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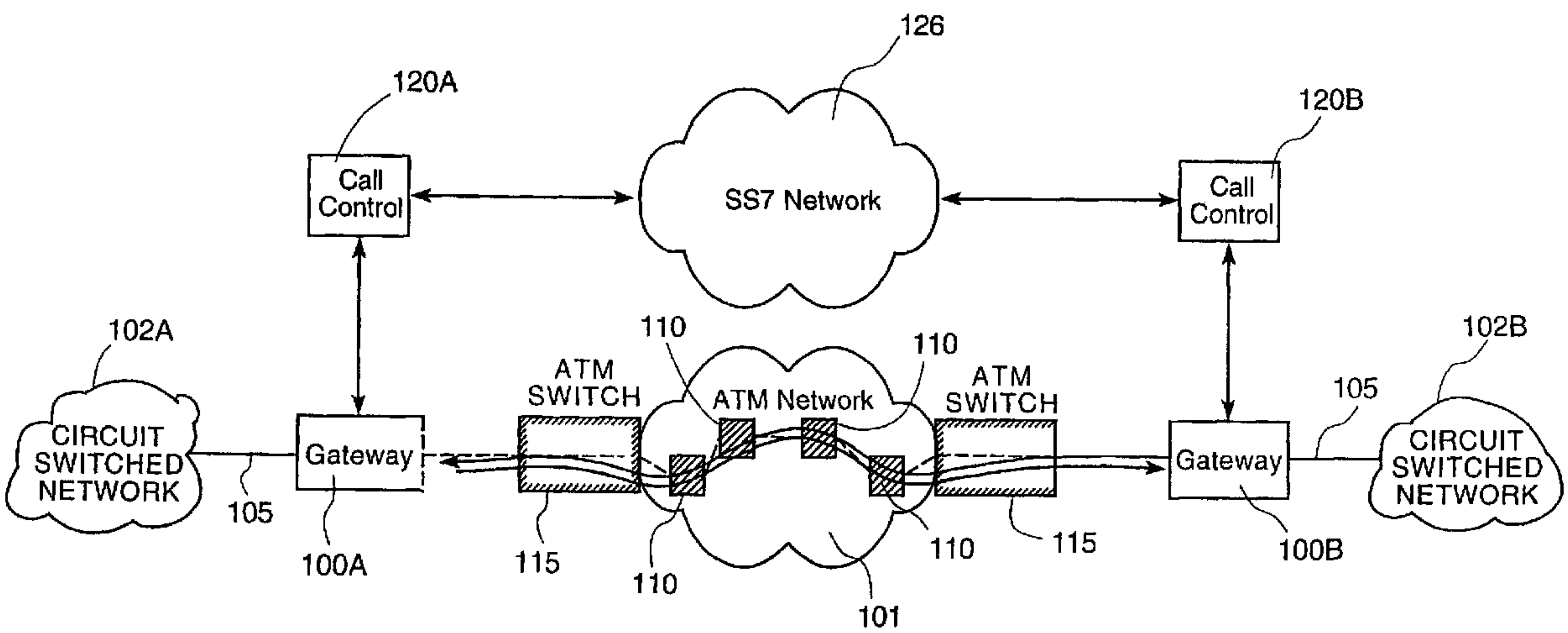
(54) Title: COMMUNICATIONS USING HYBRID CIRCUIT-SWITCHED AND PACKET-SWITCHED NETWORKS



(57) Abrégé/Abstract:
Techniques for communicating include transporting circuit-switched narrowband traffic over a packet network (101) and delivering the narrowband traffic from the packet network to a circuit-switched network (102B). The circuit-switched narrowband traffic can be transported dynamically over the packet network (101), and multiple circuit-switched narrowband calls can be multiplexed over a single connection in the packet network. A system incorporating such techniques can support voice or other narrowband calls over a packet backbone network, while interfacing seamlessly with an existing SS7-based public telephone network (126) that uses circuit-switched technology.

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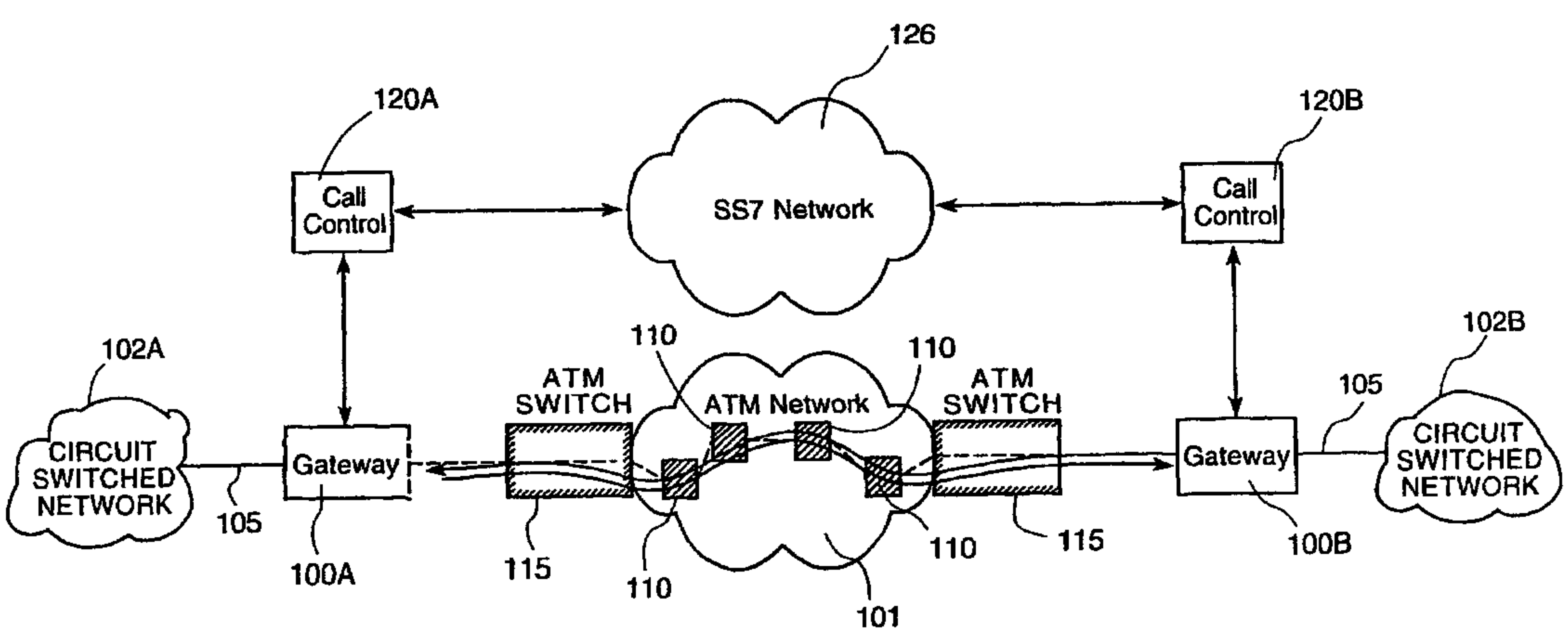

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COMMUNICATIONS USING HYBRID CIRCUIT-SWITCHED AND PACKET-SWITCHED NETWORKS

BACKGROUND

The invention relates to communications using hybrid circuit-switched and packet-switched networks.

A traditional telephone exchange configuration provides circuit connections between remote locations. Many of the telecommunications networks currently used are synchronous digital networks. Digitized voice communications are transmitted synchronously over the networks at a fixed rate. Discrete time periods (time slots) are packed with the digital information for a particular call, and digital information for multiple calls can be packed sequentially to form a time division multiplexed (TDM) data stream. The connections may be provided, for example, using network switches having dedicated inter-switch connections. Because the number of inter-switch connections is static, the number of incoming circuits that can be routed to each output port of the exchange also is static.

Situations may arise in which the demand for connections to a particular location reaches its limit, while the demand for connections to another location is below its limit. In such cases, it would be advantageous to be able to reconfigure the network connections to allow more circuits to be connected to the location having the high demand. However, that is not possible in a system having dedicated inter-switch connections. In addition, systems using time division multiplexing are not easily scalable. As connections are added, the availability of tandem-layer switches can become quickly exhausted.

Packet-domain network architectures, such as asynchronous transfer mode (ATM) networks, allow connections to be made between endpoints without dedicated inter-switch connections. Fixed-size packets of data, known as cells, are transferred between the ATM switches, which are packet switches that provide virtual circuits between the end points of a network. The virtual circuits may be reconfigured depending upon data traffic volume. Hence, an ATM network can provide a more efficient way to connect end points in a network with rapidly changing connectivity requirements, such as a telephone system.

SUMMARY

According to one aspect, a method of communicating includes transporting circuit-switched narrowband traffic over a packet network and delivering the narrowband traffic from the packet network to a circuit-switched network. In various implementations, the connection through the packet network for the narrowband traffic can be provided dynamically. Multiple circuit-switched narrowband calls can be multiplexed over a single connection in the packet network.

According to another aspect, a method of establishing a path for narrowband traffic includes establishing a packet network connection between first and second interface points in one or more circuit-switched networks. The packet network connection is associated with a narrowband circuit allocated to service the narrowband traffic.

Various implementations may include one or more of the following features. The packet network connection can include a switched virtual connection. An identification code that uniquely identifies a narrowband circuit allocated to service the traffic can be forwarded between first and second gateways configured to perform adaptations between circuit-switched signals and packet-switched bearers. The identification code can be forwarded from the first gateway to the second gateway, for example, using Signaling System 7 (SS7) messages. The identification code can include a DS0 circuit identification code.

The method also can include identifying a channel in the packet network connection over which the narrowband traffic is to be sent. The narrowband circuit allocated to service the call can be associated with the channel in the packet network connection.

In another aspect, a method of communicating includes multiplexing multiple circuit-switched narrowband calls over a single packet network connection and releasing resources allocated to service a particular one of the circuit-switched calls.

For example, resources in the packet network servicing the particular circuit-switched call can be released once the call is terminated.

A communications system also is disclosed and can include at least one circuit-switched network including first and second interface points, a packet network, and gateways coupled respectively to the interface points and the packet network. The gateways are configured to perform adaptations between circuit-switched bearers and packet-switched bearers. The system includes at least one controller arranged to provide call control signals to allow a packet network connection to be established between the first and second interface points and to allow the packet network connection to be associated with a narrowband circuit allocated to service narrowband traffic that is to be transported across the first and second interface points.

The techniques can be used with different types of packet networks.

Various implementations can include one or more of the following advantages. Service providers can consolidate circuit-switched and variable bit rate data services over a single, broadband network. High-quality narrowband services can be delivered over packet and cell networks, such as ATM and Internet Protocol (IP). In particular, the system can support voice or other narrowband calls over an ATM or IP backbone network, while interfacing seamlessly with an existing SS7-based public telephone network that uses circuit-switched technology. It also can provide better network utilization by ensuring that bandwidth is allocated where it is needed and not stranded in dedicated trunks as it is with circuit-switched networks.

Other features and advantages will be readily apparent from the following detailed description, the accompanying drawings and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a telephone connection through a hybrid ATM network and an associated signaling network.

FIG. 2 is a simplified block diagram of an exemplary media gateway.

FIG. 3 shows an exemplary conversion of a digital telephone signal bit stream into ATM cells.

FIG. 4 is a flow chart of a voice call set up process between TDM circuit switches over an ATM network.

FIG. 5 is a signal flow diagram for a voice call set up process between TDM circuit switches over an ATM network.

FIG. 6 is a signal flow diagram illustrating details of establishing a packet-domain connection for the voice call set up process of FIG. 5.

FIG. 7 is a signal flow diagram for an alternative voice call set up process between TDM circuit switches over an ATM network.

FIG. 8 is a signal flow diagram for a call set up process in which multiple TDM calls share a single ATM connection.

FIG. 9 is a signal flow diagram for releasing a voice call over an ATM connection.

DETAILED DESCRIPTION

A call control mechanism for carrying narrowband traffic, such as voice calls, modem data or facsimile data, over an asynchronous transfer mode (ATM) or other packet network connection is described below. In particular, a switching system is described that supports narrowband calls over a packet backbone network, while interfacing seamlessly with an existing SS7-based public telephone network that uses circuit-switched technology.

As shown in FIG. 1, a continuous call path is established starting with a narrowband Signaling System 7 (SS7) call that originates, for example, in a Public Switched Telephone Network (PSTN) 102A. The path is established using a virtual circuit over an ATM network 101 and completes on the terminating side in a narrowband circuit-switched SS7 call to the terminating subscriber through another circuit switched network 102B. The control mechanism interacts with the circuit-switched and packet-switched networks to correlate SS7 and ATM connections to establish a single continuous information path.

A large number of individual telephone circuits, such as DS0 circuits, that are to be connected to the packet network 101 can be carried, for example, on fiber optic carriers 105 using time-division multiplexing (TDM) according to the Telcordia Synchronous Optical Network (SONET) standards. The TDM carriers 105 are coupled to access ports 116 (*see* FIG. 2) in media gateways 100A, 100B.

The gateways 100A, 100B can adapt the TDM telephone line signals to packet-based signals and vice-versa. Each gateway 100A, 100B can separate incoming TDM signals into individual DS0 signal streams. The TDM telephone signals are circuit-switched, in other words, the bit stream can be divided temporally into individual DS0 circuits. By contrast, in packet-based signals, the bit stream can be divided according to the destination address of each packet.

In one implementation, shown in FIG. 2, each gateway, such as the gateway 100A, includes a TDM switching matrix 117 that provides full switching capabilities. The switching matrices 117 permit the DS0 circuits to be interconnected flexibly with narrowband channels appearing on the gateways. Echo cancellation and other digital signal processing functions can be performed in a digital signal processing portion 118 of each gateway. The DS0 streams are adapted by an ATM adaptation layer 120 into ATM cells. As shown in FIG. 3, the ATM adaptation layer 120 combines incoming DS0 signals from a particular carrier 105 into payloads 132 for ATM cells 130. A header 134 is provided as part of each cell 130 and can be interpreted by the gateway to identify which call the ATM cell is associated with. After the payload 132 of a cell 130 is loaded with data, the cell is inserted through the ATM ports 21 into the ATM cell stream 135 that traverses an ATM network 101. Each gateway includes a control section 119 that controls overall operation of the gateway. In one implementation, the gateways 100A, 100B are implemented as Salix 7720 Class-Independent Switches available from Tellabs Operations, Inc.

As illustrated in FIG. 1, each gateway 100A, 100B is connected to a respective ATM end point switch 115. The connection between a gateway and an ATM end point switch 115 and the connection between the ATM end point switch and the ATM network 101 are user-network interfaces (UNIs). Within the ATM network 101, there are a number of ATM switches 110 which are interconnected by network-node interfaces (NNIs).

A call control network 126, which forms part of an existing telephone system, runs parallel to the voice network. The call control network 126 primarily controls telephone switching equipment to connect the originating and terminating ends of a telephone call using SS7 messages. A call controller 120A, 120B is coupled to each gateway 100A, 100B and provides an interface between the gateway and the call control network 126. As discussed below, the exchange of call control signals allows the gateways 100A, 100B to establish a connection through the ATM network 101 to enable the transmission of narrowband traffic between the end points.

As shown in FIGS. 4 and 5, to establish a voice connection, a user at the originating end dials 210 a telephone number. A connection is established through an originating TDM circuit switch in the circuit switched network 102A, and the call controller 120A at the originating end receives 215 an SS7 initial address message (IAM) 150. The call controller 120A routes the call, in other words, it identifies a call controller 120B associated with a terminating DS0 circuit in the circuit switched network 102B. Next, the call controller 102A sends 220 a connection control message (CreateConn) 152 to the originating gateway 100A to initiate a connection through the ATM network 101. In response, the gateway 100A returns 225 an acknowledgement message (CreateAck) 154 that includes a connection descriptor ("conndesc"). The connection descriptor includes an ATM address for the gateway 100A as well as information that uniquely identifies the call. The information that uniquely identifies the call can identify a connection-related resource such as the narrowband circuit (e.g., DS0 circuit) handling the call on the originating side.

Next, the call controller 120A sends 230 an IAM message 156 to the terminating call controller 120B. The message 156 includes the information contained in the connection descriptor. Upon receiving the IAM message 156, the terminating call controller 120B routes the call. In other words, the terminating call controller 120B selects a TDM circuit on a particular gateway, such as the gateway 100B, to handle the call. The call controller 120B then sends 235 a connection control message (CreateConn) 158 to the terminating gateway 100B. The CreateConn message 158 also includes the information contained in the connection descriptor. In response, the terminating gateway 100B establishes 240 a packet domain connection with the originating gateway 100A through the packet network 101.

Details of establishing a packet-domain connection between the gateways 100A, 100B through the ATM network 101 are illustrated in FIG. 6. ATM Setup messages (e.g., UNI Setup and PNNI Setup messages) can be used to establish the packet-domain connection. For example, a UNI Setup message 160 is passed from the terminating gateway 100B to a first ATM switch 115. PNNI or B-ISUP Setup messages 162 are sent from one ATM switch 110, 115 to the next ATM switch 110, 115 in the network 101. Finally, a UNI Setup message 164 is sent from the last ATM switch 115 to the originating gateway 100A. Each of the UNI Setup and PNNI Setup messages 160, 162, 164 includes the information contained in the connection descriptor so that each network element in the packet domain connection is informed of the connection identifier that uniquely identifies the narrowband voice call. The originating gateway 100A then associates 245 the packet-domain connection with the circuit-domain connection.

The gateways 100A, 100B and ATM switches 110, 115 also negotiate the ATM routing headers that will be used between hops along the packet-domain connection. Various UNI connect messages 166, 174 and PNNI connect messages 170, as well as connect acknowledgement (Connect Ack) 168, 172, 176 messages can be used, as shown in FIG. 6. A control message (CreateAck) 178 then is sent by the terminating gateway 100B to the terminating call controller 120B to acknowledge that the packet-domain connection has been established for the voice call.

The terminating call controller 120B sends 250 a message to the originating call controller 120A to acknowledge that a connection has been established. The terminating call controller 120B also sends 255 a message to the terminating TDM circuit switch in the circuit switched network 102B to establish a connection to the called party's telephone set. Standard SS7 signaling occurs 260 between the terminating and originating ends to complete the voice call. The information contained in the connection descriptor can, therefore, be used to permit the implementation of a switching system that supports narrowband calls over an ATM or other packet backbone network, while interfacing seamlessly with an existing SS7-based public telephone network that uses circuit-switched technology.

The foregoing technique can be used when different call controllers 120A, 120B are associated with the gateways 100A, 100B. However, in some cases, both the originating and terminating gateways 100A, 100B may share a common call controller, such as the call controller 120A. In that case, a technique similar to that discussed above can be used with a single call controller performing the functions of both call controllers 120A, 120B. When the call controller 120A routes the call after receiving the IAM message 150 (FIG. 5), it selects the terminating TDM circuit switch and the corresponding terminating gateway 100B to handle the call. Also, when a single call controller 120A is involved, the IAM message 156 need not be used.

In the techniques described above, the packet-domain connection is established in the upstream (or backward) direction, in other words, from the terminating gateway 110B to the originating gateway 110A. That technique is particularly advantageous for minimizing the number of SS7 messages and, therefore, increasing the capacity of the call controllers to handle a greater number of calls. On the other hand, if the call setup crosses network boundaries, establishing the packet-domain connection in the upstream direction can limit the ability of the originating carrier to select the optimal route for the call. To allow the originating carrier to select an optimal route, the packet-domain connection can be established in the downstream (or forward) direction, in other words, from the originating gateway 100A to the terminating gateway 100B as illustrated in FIG. 7.

Referring to FIG. 7, when a subscriber at the originating end dials a telephone number, a connection is established through an originating TDM circuit switch in the circuit switched network 102A, and the call controller 120A at the originating end receives an IAM message 180. The call controller 120A routes the call, in other words, it identifies the call controller 120B associated with a terminating DS0 circuit in the circuit switched network 102B. Next, the call controller 102A sends an IAM message 182 to the terminating call controller 120B requesting that a connection be established for the call.

Upon receiving the IAM message 182, the terminating call controller 120B routes the call. In other words, the terminating call controller 120B selects a TDM circuit on a particular gateway, such as the gateway 100B, to handle the call. The call controller 120B then sends a connection control message (CreateConn) 184 to the terminating gateway 100B to initiate the packet-domain connection. In response, the gateway 100B returns an acknowledgment message (CreateAck) 186 that includes a connection descriptor ("conndesc"). In this case, the connection descriptor includes an ATM address for the terminating gateway 100B, as well as a connection identifier that uniquely identifies the connection-related resource (e.g., the DS0 circuit) handling the call on the terminating side.

The call controller 120B then sends an SS7 facility (FAC) or other ISUP message 188 to the originating call controller 120A. The message 188 includes the information contained in the connection descriptor. Upon receiving the IAM message 188, the originating call controller 120A sends a connection control message (CreateConn) 190 to the originating gateway 100A. The message 190 also includes the information contained in the connection descriptor. Next, the originating gateway 100A establishes a packet-domain connection with the terminating gateway 100B through the packet network 101. The details for establishing the packet-domain connection in the ATM network 101 are similar to those illustrated in FIG. 6, except that the connection is established in the forward direction rather than in the backward direction. Once the packet-domain connection is established, a connection control message (CreateAck) 192 is sent from the gateway 100A to the call controller 120A. As before, the information contained in the connection descriptor is used to permit the implementation of a connection that supports voice calls over an ATM backbone network, while interfacing seamlessly with an existing SS7-based public telephone network that uses circuit-switched technology. Once the packet-domain connection is established, the terminating gateway 100B can associate the packet-domain connection with the circuit-domain connection. Standard SS7 signaling can be used to complete the voice call. If both gateways 100A, 100B share a common call controller, then the SS7 messages 182, 188 can be eliminated.

The techniques described above can be used in cases where one narrowband call is assigned per ATM channel. In such situations, the setup messages for the packet-domain connection explicitly indicate which ATM virtual channel connection (VCC) to use, and the connection ID allows the gateway to associate the new VCC with the correct narrowband call. Where multiple TDM calls, however, are multiplexed over the same ATM connection, three distinct items must be identified: the narrowband call, the ATM connection, and the particular channel within the ATM cell that is associated with the call. When a virtual channel connection does not exist between the gateways 100A, 100B for the narrowband call to be multiplexed into, the connection can be established as previously described with the additional use of a network call correlation identifier (NCCI) to identify the specific ATM VCC. For example, when the terminating gateway 100B establishes the packet-domain connection through an ATM Setup message, it includes the NCCI which then is communicated to the originating gateway 100A. Both gateways 100A, 100B store the NCCI and associate it with the specific ATM VCC.

For subsequent narrowband calls that are to be multiplexed onto the same ATM VCC, ATM Setup messages are not required because the ATM connection already has been established. Therefore, another mechanism is provided to communicate to the originating gateway 100A which channel to use in the ATM VCC. As shown in FIG. 8, establishing a voice call over the same ATM VCC initially can proceed in the same manner as described previously with respect to FIG. 5. In other words, the messages 152, 154, as well as the messages 154, 156 and 158 that contain the information for the connection descriptor (conndesc), are sent as previously described. Upon receiving the CreateConn message 158, the terminating gateway 100B recognizes the originating gateway 100A as the source of the call and determines that there already is an active VCC to the gateway 100A. The terminating gateway 100B then allocates a TDM circuit switch in the network 102B to be used for the current call. The gateway 100B also determines the NCCI of the ATM VCC to be used. Finally, the gateway selects an unused channel in the VCC and determines the channel identifier (CID).

The NCCI and the CID are communicated to the originating gateway 100A. To accomplish that, the termination gateway 100B returns a connection control message (CreateAck) 300 to the terminating call controller 120B. The message 300 includes the information contained in the original connection descriptor (conndesc), as well as the NCCI, the CID and the ATM address for the terminating gateway 100B. The call controller 120B then sends an FAC or other SS7 message 302 to the originating call controller 120A. The message 302 forwards the information contained in the connection descriptor (conndesc), as well as the NCCI, the CID and the ATM address for the terminating gateway 100B, to the call controller 120A. The call controller 120A sends a message (ModifyConn) 304 to the originating gateway 100A. The message 304 also includes the information contained in the connection descriptor (conndesc), as well as the NCCI, the CID and the ATM address for the terminating gateway 100B. The gateway 100A uses that information to associate the previously allocated TDM circuit with the correct ATM VCC (as indicated by the NCCI) and the correct channel within the VCC (as indicated by the CID). Finally, the gateway 100A sends a message (ModifyAck) 306 to the call controller 120A to acknowledge the association of the circuit-switched connection with the particular channel in the ATM VCC.

FIG. 9 illustrates a process of releasing a call, for example, when the party that initiated the call hangs up its telephone set. The originating TDM circuit switch sends an SS7 release message (REL) 310 to the call controller 120A identifying which DS0 circuit was handling the call. In response, the call controller 120A sends a delete message (DEL) 312 to the originating gateway 100A. The message 312 includes the information contained in the connection descriptor (conndesc), as well as the NCCI and the CID, to identify the call that is being terminated, the ATM VCC and the particular channel within the VCC. The gateway 100A then returns a message (Delete Ack) 316 to the originating call controller 120A to indicate that the ATM channel identified by the CID is now free and that the gateway no longer contains an association between the TDM circuit switch and the ATM channel used for the call. The call controller 120A recognizes that the TDM trunk previously used for the call is now idle and is available to be used for other telephone calls. Once the call controller

120A receives the Delete Ack message 316, it sends an SS7 release complete message (RLC) 318 to the originating TDM circuit switch.

In some cases, for example, if the call to be released is the last remaining call on the particular ATM VCC, the gateway 100A also may initiate UNI/NNI signaling 314 to release the internal resources dedicated to the ATM connection. The UNI/NNI release message is relayed through the ATM network 101. Each ATM switch 110 receives the release message, releases the path for the connection, and responds with a release complete message.

The call controller 120A also sends an SS7 message (REL) 320 to the terminating call controller 120B. The REL message 320 includes the information contained in the connection descriptor, as well as the NCCI and the CID, to identify the call that is being terminated, the ATM VCC and the particular channel within the VCC. Once the originating call controller 120A sends the REL message 320, it recognizes that the packet trunk previously used for the call is idle and can be used for other calls.

When the terminating call controller 120B receives the REL message 320, it sends a message (Delete) 322 to the terminating gateway 100B. The Delete message 322 also includes the information contained in the connection descriptor, as well as the NCCI and the CID. In response, the gateway 100B returns a message (Delete Ack) 324 to the terminating call controller 120B to indicate that the ATM channel identified by the CID is now free and that the gateway no longer contains an association between the terminating TDM circuit switch and the ATM channel used for the call. The terminating call controller 120B recognizes that the packet trunk previously used for the call is now idle and can be used for other calls.

The terminating call controller 120B sends an SS7 release message (REL) 326 to the terminating ATM circuit switch and sends a release complete message (RLC) 328 to the originating call controller 120A. The terminating TDM circuit switch returns an SS7 release complete message (RLC) 330 to the call controller 120B, which recognizes that the terminating TDM trunk is now idle and can be used for other telephone calls. Release of the resources associated with the call is completed.

In some implementations, some of the messages, such as the CreateConn, Create Ack, Delete, Delete Ack, Modify and Modify Ack, are Media Gateway Control Protocol (MGCP) messages, although other protocols can be used as well.

Although the foregoing implementations have been described with respect to ATM networks, circuit-switched traffic can be routed over other packet-domain networks, such as frame relay, Ethernet and Internet Protocol (IP) networks, as well.

Various features of the system can be implemented in hardware, software, or a combination of hardware and software. For example, some aspects of the system can be implemented in computer programs executing on programmable computers. Each program can be implemented in a high level procedural or object-oriented programming language to communicate with a computer system. Furthermore, each such computer program can be stored on a storage medium, such as read-only-memory (ROM) readable by a general or special purpose programmable computer, for configuring and operating the computer when the storage medium is read by the computer to perform the functions described above.

Other implementations are within the scope of the claims.

What is claimed is:

1. A method of communicating comprising:

transporting circuit-switched narrowband traffic over a packet network; and

delivering the narrowband traffic from the packet network to a circuit-switched network.

2. The method of claim 1 including dynamically providing a connection through the packet network for the narrowband traffic.

3. The method of claim 1 including multiplexing multiple circuit-switched narrowband calls over a single connection in the packet network.

4. The method of claim 1 wherein the packet network comprises an asynchronous transfer network.

5. The method of claim 1 wherein the packet network comprises an Internet Protocol network.

6. The method of claim 1 wherein the packet network comprises a frame relay network.

7. The method of claim 1 wherein the packet network comprises an Ethernet network.

8. A method of establishing a path for narrowband traffic comprising:

establishing a packet network connection between first and second interface points in one or more circuit-switched networks; and associating the packet network connection with a narrowband circuit allocated to service the narrowband traffic.

9. The method of claim 8 wherein the packet network connection comprises a switched virtual connection.

10. The method of claim 8 including forwarding an identification code from a first gateway to a second gateway, wherein the gateways are configured to perform adaptatons between circuit-switched bearers and packet-switched bearers, and wherein the identification code uniquely identifies a narrowband circuit allocated to service the traffic.

11. The method of claim 10 wherein forwarding the identification code from the first gateway to the second gateway includes using Signaling System 7 messages.

12. The method of claim 10 wherein the identification code is forwarded from the first gateway to the second gateway in a direction in which the narrowband traffic is to be sent and includes using Signaling System 7 messages, and wherein the identification code is forwarded from the second gateway to the first gateway through the packet network during establishment of the packet network connection.

13. The method of claim 10 wherein the identification code is forwarded from the first gateway to the second gateway in a direction opposite the direction in which the narrowband traffic is to be sent and includes using Signaling System 7 messages, and wherein the identification code is forwarded from the second gateway to the first gateway through the packet network during establishment of the packet network connection.

14. The method of claim 10 wherein the identification code comprises a DS0 circuit identification code.

15. The method of claim 10 including communicating from one gateway to the other gateway a channel identifier that indicates over which channel in the packet network connection the narrowband traffic is sent.

16. The method of claim 8 including identifying a channel in the packet network connection over which the narrowband traffic is to be sent.

17. The method of claim 8 including associating the narrowband circuit with a channel in the packet network connection over which the traffic is to be sent.

18. A method of establishing a path for narrowband traffic comprising:

associating a packet network stream transmitted between first and second interface points in one or more circuit-switched networks with a narrowband circuit allocated to service the narrowband traffic.

19. A method of communicating comprising:

multiplexing multiple circuit-switched narrowband calls over a single packet network connection; and

releasing resources allocated to service a particular one of the circuit-switched calls after the particular call is terminated.

20. The method of claim 19 including releasing resources in the packet network allocated to service the particular circuit-switched call.

21. A call controller for use in a communications system, wherein the call controller is configured to provide call control signals to allow a packet network connection to be established between first and second interface points in one or more circuit-switched networks and to allow the packet network connection to be associated with a narrowband circuit allocated to service narrowband traffic that is to be transported across the first and second interface points.

22. The call controller of claim 21 configured to provide call control signals to allow the narrowband circuit to be associated with a particular channel in the packet network connection.

23. A call controller for use in a communications system, wherein the call controller is configured to provide call control signals to allow release of packet network resources allocated to service a particular one of multiple circuit-switched narrowband calls multiplexed over a single packet network connection after the particular call is terminated.

24. A communications system comprising:

at least one circuit-switched network including first and second interface points;

a packet network;

gateways coupled respectively to the interface points and the packet network, wherein the gateways are configured to perform adaptations between circuit-switched bearers and packet-switched bearers; and

at least one controller arranged to provide call control signals to allow a packet network connection to be established between the first and second interface points and to allow the packet network connection to be associated with a narrowband circuit allocated to service narrowband traffic that is to be transported across the first and second interface points.

25. The system of claim 24 wherein the controller is arranged to provide call control signals to identify a channel in the packet network connection over which the narrowband traffic is to be sent.

26. The system of claim 24 wherein the call control signals comprise Signaling System 7 messages.

27. The system of claim 24 wherein the packet network connection comprises a switched virtual connection.

28. An article comprising a computer-readable storage medium including computer-executable instructions for causing a computer system to:

establish a packet network connection between first and second interface points in one or more circuit-switched networks; and

associate the packet network connection with a narrowband circuit allocated to service narrowband traffic to be transported across the first and second interface points.

29. The article of claim 28 including instructions to cause the computer system to communicate from a first gateway to a second gateway a channel identifier that indicates over which channel in the packet network connection the narrowband traffic is sent, wherein the gateways are configured to perform adaptations between circuit-switched bearers and packet-switched bearers.

30. The article of claim 29 including instructions for causing the computer system to associate the narrowband circuit with the channel in the packet network connection.

31. An article comprising a computer-readable storage medium including computer-executable instructions for causing a computer system, in response to termination of a particular one of multiple circuit-switched narrowband calls multiplexed over a single packet network connection to release packet network resources allocated to service the particular call.

FIG. 1

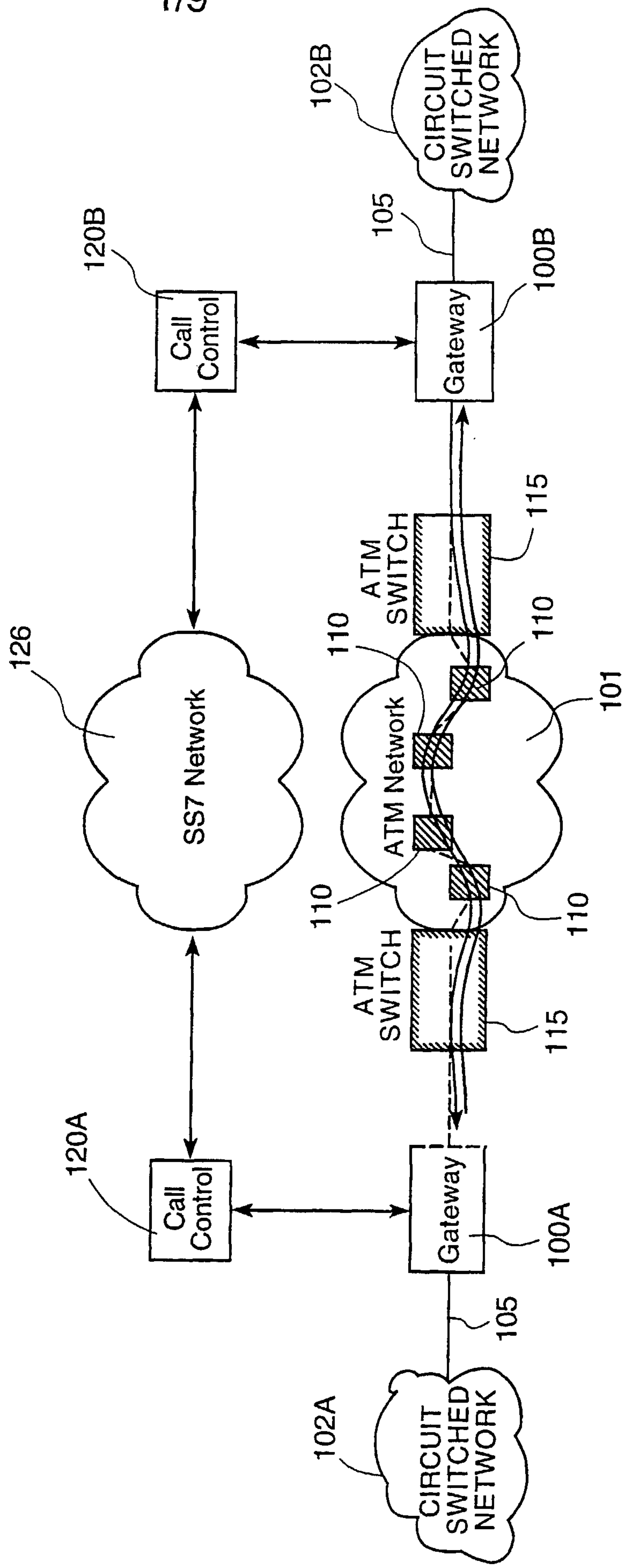

102B
CIRCUIT SWITCHED NETWORK
105
100B
Gateway
120B
Call Control
115
ATM SWITCH
110
110
126
SS7 Network
101
ATM Network
110
110
ATM SWITCH
115
120A
Call Control
Gateway
100A
105
102A
CIRCUIT SWITCHED NETWORK

FIG. 2

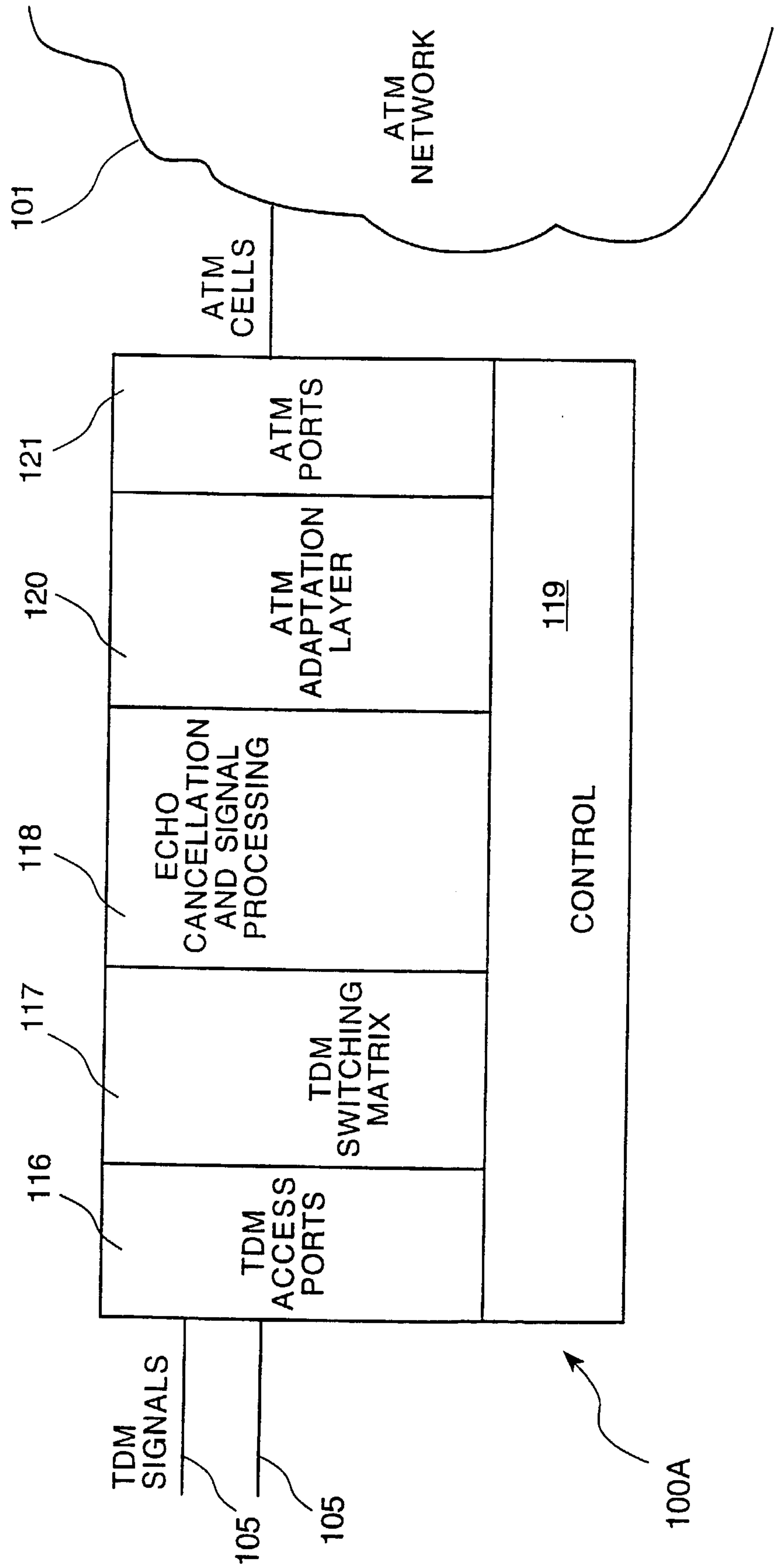

ATM NETWORK
101
ATM CELLS
ATM PORTS
121
ATM ADAPTATION LAYER
120
ECHO CANCELLATION AND SIGNAL PROCESSING
118
TDM SWITCHING MATRIX
117
TDM ACCESS PORTS
116
119
CONTROL
TDM SIGNALS
105
105
100A

FIG. 3

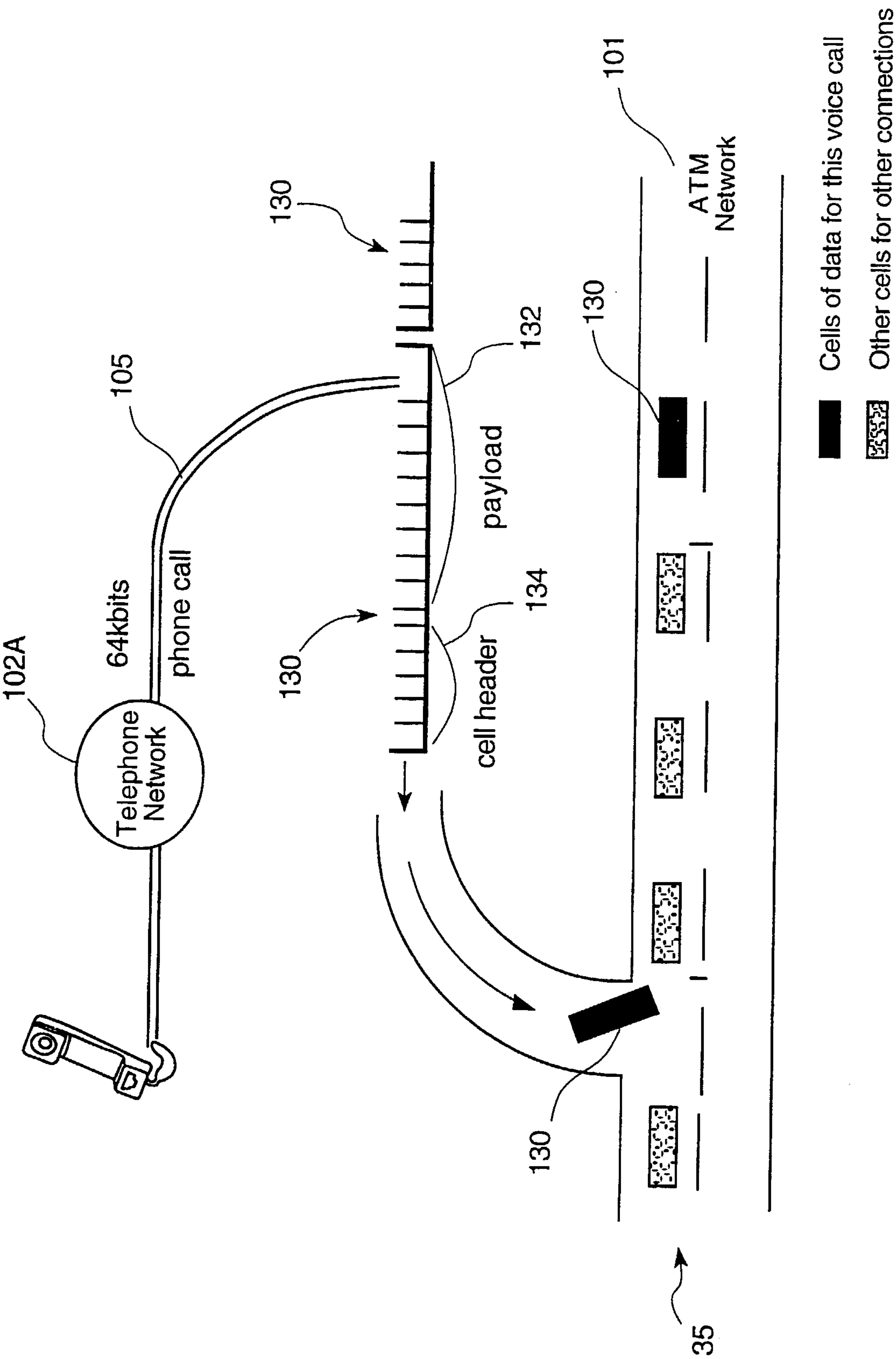

102A
Telephone Network
64kbits
phone call
105
130
132
payload
134
cell header
130
130
101
ATM Network
130
135
Cells of data for this voice call
Other cells for other connections

FIG. 4

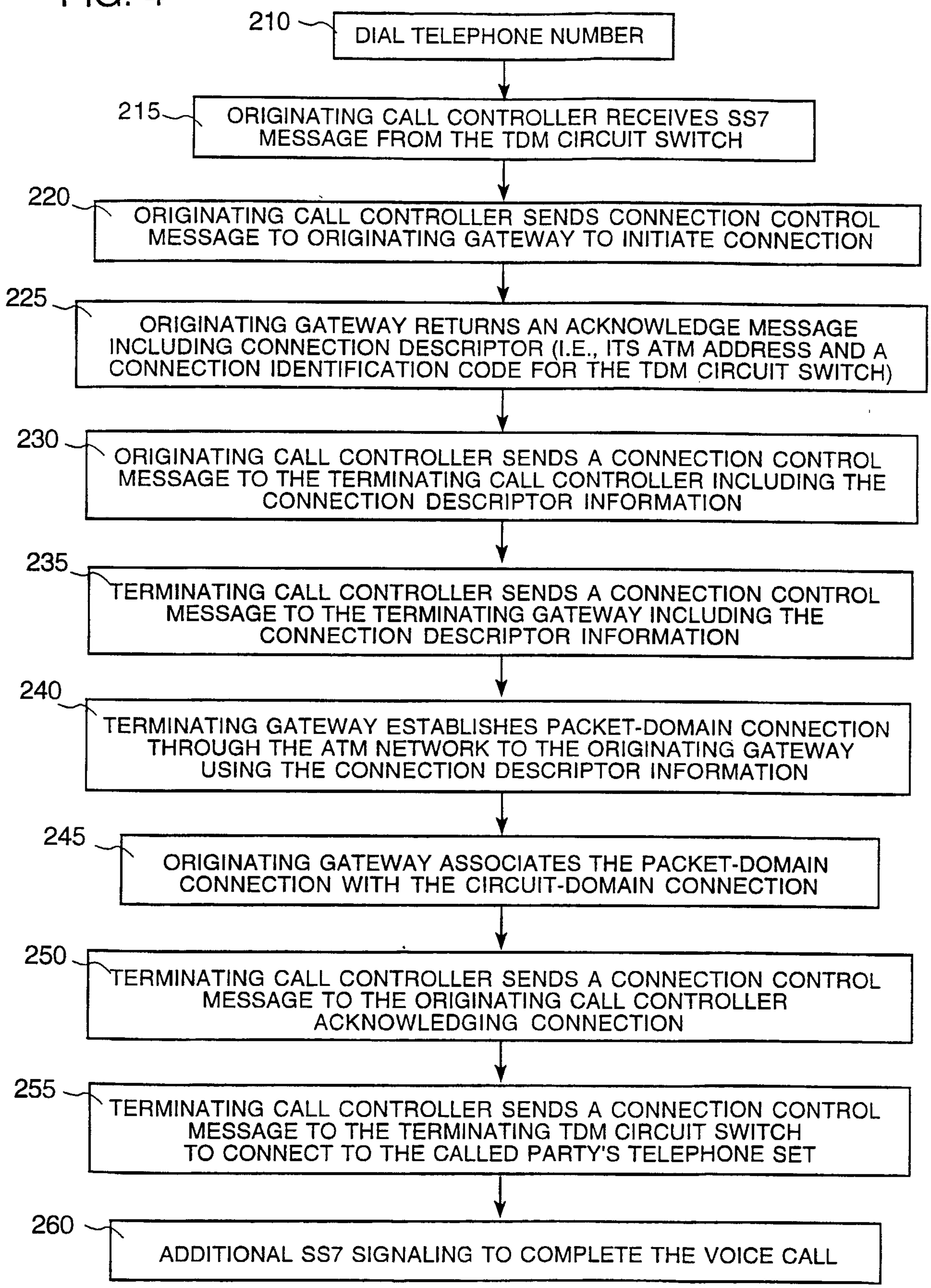

210
DIAL TELEPHONE NUMBER
215
ORIGINATING CALL CONTROLLER RECEIVES SS7 MESSAGE FROM THE TDM CIRCUIT SWITCH
220
ORIGINATING CALL CONTROLLER SENDS CONNECTION CONTROL MESSAGE TO ORIGINATING GATEWAY TO INITIATE CONNECTION
225
ORIGINATING GATEWAY RETURNS AN ACKNOWLEDGE MESSAGE INCLUDING CONNECTION DESCRIPTOR (I.E., ITS ATM ADDRESS AND A CONNECTION IDENTIFICATION CODE FOR THE TDM CIRCUIT SWITCH)
230
ORIGINATING CALL CONTROLLER SENDS A CONNECTION CONTROL MESSAGE TO THE TERMINATING CALL CONTROLLER INCLUDING THE CONNECTION DESCRIPTOR INFORMATION
235
TERMINATING CALL CONTROLLER SENDS A CONNECTION CONTROL MESSAGE TO THE TERMINATING GATEWAY INCLUDING THE CONNECTION DESCRIPTOR INFORMATION
240
TERMINATING GATEWAY ESTABLISHES PACKET-DOMAIN CONNECTION THROUGH THE ATM NETWORK TO THE ORIGINATING GATEWAY USING THE CONNECTION DESCRIPTOR INFORMATION
245
ORIGINATING GATEWAY ASSOCIATES THE PACKET-DOMAIN CONNECTION WITH THE CIRCUIT-DOMAIN CONNECTION
250
TERMINATING CALL CONTROLLER SENDS A CONNECTION CONTROL MESSAGE TO THE ORIGINATING CALL CONTROLLER ACKNOWLEDGING CONNECTION
255
TERMINATING CALL CONTROLLER SENDS A CONNECTION CONTROL MESSAGE TO THE TERMINATING TDM CIRCUIT SWITCH TO CONNECT TO THE CALLED PARTY'S TELEPHONE SET
260
ADDITIONAL SS7 SIGNALING TO COMPLETE THE VOICE CALL

FIG. 5

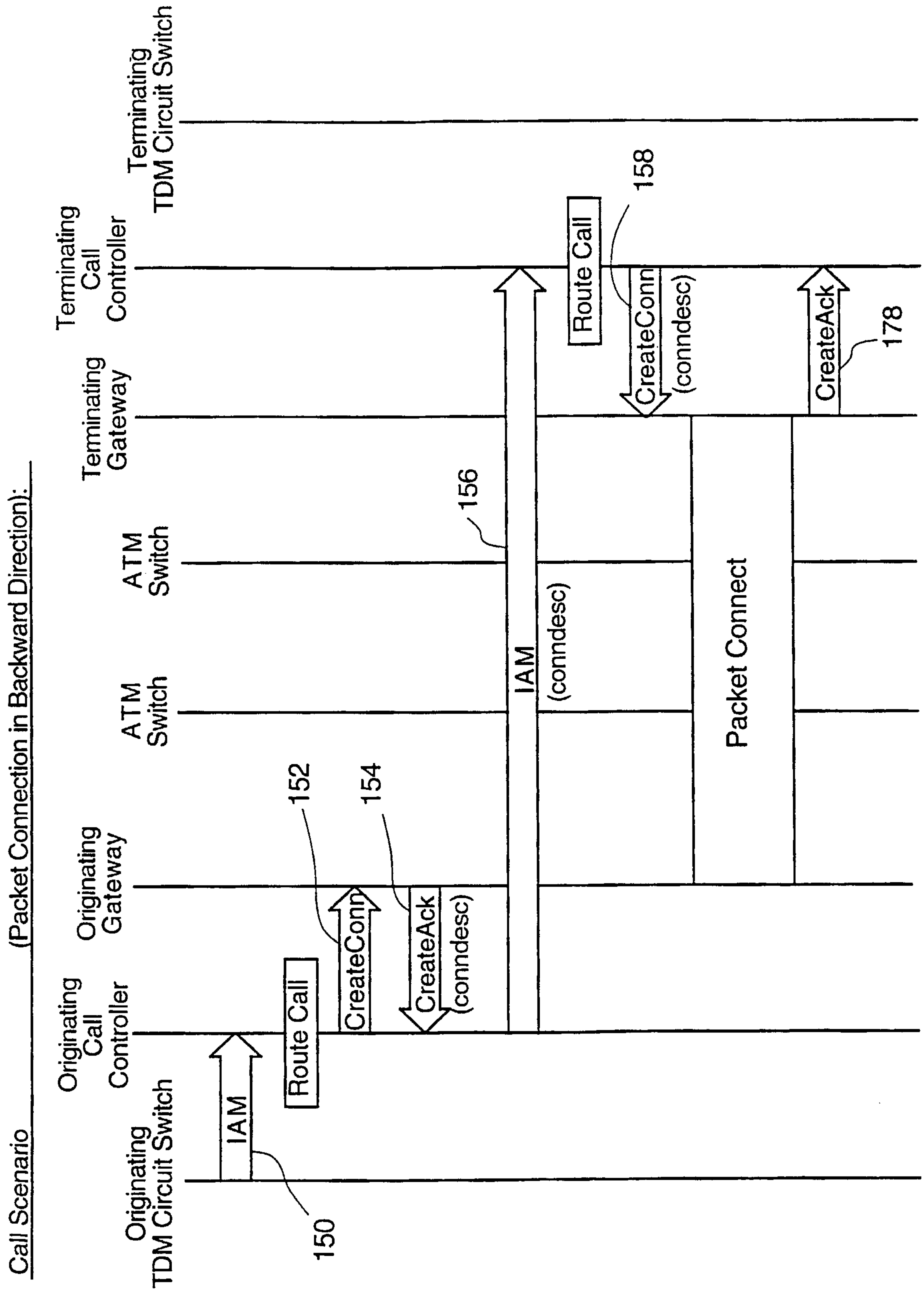

Call Scenario
(Packet Connection in Backward Direction):
Originating TDM Circuit Switch
Originating Call Controller
Originating Gateway
ATM Switch
ATM Switch
Terminating Gateway
Terminating Call Controller
Terminating TDM Circuit Switch
IAM
150
Route Call
CreateConn
152
CreateAck
(conndesc)
154
IAM
(conndesc)
156
Route Call
CreateConn
(conndesc)
158
Packet Connect
CreateAck
178

FIG. 6

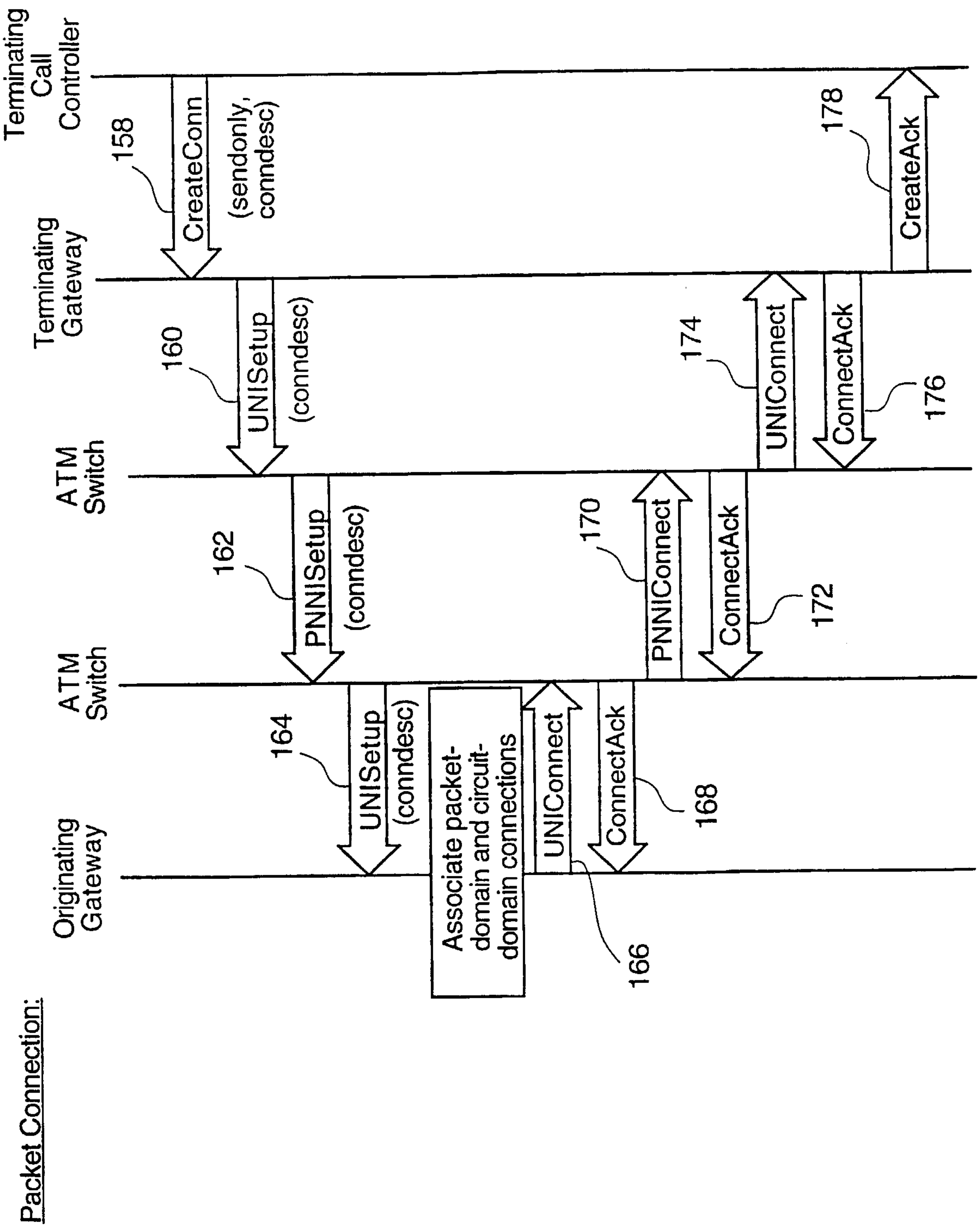

Packet Connection:
Terminating Call Controller
Terminating Gateway
ATM Switch
ATM Switch
Originating Gateway
158
CreateConn
(sendonly, conndesc)
160
UNISetup
(conndesc)
162
PNNISetup
(conndesc)
164
UNISetup
(conndesc)
Associate packet-domain and circuit-domain connections
UNIConnect
166
ConnectAck
168
170
PNNIConnect
ConnectAck
172
174
UNIConnect
ConnectAck
176
178
CreateAck

FIG. 7

Call Setup - Packet Connection Established in Forward Direction:

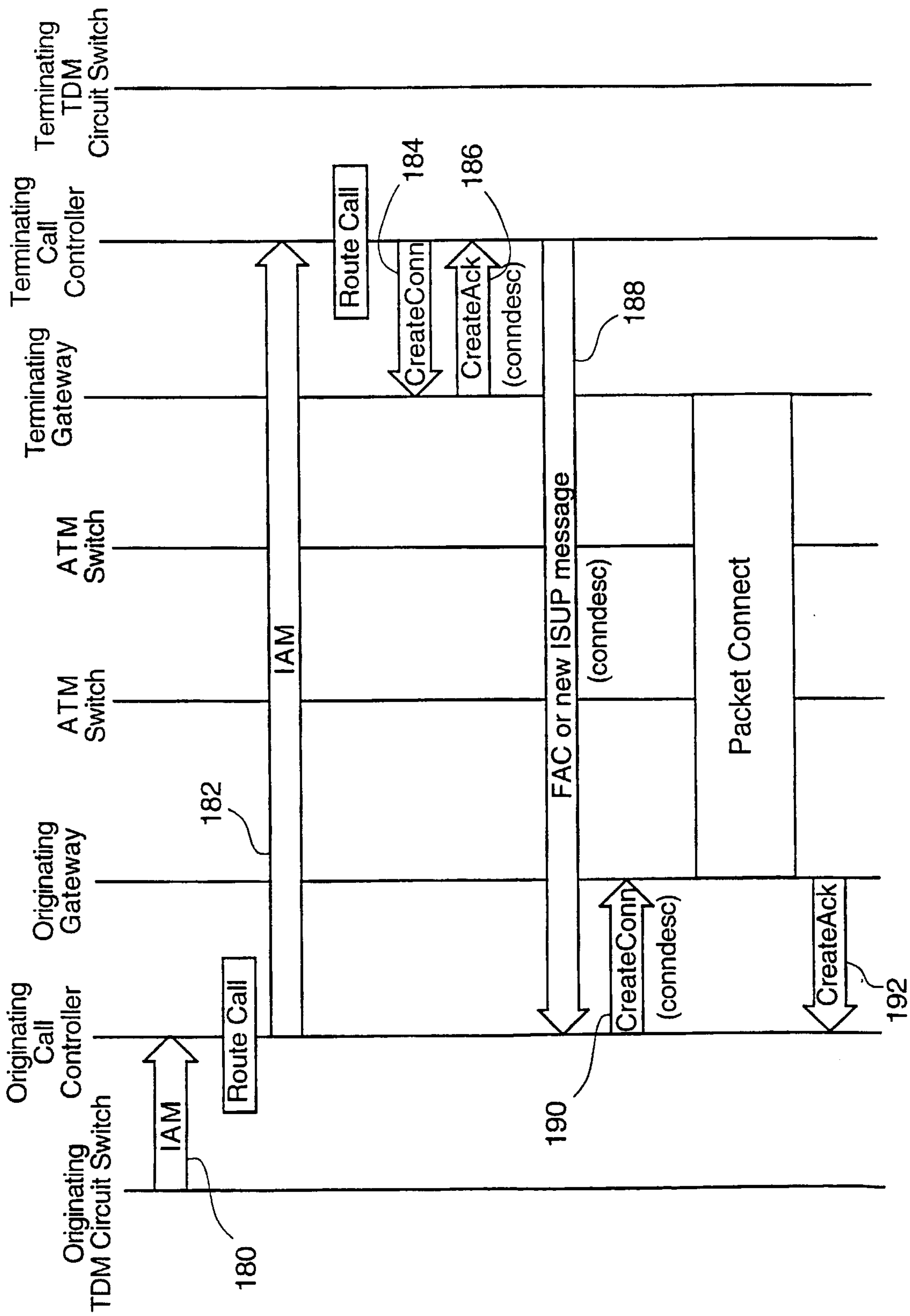


FIG. 8

Call Scenario for Multiple Calls associated with one VCC:

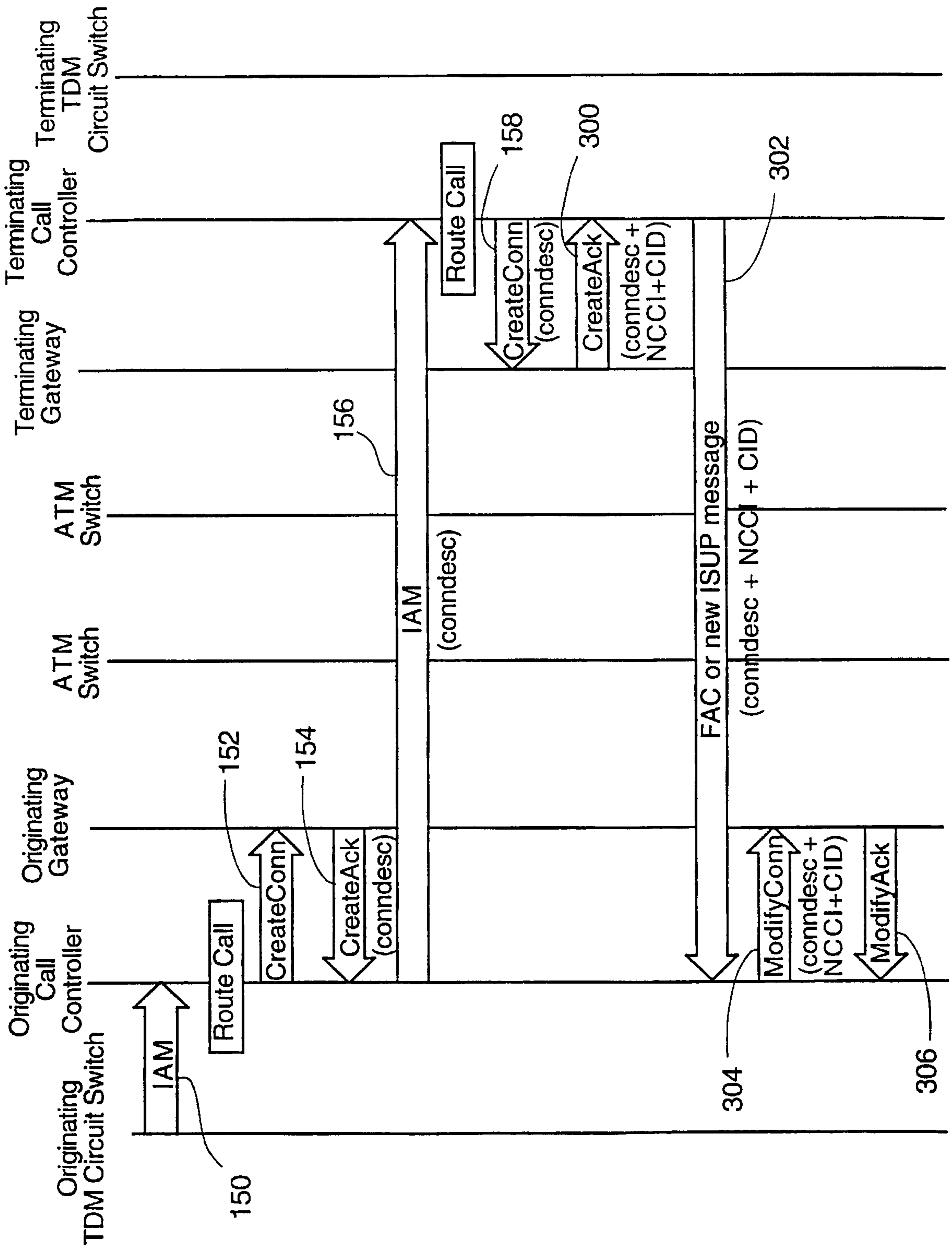
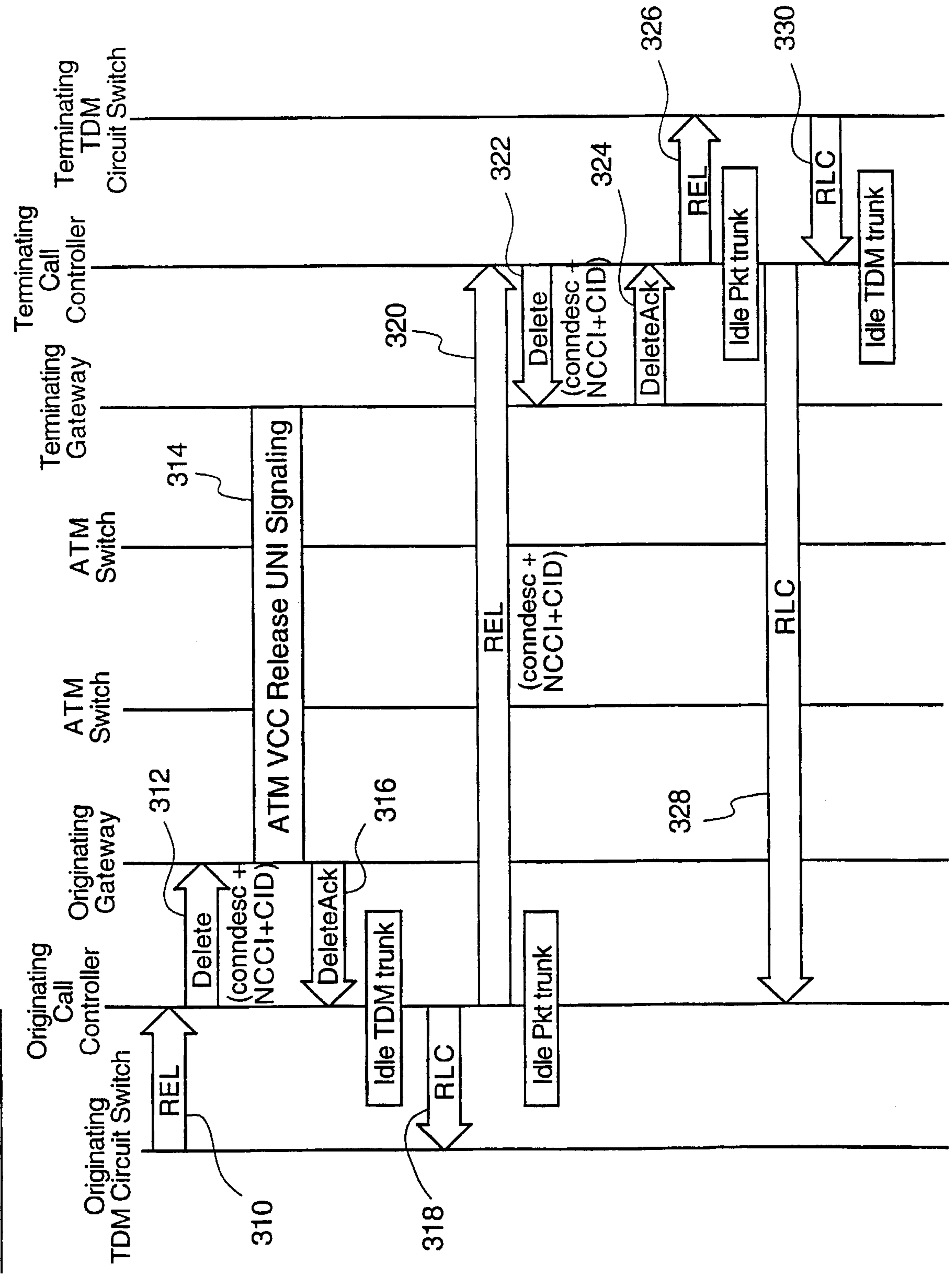
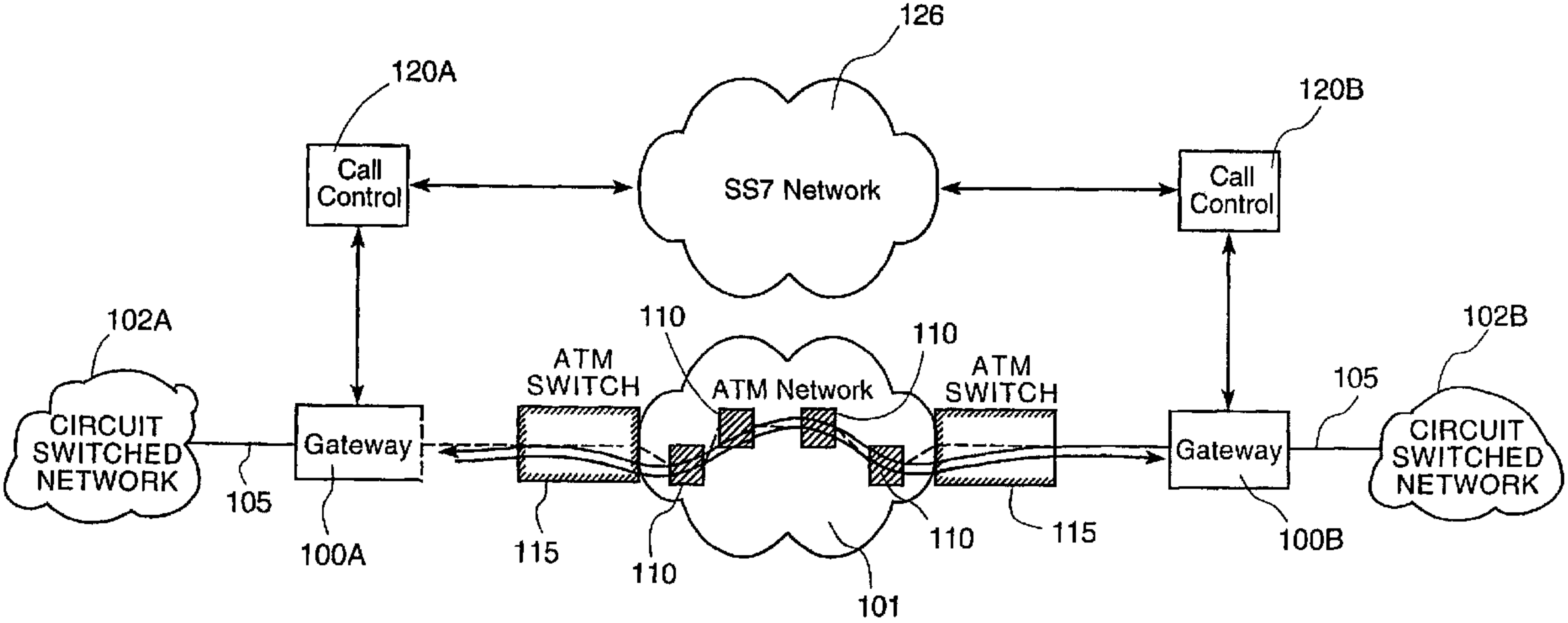


FIG. 9

Call Release Scenario :




126
120A
120B
Call Control
SS7 Network
Call Control
102A
110
110
102B
ATM SWITCH
ATM Network
ATM SWITCH
105
CIRCUIT SWITCHED NETWORK
Gateway
Gateway
CIRCUIT SWITCHED NETWORK
105
100A
115
110
101
110
115
100B