capability, a call model is an essential part of the IN architecture.[4), 5)] In this chapter, we focus on an IN call model for B-ISDN that will be applied to both the Step 1 and Step 2 network described in Section 3.2.

4.1 Requirements for the call model

The call model is a fundamental element for standardizing the interface between the SCF and SSF/CCF. The call model consists of a call segment model (CSM) and a basic call state model (BCSM). The CSM represents the call control information abstractly from the SCF viewpoint. The BCSM is a CCF basic call processing model of the CCF which defines call state transitions points in calls (PICs) and detection points (DPs). The ease with which services and design applications can be developed depends on the flexibility of the call model. It should also be remembered that the call model must follow the migration of B-ISDN signaling capability from SCS-1 to beyond SCS-2.

The conventional call model was studied with POTS and narrowband ISDN in mind. It is therefore difficult to directly apply it to B-ISDN service control, which must manage connection types other than point-to-point. Research into enhancements of the conventional call model has been reported.[6), 7)] These reports discuss only the basic-concept or enhanced BCSM; however, they give no specifications for the CSM, which must also be enhanced for B-ISDN.

The B-ISDN call model requires the following:

1) Multiparty and asymmetric connection

After the Step 1 network has matured, the number of services accompanied with unidirectional and multiparty connection types will increase. Therefore, a call model must be constructed for services using a uniform control method for all connection types. Moreover, the call model must be designed so that the service logic for the various connection types is simplified.

2) Multimedia services

After the Step 1 network has matured, it is also expected that the need for multimedia services will increase. For such services, subscribers will be assigned multiple virtual channels (VCs). Thus, a call model must provide flexible VC control. This flexible control includes independent control of each VC and simultaneous control of multiple VCs. A call model must also provide control capability for dynamic addition and deletion of a connection in a call.

3) Dynamic modification of bearer capability

In an ATM network, which is the most promising network for realizing B-ISDN, a VC is used as a logical communication path. Since the bearer capability of a VC can be modified dynamically for each call, new services are expected to use this feature. The call model should therefore be defined to modify a VC's parameters when IN services are executed.

4) Communication among various terminals and servers

With the increase in multimedia services, various types of terminals and IP servers will be connected to B-ISDN. A network should support communications among these terminals and servers, and the call model should enable establishment of any possible interconnection between them.

4.2 Basic concept

Before discussing the call model, we must consider the function arrangement and information flow between the SCF and SSF/CCF.

1) CCF for B-ISDN

If a conventional CCF is used, the service logic (SL) in the SCF will be very complicated and the information flow between the SCF and SSF/CCF will be very large because basic call processing in the CCF is too simple to handle multiparty and/or multiconnection services. Therefore, the CCF for B-ISDN should be enhanced to enable a subscriber to set up a multiparty and/or a multiconnection call and add/drop parties or connections during a call.

We have determined that the CCF should be divided into two types of functional modules (call control modules [CLCs] and connection control modules [CNCs]) according to the SCS-2 B-ISDN signaling capability. The CLC has call signaling termination and connection coordination functions. The CNCs have switching resource management functions, bearer signaling termination functions, and VC management functions. A basic call is executed by interworking the CLC and CNC modules.

As described in Subsection 3.2.1, in the initial stage of the Step 1 network, SCS-1 will be sufficient for the initial MOD service, which requires only single point-to-point connection. In this stage, the CLCs will not need to support all the functions needed for SCS-2, and the actual service control will be almost completely handled by the CNCs. That is, the call model based on this separated module concept can follow the migration of B-ISDN signaling capability from SCS-1 to beyond SCS-2.

2) Information flow between the SCF and SSF/CCF

There are two possible schemes for defining the information flow between the SCF and SSF/CCF when the CCF is enhanced as described above. The first scheme is to define an interworking relationship only between the SL and the CLCs. The second scheme is to define multi-interworking relationships between the SL, CLCs, and CNCs.

The first scheme hides detailed information about connection control states from the SL. Therefore, the SL and the interworking mechanism could be simple. On the other hand, for the second scheme, the SCF can control the CCF functions in more detail because the SL can also directly interwork with the CNCs. We propose a call model based on the first scheme because the first scheme is closer to the basic IN purpose of rapid service development and realization of service customization and because it can be realized by extending the current IN mechanism. **Figure 5** shows the proposed CCF structure based on the first scheme.

We also evaluated the two schemes theoretically from the service control overhead viewpoint. The evaluation results show that the first scheme

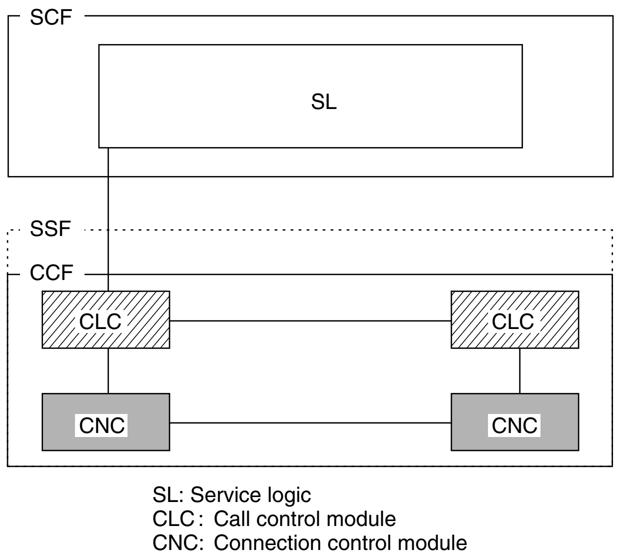


Fig.5– CCF functional modules and interworking relationship.

reduces the message traffic between the SCF and SSF/CCF as compared with the second scheme, especially in multiconnection control. This reduction effect becomes more notable as the number of connections to be controlled increases. The reason for this is as follows. In the second scheme, each CNC corresponds to a specific connection, and the SL must control multiple CNCs concurrently to control multiconnection. That is, multiple control messages from the SCF to SSF/CCF are needed. On the other hand, for the first scheme, the multiple control orders for connections can be sent by one message to the CLCs.

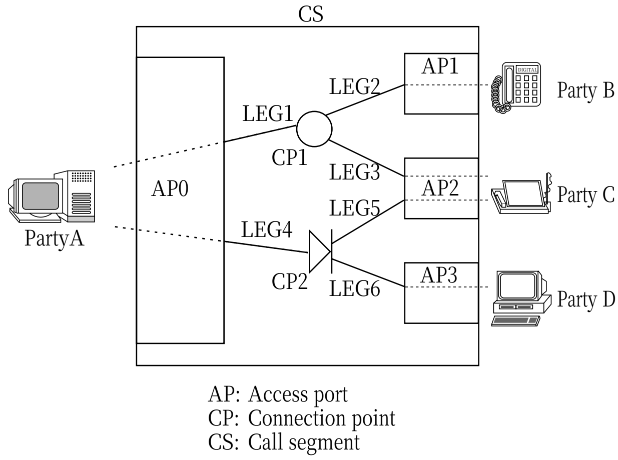


Fig.6– Graphical representation of CSM.

4.3 Proposed call model

In this section, we propose an IN call model for B-ISDN based on the requirements and basic concept described above.

4.3.1 Call segment model (CSM)

The CSM represents call control information, for example, the connection type, various resource attributes (e.g., various VC setup parameters), and relationships among resources (e.g., connectivity relationship and containment relationship). The CSM is independent of SSF/CCF implementation.

To satisfy the requirement of Section 4.1, each connection and party should be identified in the CSM, and their attributes and relationships should be explicitly represented.

The proposed CSM for B-ISDN consists of legs, connection points (CPs), access ports (APs), and a call segment (CS). **Figure 6** shows the CSM. The figure shows the state in which an IN service request is detected for party A and a corresponding IN service is invoked while the multiparty and multiconnection control function is executed in the CCF as a basic call.

The CSM components are described below.

1) Legs

A leg is a VC allocated to a subscriber or to a neighboring switching system by the CCF which has the CSM. These VCs are managed by the CNCs and are controlled by the CLC, which detects the trigger. A leg has several attributes, for example, the VC status, information rate, and quality of service (QOS) allocated to the VC.

2) Connection points (CPs)

Only single connection (bidirectional point-to-point connection) is considered in the current IN architecture. The meaning of the term "CP" is not fully clear because call and connection establishment are the same.

With the separation of CLCs and CNCs in the CCF for B-ISDN, the SL should be able to distinguish between connections and calls. A CP is defined as a logical resource which connects legs via a connection type. The SL can control each connection separately by indicating the corresponding CP; this meets one of the requirements described in 4.1 2). A CP is generated for the resources (e.g., a speech path and a conference trunk) and the corresponding control functions which are used to establish the connection in the switching system. A CP has attributes such as the reservation status of the corresponding resource, connection type, and leg information. In Fig. 6, the symbols used for CP1 and CP2 represent a conference-type connection and broadcast-type connection, respectively.

3) Access port (AP)

An AP is a newly defined component for enabling control of each party. One AP is created for each CLC. Each AP is a logical resource that bundles all VCs controlled by the CNCs under the CLC for which the AP was created. A CLC-related AP that detects an IN service request is called the control-AP. When a CLC detects a signal for adding or dropping a party, the corresponding processing (e.g., simultaneous setup/release of multiple VCs) is executed in the CCF containing the CLC.

4.3.2 Basic call state model (BCSM)

Figure 7 shows a B-ISDN BCSM for an originating party. The enhanced portions of this BCSM are summarized as follows:

1) "O_Establish_Call" and "O_Establish_Connection" points in calls (PICs) and "O_Only_Call_Established" detection point (DP) have been defined to support the separation of call control and connection control.
2) DPs detected at "O_Active" PIC except "O_Mid_Call" and "O_Disconnect_Call" are also added to enable event detection of add or drop party/connections in the active state.

Because of these enhancements, CCFs can interact with SCFs at B-ISDN-specific DPs during basic call processing, and flexible control of various B-ISDN services is possible.

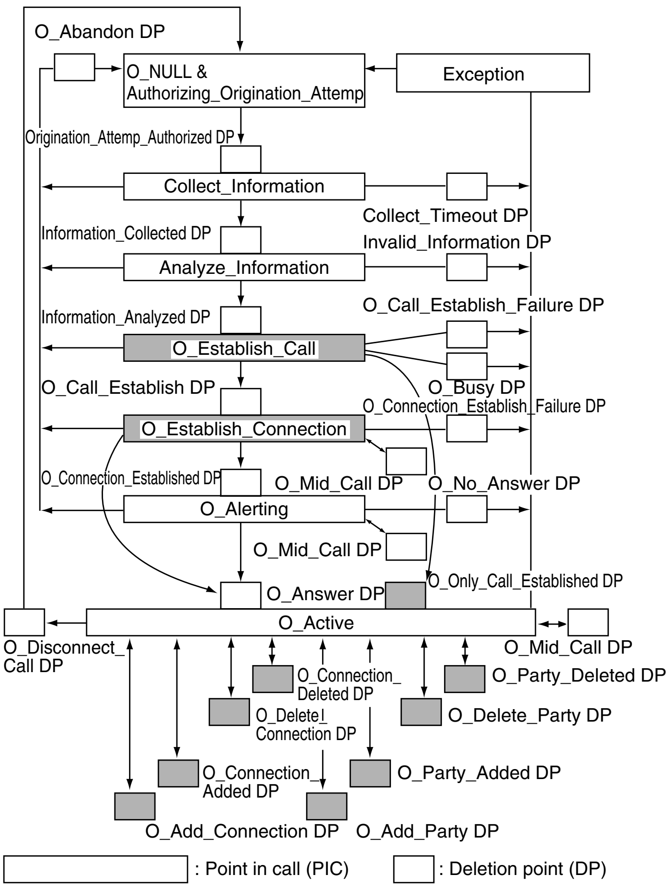


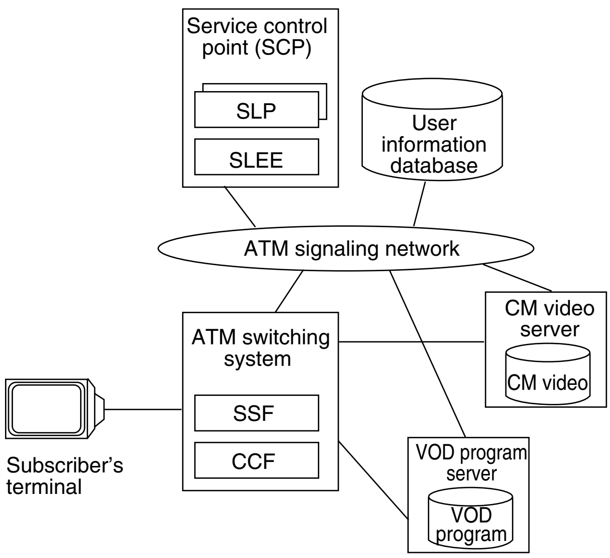
Fig.7– Basic call state model for originating party.

5. MOD service control example

One of the most important issues regarding the popularity of VOD services is user fees. VOD service charges must be competitive with video rental services. One effective method to ensure that charges are reasonable is to insert a commercial message (CM) into the VOD programs. This chapter describes an example VOD service control with CMs that is based on the proposed IN call model.

5.1 Network configuration

In a VOD service with CMs, a CM video is sent to the subscriber's terminal during, before, or after the VOD program, and the CM sponsor pays a part of the VOD service charge. **Figure 8** shows an example network configuration for a VOD service with CMs that is based on the Step 2 network (the RDP server is omitted for simplicity). The



SLEE: Service logic execution environment

Fig.8– Example network configuration for VOD service with CM.

user information database manages information about the users of the service, for example, the users' occupations and interests. This information is used by an SCP to select CM videos which meet the users' interests. This method will enhance the usefulness of CMs for users and sponsors.

In the example shown in Fig. 8, the CM video and VOD programs are in different video servers at different locations. Thus two VC connections must be allocated, and these connections must be switched when the CM video or VOD program ends. To achieve this, there are two methods for VC connection control:

1) The first VC connection is torn down, then the second one is established.
2) The second VC connection is established, then the first one is torn down.

Method 1) can be achieved with a B-ISDN, signaling-capable SCS-1 that is used for the initial stage of the Step 1 network. Method 2) needs multipoint-to-point connection control (i.e., beyond SCS-2) and it makes service control more complex than method 1). However, from the user's viewpoint, method 2) can make instantaneous changeovers between the CM video and the VOD program. Therefore, we have adopted method 2) based on the Step 2 network for the service control of VOD services with CMs.

5.2 Service control flow

Figure 9 shows the IN service control flow

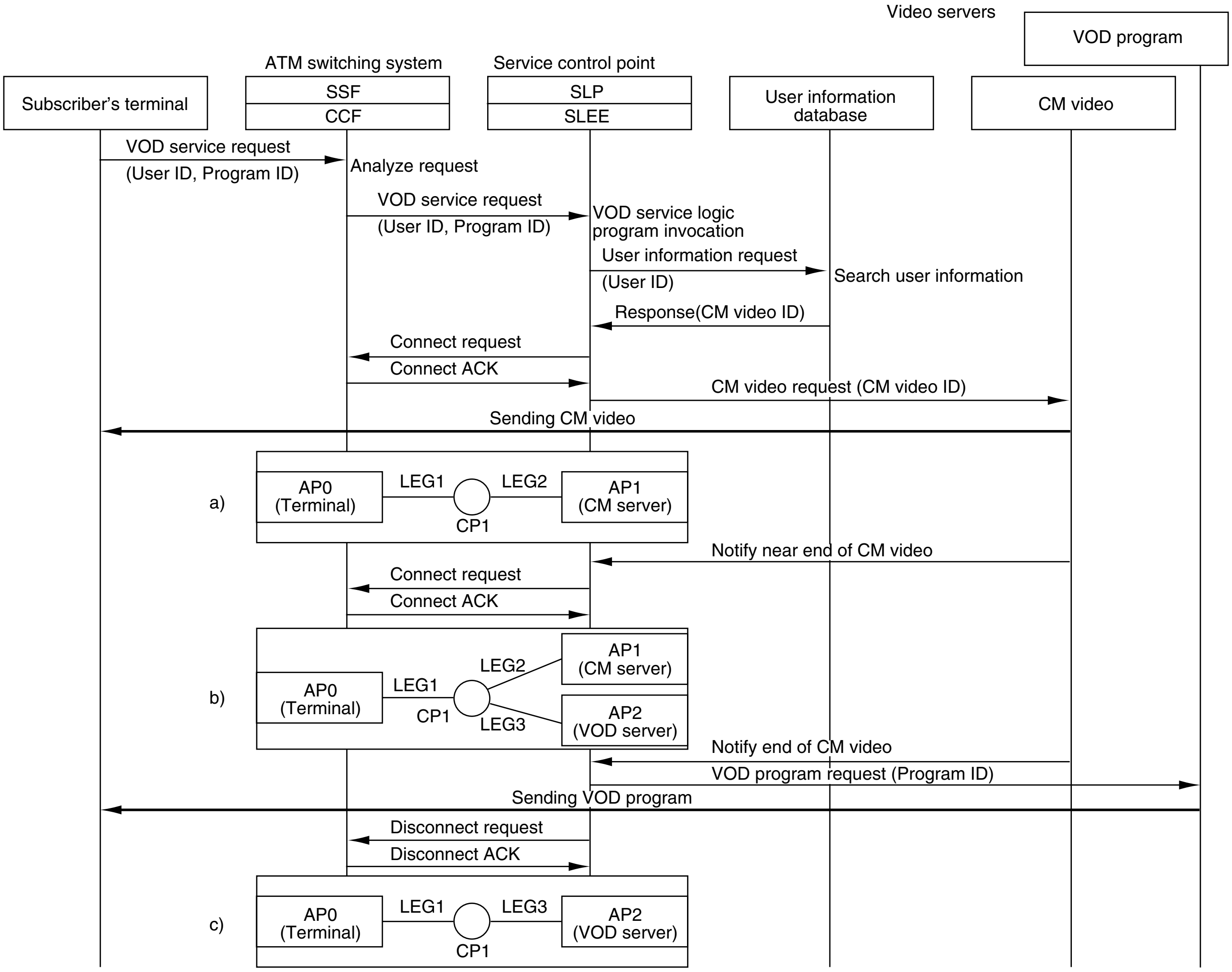


Fig.9– Example IN service control flow for VOD service with CM.

of a VOD service with CMs that is based on method 2). The following is an outline of the service control flow:

1) When a subscriber requests a VOD service with CMs, a request message is sent to the CCF in the ATM switching system. The CCF detects a trigger and carries out service analysis and user authorization. Then, the SSF sends a trigger to the SCP.
2) Using the service logic program (SLP), the SCP requests the user information database to select a CM video that meets the users' interests and then receives the ID of the selected video.
3) The SCP requests the SSF/CCF to establish a VC connection between the CM video server and the subscriber terminal.
4) The SCP activates the CM video server and specifies the CM video. Then the server starts sending the CM video. A graphical representation of the CSM in this state is shown in Fig. 9 a).
5) When the CM video is nearly finished, the SCP is notified. Using the SLP, the SCP request the SSF/CCF to establish a VC connection between the VOD program server and the subscriber's terminal. When the connection is established, the SCP is notified. A graphical representation of the CSM in this state is shown in Fig. 9 b) (LEG 3 is created and connected to CP 1).
6) When the CM video ends, the SCP is notified. The SCP activates the VOD program server, and the server starts sending the VOD program.
7) Using the SLP, the SCP requests the SSF/CCF to tear down the VC connection (LEG2) between the CM video server and the subscriber's terminal. When the connection is torn down, the SCP is notified. A graphical representation of the CSM in this state is shown in Fig. 9 c).

6. Conclusion

We have proposed a broadband IN architecture for an MOD service. We have focused on the call model, which is an essential element of the IN architecture. The proposed call model can be applied not only to MOD service control but to control of evolutionary B-ISDN multimedia services. An MOD service, namely a VOD service with a commercial message, was described as a control example based on the Step 2 network.

We will continue to study issues regarding the implementation of the proposed architecture, especially for Step 2. For example, we will study internetworking with a private network (e.g., ATM-LAN), real-time distributed processing, and an ATM signaling network.

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