A Framework for an Intelligent Network Call Model for ATM Networks

Oliver C. Ibe

Laboratory for Information and Decision Systems
Massachusetts Institute of Technology
Cambridge, MA 02139

Abstract

The intelligent network (IN) is a telecommunication network control architecture that separates the service delivery functionality from the service creation functionality. This permits new services to be developed and deployed more rapidly with minimal impact on the basic switching functionality. Broadband ISDN (BISDN), with ATM as the underlying transmission and switching scheme, is expected to support both the current narrowband services and the emerging broadband services such as multimedia communications. The IN call model has been specified for calls with a single bearer service, typically voice. This paper proposes an IN call model for BISDN where a call can have multiple bearer services, such as a videoconference call. A bottom-up approach is used whereby the experience gained in IN call models for narrowband ISDN is extended to BISDN.

1 Introduction

Two of the telecommunication technologies that have changed the manner in which telecommunication services are provided are the intelligent network (IN) and the broadband integrated services digital network (BISDN). Although these technologies are being developed independently, they are expected to meet at the public switched telephone network when the local exchange carriers (LECs) begin to widely deploy asynchronous transfer mode (ATM) switches. Currently the non-LEC telecommunications service providers are far ahead of the LECs in ATM deployment. The service offered by these providers consists mostly of LAN interconnection (ATM LANs). Although ATM is a versatile scheme, much standards work remains to be done before it can be used by the LECs to provide traditional telecommunication services. In fact, much of work being done in the ATM Forum deals with providing LAN interconnection. One of the more demanding aspects of ATM is designing protocols that can enable it to be used to provision such advanced voice services as call waiting and call forwarding in a *flexible* manner; that is, providing these services based on a number of criteria such as time of day, day of week, and calling number.

In the past few years the LECs have been committing so much of their resources toward upgrading their networks to at least the AIN Release 0.1 level [1], [2]. Thus a wide deployment of ATM switches by the LECs can only be economical if broadband services are offered within the framework of IN. Before broadband services can be offered as IN services, a specification of an IN call model for BISDN is essential. A call model is a finite state machine representation of the basic call processing in an IN environment.

The purpose of this paper is to propose a call model for an integrated BISDN-IN system, which we refer to as *broadband IN*. An alternative object-oriented approach has been proposed [3]. This approach is different from the method used in the past to specify call models for narrowband systems. Our model attempts to extend the traditional approach to BISDN. The paper is organized as follows. In section 2, an overview of IN and BISDN is presented. A basic

call model for BISDN is presented in section 3, and a connection view of the model is presented in section 4.

2 Overview of IN and BISDN

In traditional telecommunication systems, the service software is integrated with the switching software in the telephone switch. The implication of this integration is that service development in the service software has a great impact on the switch hardware and takes a long time. IN is a telecommunication network call control architecture that provides a framework for econonmical and rapid creation and modification of network services [4], [5], [6], [7]. The key to IN is the separation of the software that controls basic switching functionality (such as setting up call paths, and basic call processing) from that which controls more advanced call features. In this way the service delivery platform is separated from the service creation platform with the result that a LEC can develop and deploy new services rapidly with minimal impact on the basic switching functionality. The physical configuration of IN is shown in Figure 1. It consists of the following components:

Service switching points (SSPs), which provide the basic call processing function. They also provide *trigger detection* function as follows. When a call is received, the SSP examines the network events and the information received from the user to determine the need for more advanced call processing. If this need arises, the SSP suspends normal call processing, refers the call to the service control point (SCP) or adjunct, and when it receives a response, it resumes call processing in accordance with instructions it receives from the SCP or adjunct.

Service control points (SCPs), which are transaction processors with associated database. An SCP contains the service logic programs (SLPs, which are programmed set of activities that define specific tasks to be performed) which the SSPs can access. An SCP communicates with an SSP over the SS7 network.

Adjuncts, which are functionally equivalent to SCPs but communicate directly with an SSP by high-speed lines rather than via the SS7 network.

Intelligent peripherals (IPs), which provide specialized functions such as digit collection and playing announcements.

Service management system (SMS), which manages the service data stored in the SCP, including data updates.

Because of the high speed involved in the ATM network, it is assumed that all communication related to call processing is between the SSP and the adjunct. The SS7 network is likely to introduce an appreciable delay in an SCP-to-SSP communication thereby slowing down call processing in the network.

Up till now IN call models have been restricted to calls with single bearer services, typically voice. BISDN is expected to support a diverse set of network services including the traditional narrowband services as well as the emerging broadband services. These broadband services include:

1. Interactive services (requiring 2-way exchange of information between 2 subscribers or a subscriber and the service provider)

   (a) Conversational services (or real-time transfer services): videoconferencing, videotele-phony, telemedicine, distance learning

   (b) Messaging services (non-real-time or store-and-forward services): compound document, video mail

   (c) Retrieval services (public information available on demand): document retrieval, videotext, electronic magazine

2. Distributive services (requiring 1-way transfer from the service provider to the subscriber): broadcast TV, pay-per-view TV, video-on-demand
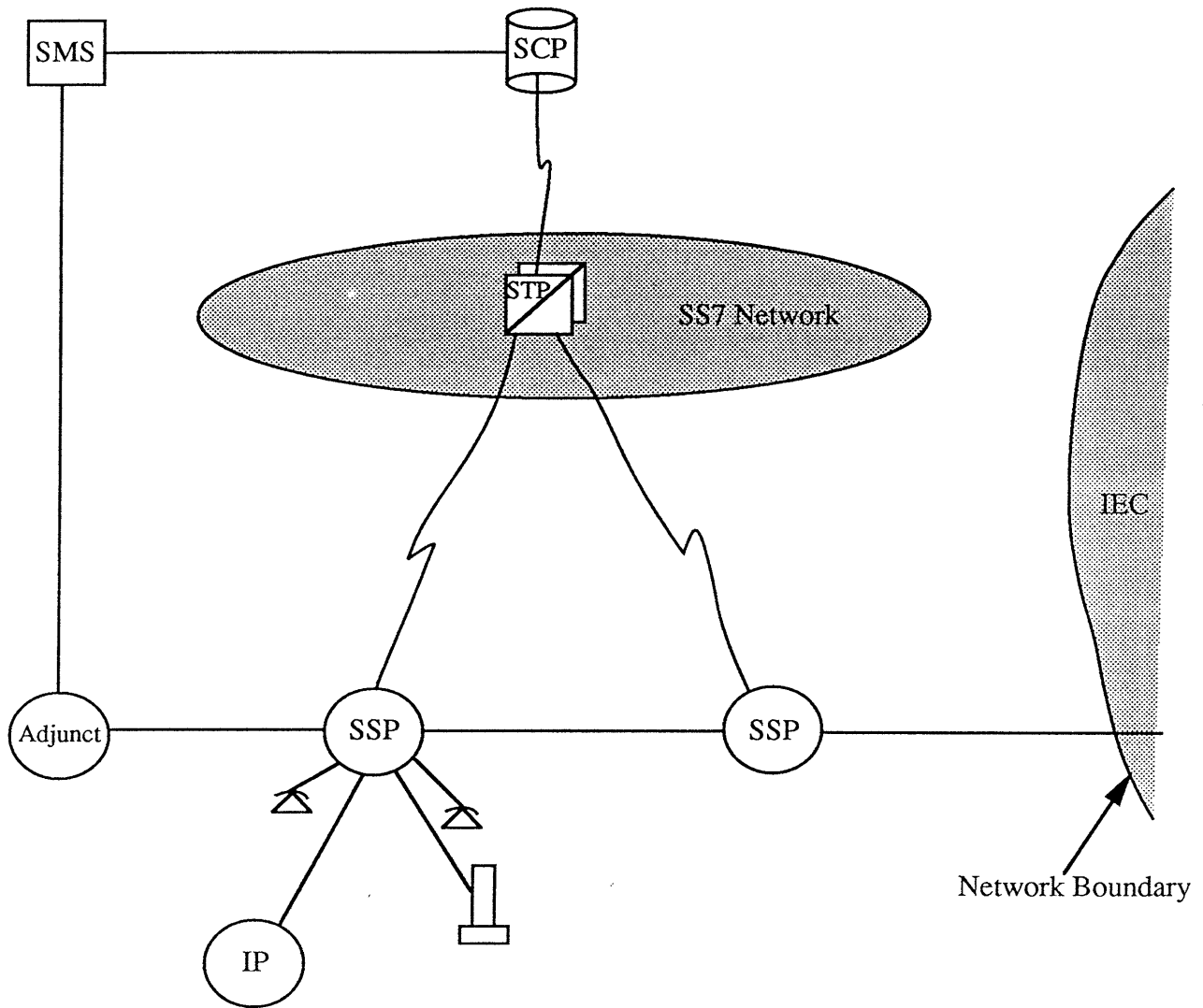
Figure 1: Physical Configuration of IN

The transmission and switching scheme for BISDN is the asynchronous transfer mode (ATM) [8], [9], [10]. ATM is a high-bandwidth multiplexing and switching scheme that uses fixed-length packets called ATM cells. Each ATM cell is 53 bytes long with a 5-byte header and a 48-byte payload. The cell header includes fields for routing, indicating the priority of the cell, header error control, and the type of information contained in the payload. The payload contains the actual data to be transfered. ATM is a connection-oriented scheme, and each ATM virtual connection is a concatenation of one or more links. The characteristics of each virtual connection are determined at the time it is established and are generally negotiated connection parameters. These parameters establish the quality of service (QOS) and include the throughput of the virtual connection, the cell loss rate, and the delay characteristics.

There are two types of virtual connections: virtual channel connection (VCC), and virtual path connection (VPC). A VCC is a logical communication channel that provides for the transport of ATM cells between two or more endpoints. Each VCC has a unique identifier called the virtual channel identifier (VCI). A VPC is a logical bundle of VCCs, and has a unique identifier called the virtual path identifier (VPI). A VPI field has no end-to-end significance over the VPC. The VCI value only has an end-to-end significance within a VPC. ATM cells are labelled individually using the VCI and VPI fields in the header.

A calling party requires a certain QOS from the network, but may stipulate acceptable alternative QOS parameter values. It can also indicate multiple bearer service choices in prioritized order. Upon receiving a SETUP message, the originating ATM switch can take one of the following actions:

1. If it is unable to provide the service at the minimum values of the QOS parameters, the call is rejected.

2. If it is able to provide the service at the specified QOS parameter values, it forwards a connection request with the desired QOS parameter values to the terminating ATM switch.

3. If is is able to provide the service at the minimum QOS parameter values but not at the specified values, it modifies the QOS paramater values to the minimum level and forwards

the connection request to the terminating ATM switch.

Upon receipt of a call establishment message from the originating ATM switch, the terminating ATM switch takes the following actions:

1. If it is able to support the requested QOS parameter values, it will accept the call.

2. If it is unable to support the minimum values of the QOS parameters, it will reject the call.

3. If it is unable to support the requested values of the QOS parameters but can provide the service at lower values (usually the minimum values), it will accept the call, modify the QOS parameter values to these lower levels and return the new values to the originating ATM switch. If these new values are acceptable to the originating ATM switch, the call is accepted; otherwise it is rejected.

2.1 Signaling Considerations for BISDN

In the current (narrowband) network, there is no separation of call control and bearer control. As shown in Figure 2, the bearer path is set up link-by-link in advance of the call being accepted. This implies that the circuit is ready as soon as the called party answers. There are problems associated with applying this traditional call establishment procedure to BISDN. These problems arise from the fact that there are two types of resources consumed in an ATM path setup: bandwidth along the path, and processing overhead required to set up the path.

In an ATM network, the broadband services require very large bandwidth. Thus, if resources are reserved and the call is rejected, the resources will be wasted. Also, a large processing overhead is associated with the bearer service path setup (to identify the best route based on the desired QOS parameters). Thus, it is desirable that this overhead be incurred only when a call setup can be fairly guaranteed to be successful. These two facts suggest that signaling be split into two phases, namely [11]
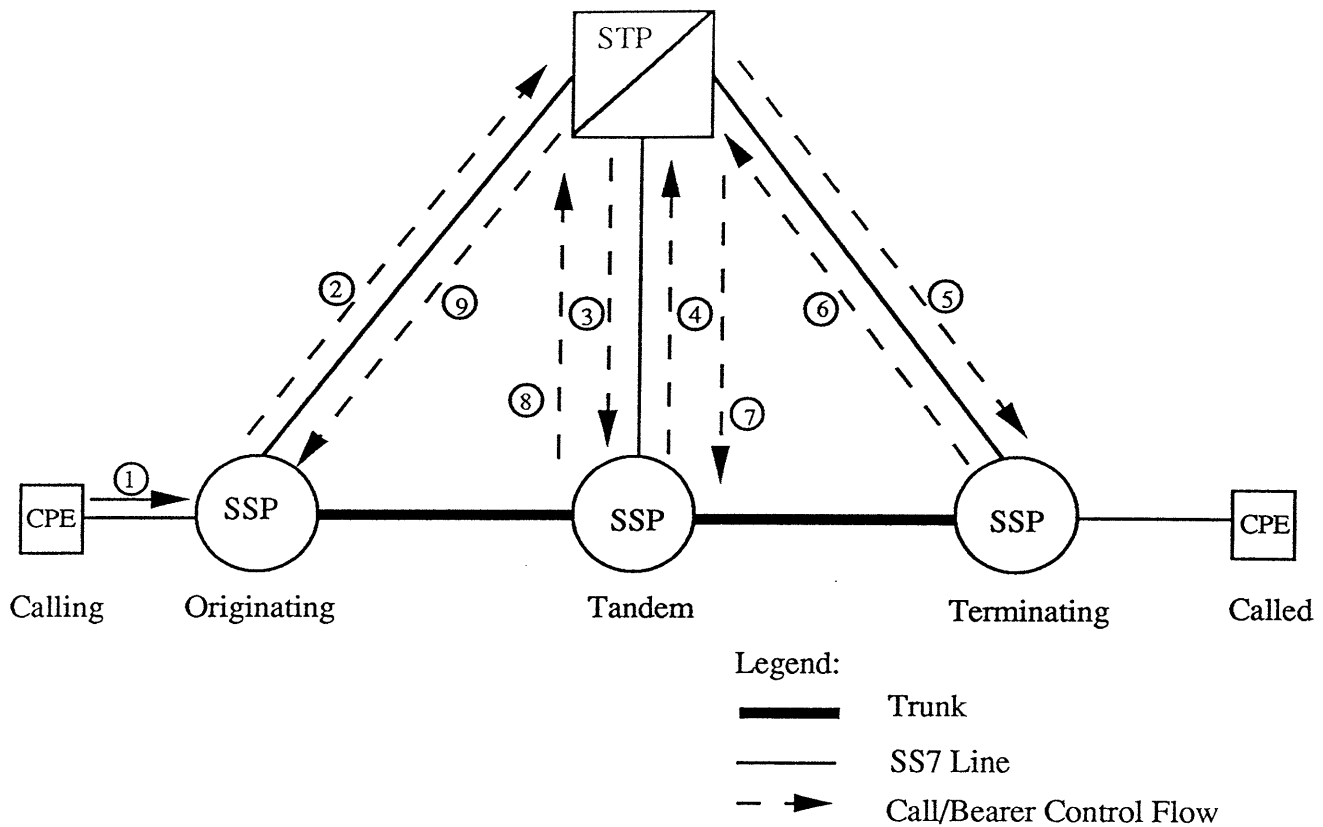
Figure 2: Call Control in Narrowband Networks

1. call control phase, which involves end-to-end resource allocation, and

2. bearer control phase, which involves link-by-link resource allocation.

Having established the need for separating call control from bearer control, the next logical issue is the point in time at which the bearer control can commence. There are two possible points:

1. after the terminating ATM switch has accepted the call, and

2. after the called party has answered.

Using the first method avoids long "awaiting answer" periods, but may be wasteful if the called party is not available. The second method is more efficient since no resource is wasted. However, it may be annoying if the called party has to wait a long time. Moreover, since path establishment will never be achieved instantaneously, the called party may commence talking before the calling
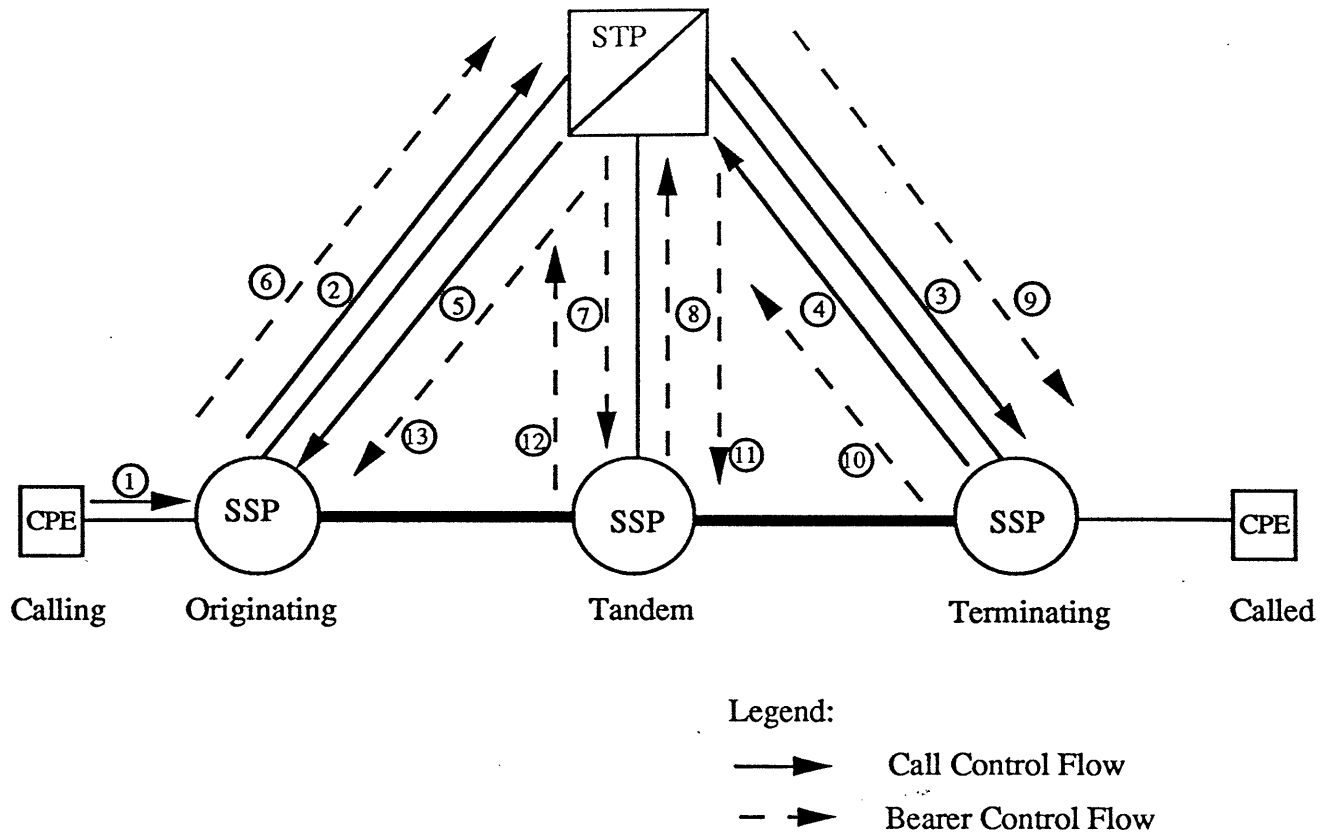
Figure 3: Separation of Call Control and Bearer Control

party has been connected. For the remainder of the paper it is assumed that the first method is used. Using the process of call control and bearer control separation, the call setup shown in Figure 2 is modified in the manner shown in Figure 3.

3 A Call Model for BISDN

As stated earlier, a call model is a finite state machine representation of the basic call processing in an IN environment. An IN call model consists of two half-call models: an originating half-call model and a terminating half-call model [4]. The SSP can be viewed as having two functionally separate sets of call processing logic that coordinate call processing activities to create and maintain a two-party call. The *originating basic call state model* (O_BCSM) models the call origination logic while the *terminating basic call state model* (T_BCSM) models the call termination logic. Figure 4 shows the two views of a call relative to the originating SSP,
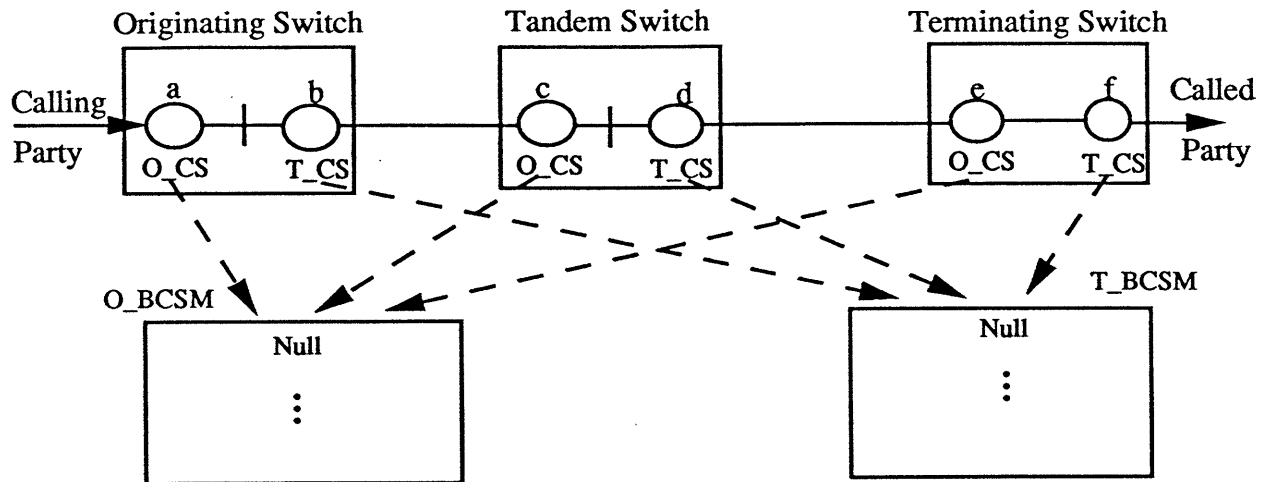
Figure 4: IN View of a Basic Call

a tandem SSP, and the terminating SSP. Each of these SSPs sees two segements of the call: an originating connection segment (O_CS) and a terminating connection segment (T_CS). The O_BCSM is associated with the O_CS, and the T_BCSM is associated with the T_CS.

The basic call state model (BCSM) consists of

- Points-in-Call (PICs), which represent "normal" call processing states in the switch

- Transitions between PICs

- Detection Points (DPs) where the IN service logic can assume control (i.e., where the SCP or adjunct can receive notification of a given event and influence subsequent call processing).

The Bellcore AIN Release 1 call model [4] is designed for single bearer calls. Also it assumes no separation between the call control and the bearer control. A BISDN call is expected to contain multiple bearer services. These bearer services may not act independently; one bearer service may affect others, especially through the process of *call synchronization*. That is, even though one bearer service setup is successful, the bearer may not be presented to the called party until other bearer services have been successfully setup. Also, the AIN Release 1 call

10

model is designed such that all SSPs have the same view of a call. But in an ATM network, due to the separation of call control and bearer control, only the originating and terminating SSPs are involved in the call control phase and all SSPs on the path for each bearer service are involved in the bearer control phase.

In an intelligent (narrowband) network, the triggers are provisioned on a line-by-line (or terminal-by-terminal) basis. Thus the terminating SSP knows the capability of each terminal equipment connected to it. With BISDN where the subscriber's equipment that interfaces the terminating SSP (i.e., the customer premises equipment, or CPE) can be a private ATM switch, knowledge of the capability of the called party's terminal equipment is not likely to be available to the terminating SSP. Therefore, it is necessary that prior to presenting a call to a called party the terminating SSP ascertains the capability of the CPE to handle the call. Thus one PIC in the T_BCSM deals with a negotiation between the terminating SSP and the called party's facility. The negotiation is necessary because the SSP may be able to support all the bearer services in a call but the facility may only be able to support a subset of the services. Thus in addition to the usual negotiation between the originating SSP and the terminating SSP, there is a negotiation between the terminating SSP and the CPE. After a successful negotiation between the terminating SSP and the facility, the latter is *marked*. Marking means that the when the bearer service path is established (and hence the service is to be presented), there is no more need to hunt for the facility as is necessary in SSPs that are not the terminating SSP.

There are essentially two parts to the model: the first part that deals with the entire call, and the second part that deals with individual bearer services within the call. This notion is fully shown in Figures 5 and 6 that show the essential PICs in the originating basic call model and the terminating call model, respectively, for a call that contains three bearer services. Each part of the model is denoted by a *submodel*. For the originating call model, the submodel for each bearer service is activated after the originating and terminating ATM switches have successfully negotiated the QOS parameter values. Similarly, for the terminating call model, the submodel for each bearer service is activated after the facility has been marked.
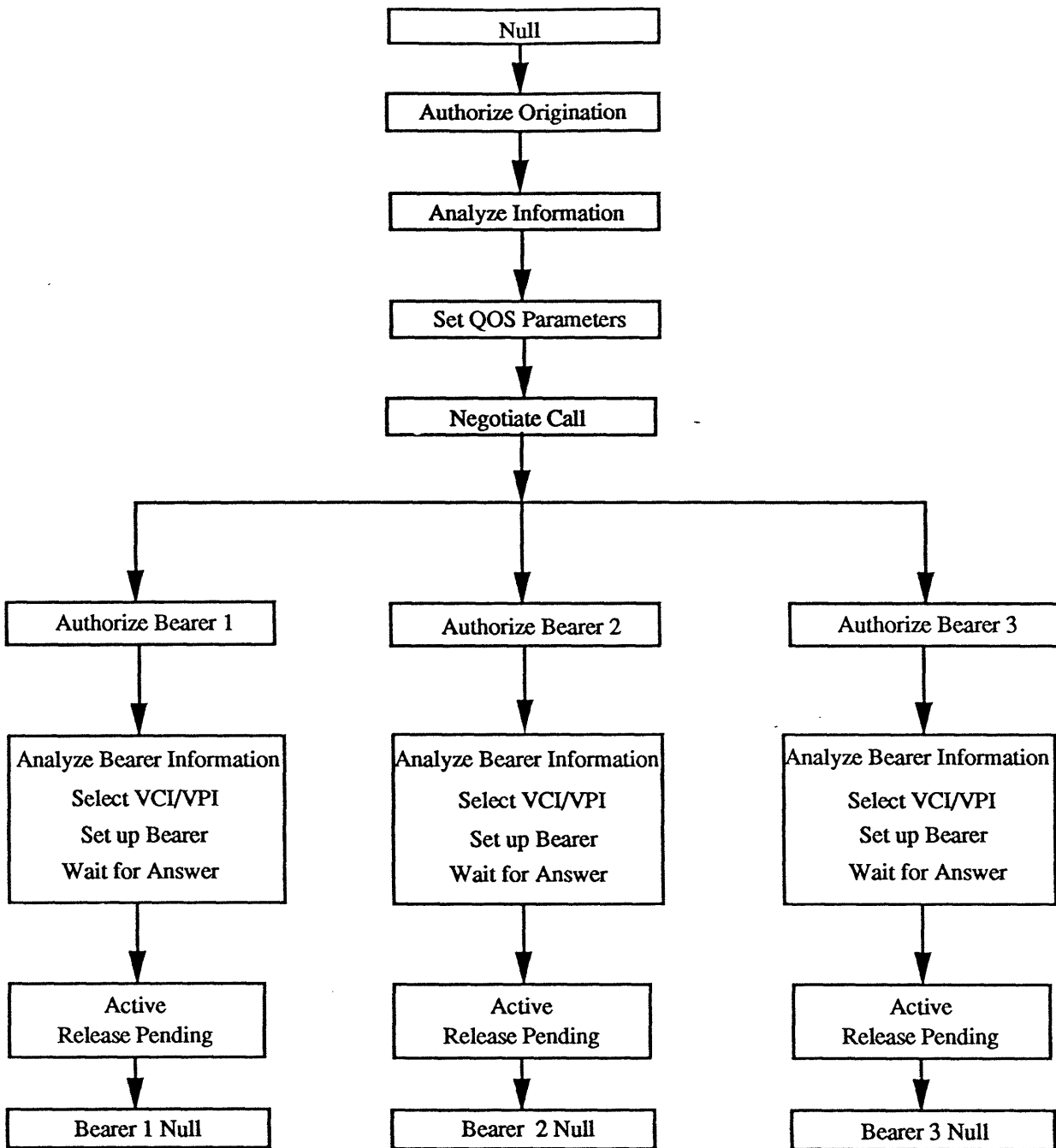
11

```
                        ┌──────────────┐
                        │     Null     │
                        └──────┬───────┘
                               ▼
                      ┌─────────────────────┐
                      │ Authorize Origination│
                      └──────────┬──────────┘
                                 ▼
                      ┌─────────────────────┐
                      │ Analyze Information  │
                      └──────────┬──────────┘
                                 ▼
                      ┌─────────────────────┐
                      │  Set QOS Parameters  │
                      └──────────┬──────────┘
                                 ▼
                      ┌─────────────────────┐
                      │    Negotiate Call    │   -
                      └──────────┬──────────┘
```

Figure 5: Overview of Originating Basic Call State Model for a Three-Bearer Service Call

```
                    ┌─────────────────────┐
                    │        Null         │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Authorize Termination│
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Analyze QOS Parameters│
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Negotiate with Facility│
                    │    Mark Facility    │
                    │   Authorize Call    │
                    └─────────────────────┘
```

┌───────────────────────────────┬───────────────────────────────┬───────────────────────────────┐
│ Authorize Bearer 1 Termination│ Authorize Bearer 2 Termination│ Authorize Bearer 3 Termination│
└───────────────────────────────┴───────────────────────────────┴───────────────────────────────┘

Hunt Facility	Hunt Facility	Hunt Facility
Present Bearer 1	Present Bearer 2	Present Bearer 3
Alerting	Alerting	Alerting

| Active | Active | Active |
| Release Pending | Release Pending | Release Pending |

| Bearer 1 Null | Bearer 2 Null | Bearer 3 Null |

Figure 6: Overview of Terminating Basic Call State Model for a Three-Bearer Service Call
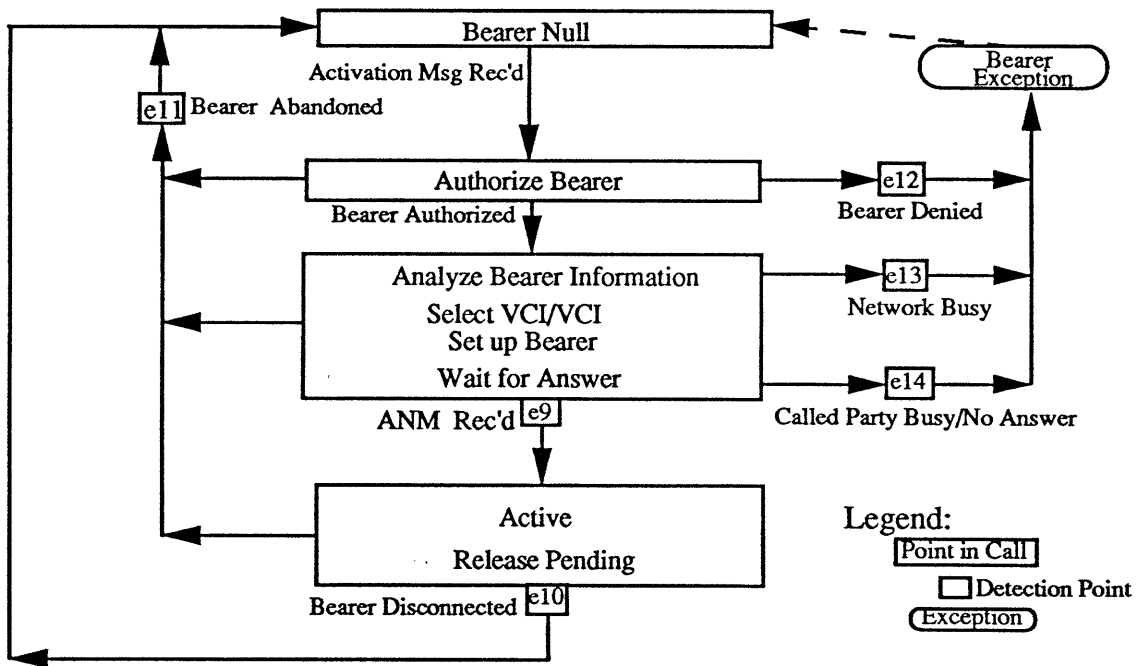
3.1 Originating Basic Call State Model

The details of the originating basic call state model are shown in Figure 7. Section (a) of the figure is the submodel for the entire call and section (b) is the submodel for a bearer service. For a complex call that contains more than one bearer service, the submodel for each bearer service runs in parallel with those of the other bearer services in the call. Only the ATM switches that are involved with the call control phase of the signaling execute submodel (a), but every ATM switch on the path of a bearer service executes submodel (b). Note that a bearer service may be terminated while the call is still active; a call remains in the **Active/Release Pending** PIC as long as at least one bearer service has not been terminated. Thus, the PIC **Bearer Null** is used to indicate when a bearer service has been disconnected. A stable call is terminated when all bearer services are in the **Bearer Null** PIC. This method of splitting the call model into two submodels, one for the call and the other for the bearer services, permits the originating and terminating ATM switches to maintain a global view of the call as well as a view of each bearer service in the call while the other switches maintain a non-global view of the call through the bearer service that needs their resources.

Because of the need for the adjunct to make the necessary association between a call and its bearer services and to keep track of when a bearer service ends, a persistent call model is required. Thus the detection points are as follows:

1. *SETUP Message Received (e1)*: When the SSP receives a setup message from a user, it informs the adjunct so that the necessary billing functions can be invoked.

2. *Information Analyzed (e2)*: After the different bearer services in a call have been identified, the SSP informs the adjunct to make the necessary association between the upcoming bearer submodels. Also, if the called number needs special treatment (e.g., an 800 number), the SSP queries the adjunct for routing instructions.

3. *Negotiation Successful (e3)*: When the SSP receives a message that the end-to-end negotiation is succesful, it informs the adjunct so that a bearer submodel can be initiated for each bearer service.
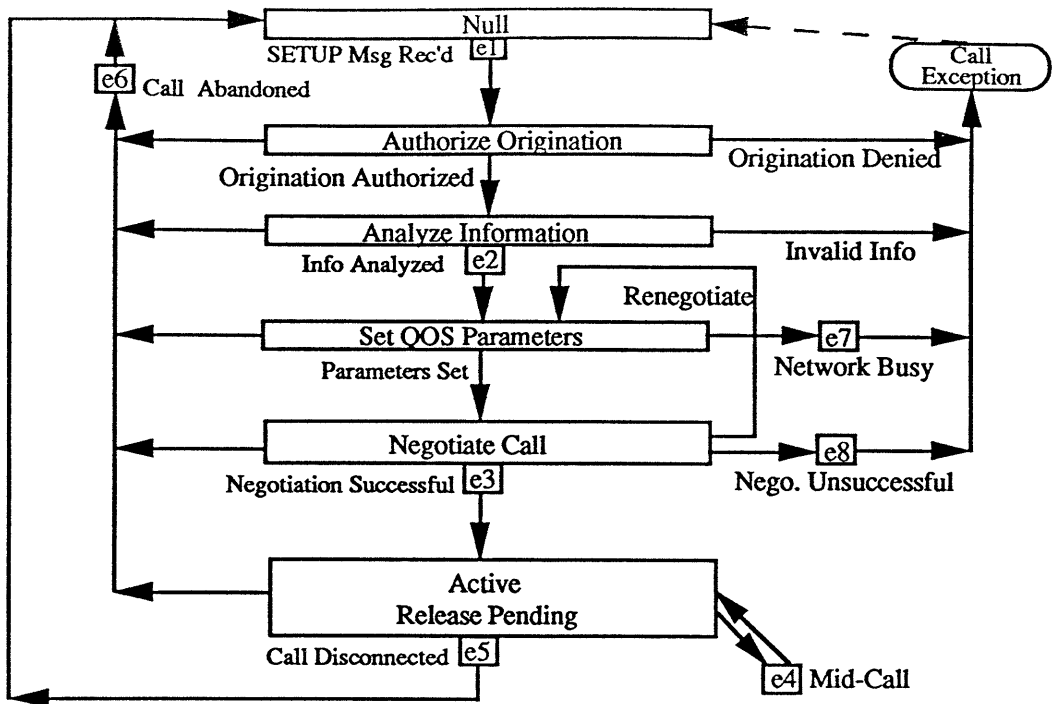
14

(a) Submodel for Call

(b) Submodel for Bearer

Figure 7: Originating Basic Call State Model

15

4. *Mid-Call (e4)*: The mid-call trigger is detected when a bearer service is in the active phase and the SSP receives a feature activation message. This can be used to alter the bandwidth of a call (by either adding a new bearer service or deleting an existing service) or to toggle between bearers in different calls in call waiting. If a new bearer service is to be established, the adjunct instructs the SSP to go the *Analyze Information* PIC.

5. *Call Disconnected (e5)*: This is detected when the SSP receives a message on the termination of every bearer service. The SSP informs the adjunct so that control of the call is cancelled.

6. *Call Abandoned (e6)*: This is detected when the SSP receives a DISCONNECT message from the calling party at any phase of the call. The SSP informs the adjunct so that any necessary billing function can be performed.

7. *Network Busy (e7)*: If by establishing the call the network resource utilization will be pushed above a pre-defined threshold, the call will be denied and the SSP informs the adjunct to cancel control of the call.

8. *Negotiation Unsuccessful (e8)*: If a message is received that the end-to-end negotiation is unsuccessful, the SSP informs the adjunct so that control of the call can be cancelled.

9. *ANM Received (e9)*: When the SSP receives the Answer Message (ANM), it queries the adjunct to determine if the bearer service processing can enter the **Active/Release Pending** PIC since synchronization of the starting time of all bearer services may be necessary.

10. *Bearer Disconnected (e10)*: This is detected when the SSP receives a RELEASE message from the terminating end. The SSP informs the adjunct so that any association between the bearer and other bearers can be deleted.

11. *Bearer Abandoned (e11)*: This is detected when the SSP receives a DISCONNECT message from the calling party at any phase after the bearer submodel has been initiated. The SSP informs the adjunct and the latter deletes the membership of the bearer from any association linked to it, and the necessary billing function can be performed.

12. *Bearer Denied (e12)*: If the bearer authorization is denied, especially at tandem switches, the SSP informs the adjunct so that the association with other bearers in the call can be cancelled.

13. *Network Busy (e13)*: If by establishing the bearer the network resource utilization will be pushed above a pre-defined threshold, the bearer will be denied. The SSP informs the adjunct to cancel all necessary associations between the bearer service and other bearer services.

14. *Called Party Busy/No Answer (e14)*: If the called party is busy or there is no answer, the SSP informs the adjunct so that any association between the bearer and other bearers can be cancelled.

The primary role of the DPs e12, e13 and e14 is to enable the adjunct to cancel any association between the bearer and other bearers when any bearer exception condition is satisfied. Note that DPs e12 and e13 are particularly applicable to tandem switches since the originating and terminating switches have already authorized the bearer service during the call negotiation process.
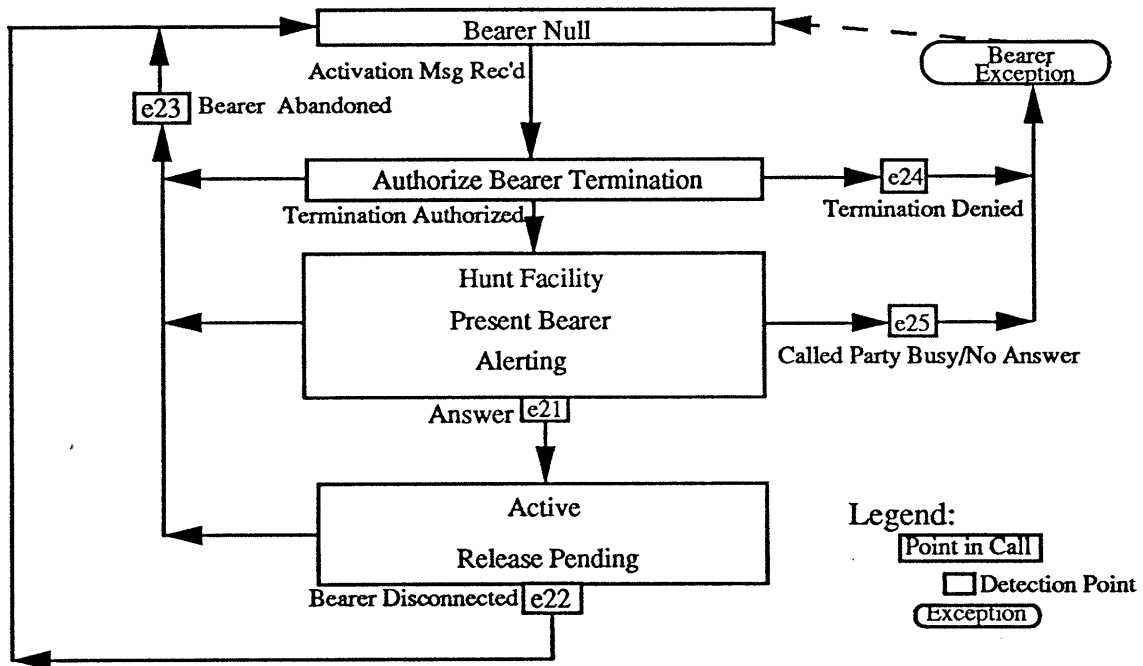
3.2   Terminating Basic Call State Model

The details of the terminating basic call state model are shown in Figure 8. As in the case of the O_BCSM, submodel (a) deals with the entire call while submodel (b) deals only with a bearer service. The detection points are as follows:

1. *SETUP Message Received (e15)*: When a call control request is received from the originating side of the basic call state model, the SSP informs the adjunct so that the necessary billing function is invoked.

2. *Negotiation Successful (e16)*: After all negotiations have been successfully completed, the SSP informs the adjunct so that all necessary associations between the call and the anticipated individual bearer services can be made.
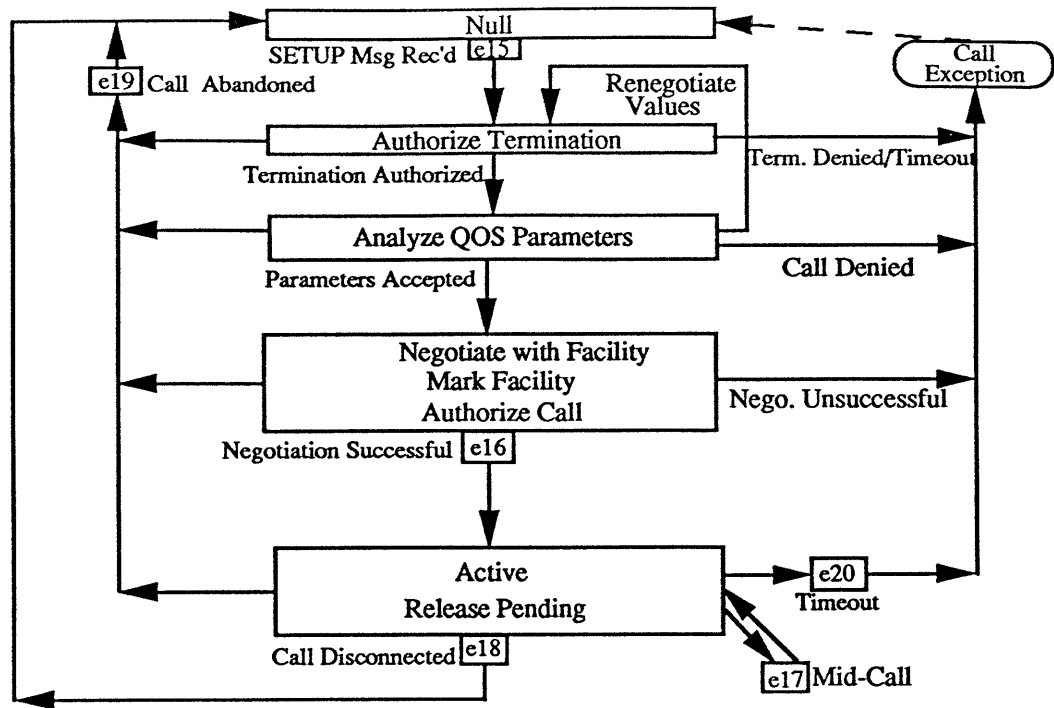
17

(a) Submodel for Call

(b) Submodel for Bearer

Figure 8: Terminating Basic Call State Model

3. *Mid-Call (e17)*: This is similar to e4.

4. *Call Disconnected (e18)*: This is similar to e5.

5. *Call Abandoned (e19)*: This is similar to e6.

6. *Timeout (e20)*: If the bearer setup requests are not received within a pre-defined time after the successful negotiation, the terminating SSP cancels the call and informs the adjunct to cancel control of the call.

7. *Answer (e21)*: After Answer message is received from the called party, the SSP inquires from the adjunct whether to make the bearer active or wait until it has been informed. (This is particularly applicable to the terminating SSP.)

8. *Bearer Disconnected (e22)*: This is similar to e10.

9. *Bearer Abandoned (e23)*: This is similar to e11.

10. *Bearer Termination Denied (e24)*: If the bearer termination is denied, the SSP informs adjunct so that association with other bearers can be cancelled.

11. *Called Party Busy/No Answer (e25)*: If the called party does not answer or a busy signal is received, the SSP informs the adjunct so that all associations with other bearers can be cancelled.

The primary role of DPs e24 and e25 is to enable the adjunct to cancel the association between the bearer and other bearers when a bearer exception condition is satisfied.

4   Connection View of BISDN Call

The connection view provides the status of connections within a half call (originating half call or terminating half call). It represents call parties within the view by *legs*, and the legs can be
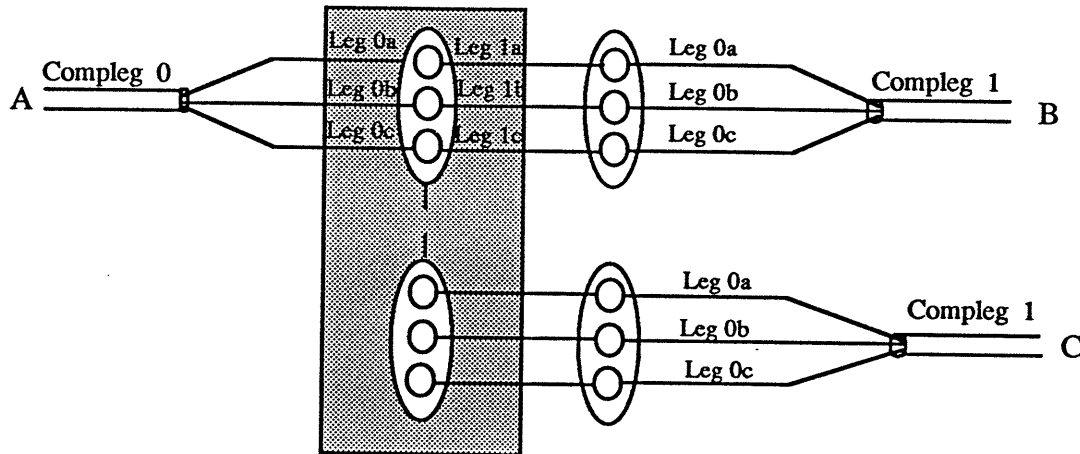
19

Figure 9: A and B Active in 3 Connections, C on Hold

manipulated to allow IN to change connections between call parties. For BISDN, we use the term *compound legs* (or complegs) for calls and reserve the term *legs* for bearer services within a call. Thus, a compleg can consist of one or more legs. Note that the compleg is seen only by the originating and terminating switches. The tandem switches see the individual legs. A tandem switch can see all the legs in a compleg, but it sees them not as one unit but as single entities. A compleg can be manipulated as a single unit, and the legs can be manipulated individually. Compleg and leg manipulation includes deletion and merging. Figure 9 shows the connection view for three parties A, B and C. Currently all the three connections of A and B are active while those of C are on hold. Figure 10 shows a three-way call in which C has been merged with A and B. Figure 11 shows the three-way call in which one connection in C has been deleted. This is equivalent to a conference call in which one component, such as graphics, is disconnected for one of the parties.
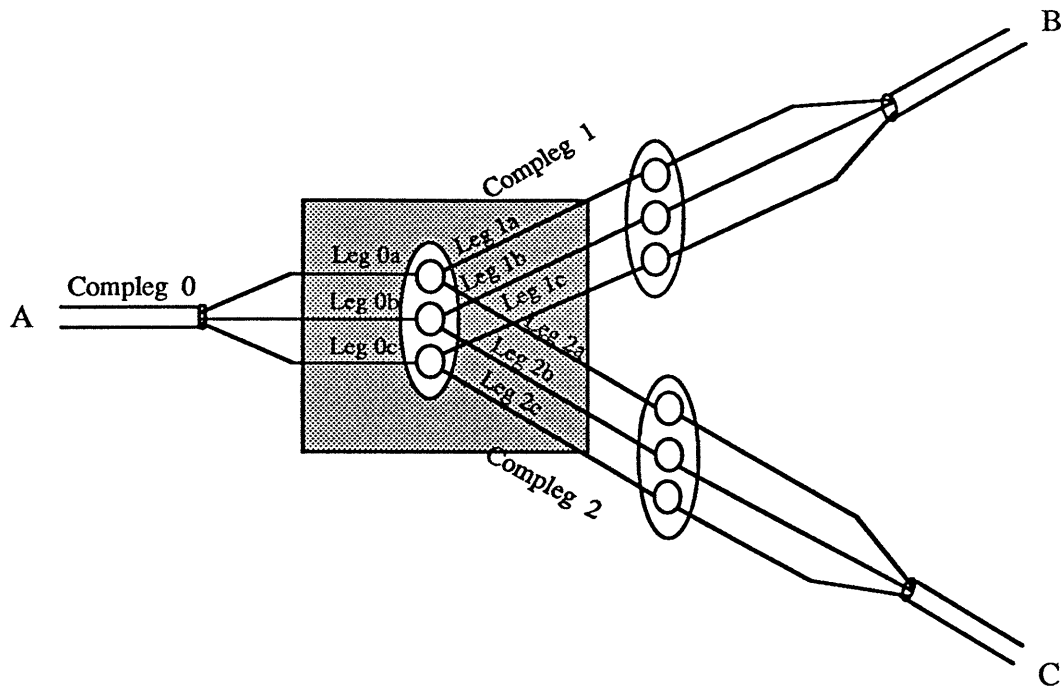
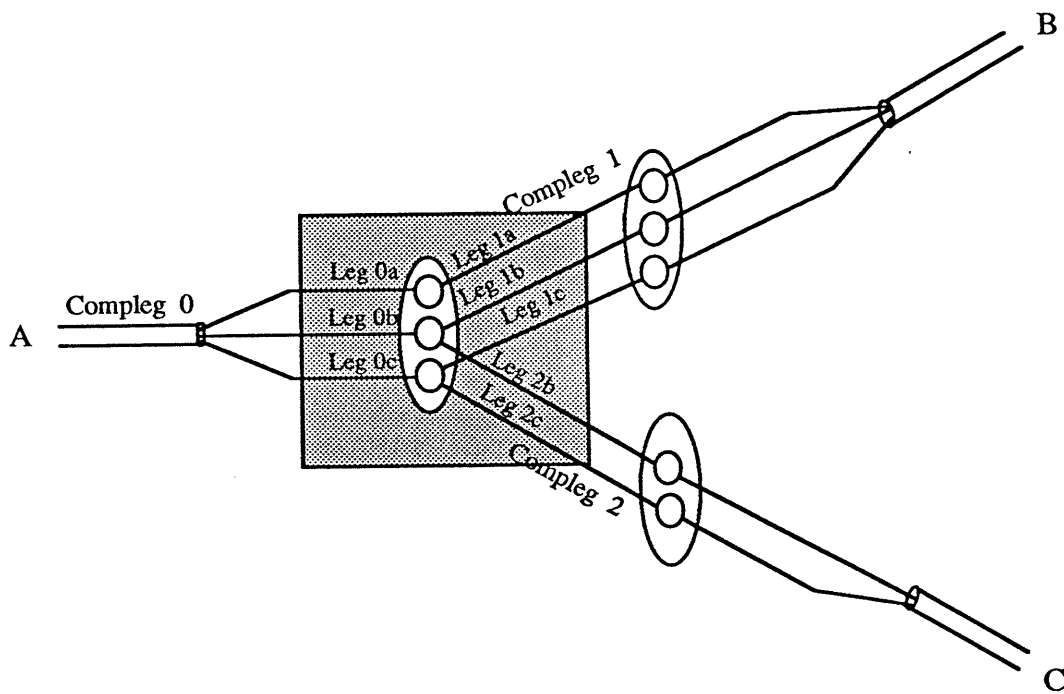Figure 10: A, B and C Merged for all 3 Connections

Figure 11: Three-way Call with 1 Connection in C Deleted

21

5 Conclusion

A framework of a call model for broadband IN has been presented. A bottom-up approach has been taken which builds upon the knowledge of call models for narrowband networks. The model incorporates the concept of separation of call control and bearer control. The model also splits the O_BCSM and the T_BCSM into two submodels, one submodel for the entire call and the other for the bearer services within the call. This permits the originating and terminating switches to maintain a global view of each call while the other switches maintain only a local view of a call via the individual bearer services. It is hoped that this approach will lead to an easier implementation of the call model.

Acknowledgement

References

[1] Bellcore, "Advanced Intelligent Network 0.1 Switching Systems Generic Requirements," TR-NWT-001284, August 1992.

[2] Bellcore, "Advanced Intelligent Network 0.1 Switch-Service Control Point (SCP) Application Protocol Interface Generic Requirements," TR-NWT-001285, August 1992.

[3] ITU-TS, "B-ISDN Signalling Capabilities Sets," Study Group 11, Document DT/11/PMG1, Geneva, May 1993.

[4] Bellcore, "Advanced Intelligent Network Release 1 Proposal," SR-NPL-001509, Issue 1, November 1989.

[5] Bellcore, "Advanced Intelligent Network Release 1 Baseline Architecture," SR-NPL-001555, Issue 1, March 1990.

[6] Bellcore, "Advanced Intelligent Network Release 1 Network and Operations Plan," SR-NPL-001623, Issue 1, June 1990.

[7] R.B. Robrock, "The intelligent network – Changing the face of telecommunications," *Proceedings of the IEEE*, volume 79, pp. 7-20, January 1991.

[8] CCITT, "Broadband Aspects of ISDN," Recommendation I.121, Blue Book, Melbourne, November 1988.

[9] CCITT, "BISDN Asymchronous Transfer Mode Functional Characteristics," Recommendation I.150, Geneva, 1992.

[10] R. Handel and M.N. Huber, *Integrated Broadband Networks: An Introduction to ATM-Based Networks,* Reading, MA: Addison-Wesley, 1991.

[11] CCITT, "Baseline Text for Harmonized Signalling Requirements," Study Group 11, Document WP XI/4-3, Geneva, October 1992.