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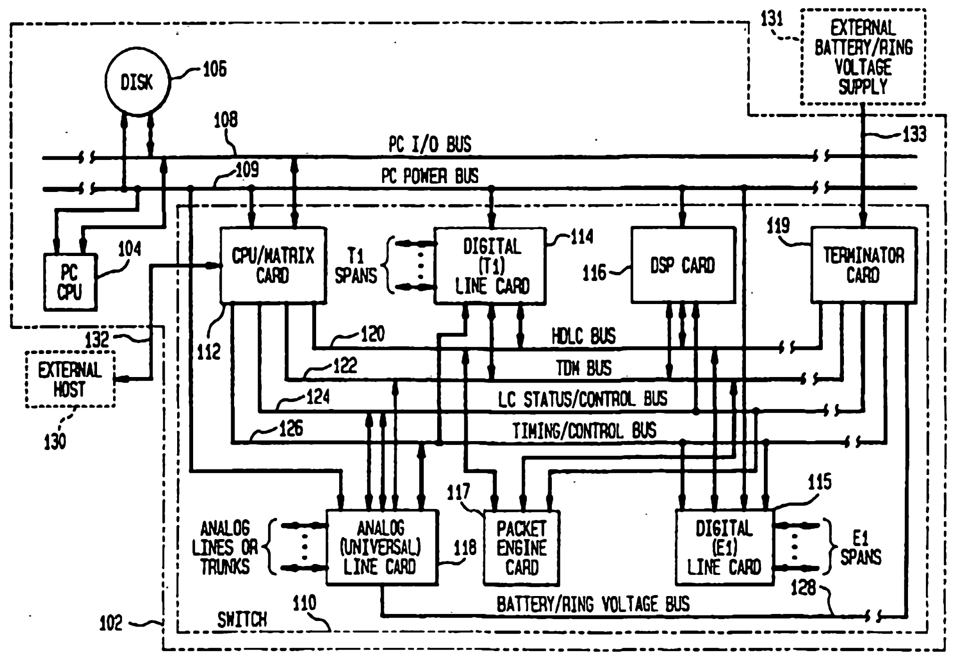


(57) Abstract

The present invention is a standardized host-to-switch application program interface (API) for performing call control processing, capable of being customized to meet telecommunications application and network signalling protocol requirements. The universal API comprises one or more generic messages having programmable fields for transmitting commands, status, and data between the host application and the switch. The present invention further comprises a programmable telecommunication switch that provides a user with the ability to define a desired API protocol, either "standard" or custom in nature, for performing any desired switching functions. The present invention includes a protocol development environment which enables a user to define a separate finite state machine for each port provided by the switch. Each finite state machine may be independently defined by combining a series of elementary processing steps, called atomic functions, into primitives, which are in turn combined with states and events to define the desired state machine. Such state machines may include atomic functions configured to generate predetermined messages under predetermined conditions and containing predetermined information. Such state machines may further include the ability to respond to state events that include the receipt of generic API messages configured to provide the state machine with information from the host application.

TELECOMMUNICATIONS SWITCH HAVING A UNIVERSAL APPLICATIONS PROGRAM INTERFACE FOR STANDARDIZED INTERACTIVE CALL PROCESSING COMMUNICATIONS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to the field of telecommunications and, more specifically, to a universal applications program interface (API) for standardized interactive call control processing with a programmable telecommunication switch and a host computer supporting various telecommunications applications.

Description of the Related Art

Programmable telecommunication switches are used in a wide variety of applications such as voice messaging, telemarketing services and the like. A computer that runs a telecommunications application program. A customer may programmable switch is usually controlled by a host device, which is typically a either purchase a commercially available application program that is compatible with the host and switch hardware or may elect to write a custom program.

In most applications, a programmable switch is connected to a public telephone network by one or more analog trunks or digital spans (e.g., a T1 span) which are terminated at the switch. The switch may also terminate one or more "lines" which are connected to devices such as telephone sets. Communication over any given trunk, span or line is carried out in accordance with an assigned signalling protocol.

For various switching system applications, the sequence of switching events must be controlled and the switching functions must be performed in accordance with the requisite protocols. Throughout the world, there are numerous "standard" signalling protocols in use, including E&M wink start, loopstart, groundstart, international compelled R2 using MFR2 address signalling, and E1 Channel Associated Signalling (CAS) protocols using DTMF/MFR1 signalling. Typically, conventional programmable switches are configured such that a particular signalling protocol is associated with a particular trunk, span or line.

To control the telecommunications switch at the various levels necessary to satisfy specialized switching functions, conventional host applications have been configured to generate digital signal commands corresponding to a plurality of switching events. Correspondingly, conventional communications switches have been configured to generate digital signal responses related to the processing of these events at the ports. These messages are constant or "hard-coded" messages, each configured to communicate specific information between the host application and the switch. The interface between the telecommunications application and the switch through which these messages are transferred is referred to as an applications program interface, or API.

Each of the signalling protocols requires predetermined host-to-switch call control processing protocols to be established, each protocol including the exchange of one or more constant messages. Thus, to control the programmable switch to perform the requisite switching events necessary to maintain communications, communications switches must be capable of supporting extremely large number of these specific host-to-switch command messages and associated protocols. Accordingly, each signalling protocol has associated with it one or more different message sets stored and indexed at the host as well as at the switch. The message sets and resulting host-to-switch protocol are also dependent upon specific telecommunications applications requirements, such as the amount and type of information an application requires for it to appropriately control the switch to support a particular signalling protocol.

Furthermore, conventional programmable switches may be connected between the public telephone network and other devices such as a voice messaging system. Because such devices may perform specialized functions and are not intended to connect directly to the public telephone network, they do not typically adhere to standard signalling protocols. Thus, for a user to be able to control the programmable switch in such a fashion that proper communication is maintained both, with the public telephone network and with other devices connected to the switch, complex and varied API signalling protocol requirements must be satisfied. Conventional communications switches implement numerous specific sets of API messages to support these varied requirements.

As a result of the implementation of constant messages and the various telecommunications applications and signalling protocol requirements, there has been no standardization of the interface between the host applications and the telecommunications switch. This has led to increased cost in developing the necessary hardware and software to support specific API protocols to satisfy host applications requirements as well as signalling protocol requirements for each trunk, span, and line.

Furthermore, as a result of having separate and distinct API messages, each dedicated to a specific command or data transfer, the addition of features to the telecommunications switch necessitates the creation and implementation of one or more additional API messages to support the associated API protocol between the host and switch. To implement each new unique message, a costly and time-consuming software change to the switch and host must be made.

What is needed, therefore, is a standardized API message protocol supporting host-to-switch call control processing that may be used regardless of the host application or signalling protocol requirements. Furthermore, such a universal API protocol must be sufficiently flexible and versatile to be customized to support present and future requirements of telecommunications applications and signalling protocols now or later developed.

SUMMARY OF THE INVENTION

According to one aspect of the present invention there is provided a telecommunications system, including:

a host device;

a programmable telecommunication switch, connected in communicating relationship with and responsive to said host device, for performing call processing functions related to communication paths established between various ones of a plurality of channels; and

a universal applications program interface (API) having standardized messages for communication between said telecommunications switch and said host device.

According to a further aspect of the present invention there is provided a telecommunications system, including:

a host device;

a programmable telecommunication switch, connected in communicating relationship with and responsive to said host device, for performing call processing functions related to communication paths established between various ones of a plurality of channels; and

means for effecting communications between said switch and said host using a programmable universal applications program interface (API) including standardized messages for transmitting information between said host and said switch.

According to a still further aspect of the present invention there is provided a functionally-layered programmable telecommunication switch including:

controllable-switching means for dynamically connecting or disconnecting communication paths between various ones of a plurality of channels in response to messages generated by a telecommunications series application;

one or more instantiations of a plurality of programmable protocol language (PPL) component state machines, each of which is associated with a PPL component of said telecommunications switch and each of which represents one of a plurality of protocols configured to perform call processing functions with respect said plurality of channels, wherein said plurality of PPL component state machines are functionally associated with the functional layers of the telecommunications switch including said PPL components; and

a programmable universal applications program interface (API) for transferring standardized messages between said functional layers and between said functional layers and said telecommunications services application.

According to a still further aspect of the present invention there is provided a universal applications program interface (API) for standardized interactive call processing communications between functional layers of a telecommunications system including a telecommunications switch and a host device coupled to the switch, including:

a first programmable message for transferring all call control processing commands and data from said host to said functional layers of said telecommunications switch; and

a second programmable message for transferring all call control processing status and data from said functional layers of said telecommunications switch to said host.

According to a still further aspect of the present invention there is provided a method for developing call-associated protocols for performing call processing functions related to communication paths established between various ones of a plurality of channels in a programmable telecommunications switch, said call processing function associated with the functions performed by a particular functional layer of said switch, the method including the steps of:

(a) creating one or more state/event tables each of which defines,

a plurality of predetermined logical states,

one or more predetermined events associated with each of said plurality of predetermined logical states, said one or more predetermined events including receipt of one or more application program interface (API) messages generated at the same or different functional layer as said created call-associated protocol, and

a primitive associated with each said one or more predetermined events, wherein said primitive is invoked upon an occurrence of said one or more associated events;

(b) creating one or more primitive tables each of which defines a predetermined series of predetermined layer-dependent functions for each said primitive, one or more of said predetermined functions generating an API message to said functional layer; and

(c) creating one or more protocols each of which is represented by a predetermined association of one or more of said state/event tables and one or more of said one or more primitive tables.

According to a still further aspect of the present invention there is provided a functionally-layered programmable telecommunication switch including:

a layer-specific processor having a state machine engine configured to execute an instantiation of a PPL component state machine representing a call processing protocol associated with a communications channel in the switch, said state machine invoking one or more predetermined functions in accordance with a current state and the occurrence of a predetermined event,

wherein said one or more predetermined functions includes generating a first application program interface (API) message having a first predetermined message format for all messages transferring call control processing information from said state machine; and

wherein said predetermined event is one of a plurality of events including the receipt of a second API message having a second predetermined message format for all messages transferring call control processing to said state machine.

According to a still further aspect of the present invention there is provided a method for communicating between two layers of a functionally-layered programmable telecommunication switch system utilizing a standardized universal application program interface (API), the method including the steps of:

(1) invoking one or more instantiations of a layer-specific program protocol language (PPL) component state machine at a layer-specific PPL processor having a state machine engine, each of said one or more instantiations representing a call processing protocol;

(2) invoking atomic functions in accordance with state/event and primitive tables defining said state machine and stored in the processor to perform various functions, said atomic functions generating internal representations of a API event indication message; and

(3) transferring said internally-represented PPL event indication message to a communications processor coupled to said processor for translation into a universal standardized PPL event indication message.

The present invention may include a standardized host-to-switch application program interface (API) for performing call control processing, capable of being customized to meet telecommunications application and network signalling protocol requirements. The universal API may comprise one or more generic messages having programmable fields for transmitting commands, status, and data between the host application and the switch. The present invention may further comprise a programmable telecommunication switch that provides a user with the ability to define a desired API protocol, either “standard” or custom in nature, for performing any desired switching functions.

The present invention may include a protocol development environment which enables a user to define a separate finite state machine for each port provided by the switch. Each finite state machine may be independently defined by combining a series of elementary processing steps, called atomic functions, into primitives, which are in turn combined with states and events to define the desired state machine. Such state machines may include atomic functions configured to generate predetermined messages under predetermined conditions and containing predetermined information. Such state machines may further include the ability to respond to state events that include the receipt of generic API messages configured to provide the state machine with information from the host application.

In addition, the present invention may serve as a development tool for creating customized API protocols having customized standard messages supporting telecommunications applications such as personal communications services (PCS), 800/900 service, voice mail, telemarketing, among others. The present invention may also be used to control or manage a wide variety of communications services within a programmable switch through the transfer of the generic API messages, including conferencing, voice recorded announcements, tone generation, tone reception, call progress analysis, voice recognition, voice compression and fax encoding/decoding.

The universal API of the present invention may be implemented to achieve communications internal to the switch as well. For example, the standardized messages of the universal API may be used to support communications between any software layer within the switch.

Advantageously, the generic message structure of the present invention enables additional call processing features to be added to the telecommunications switch that the host can initiate without implementing additional content-specific API messages dedicated to that feature. This enables the creation of customized API message protocols that can grow beyond the limitations of specific messages for specific features and functions.

Another advantage of the generic message structure of the present invention is that it may provide the commonality and flexibility necessary to be a standardized interface for application development. This may significantly reduce the complexity of the host/switch communications interface and eliminates the cost of supporting an interface composed of numerous specialized messages.

Another advantage of the present invention is that it may provide the user with the ability to transmit and receive information to all software layers of the switch using standardized messages. Significantly, this may eliminate the burden of having to store large numbers of distinct messages for managing dissimilar functions performed by the same or different software layers of the switch. Thus, the large message sets stored and indexed in conventional switches may be eliminated by the present invention.

Another advantage of the present invention is the increased degree of interaction with the host that can be achieved simply by introducing at various processing points an atomic function that sends and receives data into numerous locations in the switch.

Another advantage of the present invention is that it may enable a user to create multiple network signalling protocols by creating separate state machines to address each variation of a signalling protocol. The universal API may be programmed to achieve the necessary communications to support each of these protocol-specific state machines. Thus, the structure of the messages comprising the host-to-switch interface may remain unchanged despite the multiple signalling protocols supported by the switch.

Further features and advantages of the present invention as well as the structure and operation of various embodiments of the present invention are described in detail below with reference to the accompanying drawings. In the drawings, like reference numbers indicate identical or functionally similar elements. Additionally, the left-most one or two digits of a reference number identifies the drawing in which the reference number first appears.

BRIEF DESCRIPTION OF THE DRAWINGS

This invention is pointed out with particularity in the appended claims. The above and further advantages of this invention may be better understood by referring to the following description taken in conjunction with the accompanying drawings, in which:

Figure 1 is a block diagram of a programmable telecommunications switch which may be programmed by a user in accordance with a preferred embodiment of the present invention;

Figure 2 is diagram which depicts the layers of software used to control the switch of Figure 1;

Figures 3A and 3B depict some of the specific features and functions associated with each of the software layers depicted in Figure 2;

Figure 4 is a block diagram of a finite state machine development environment constructed in accordance with a preferred embodiment of the present invention;

Figure 5 is a block diagram illustrating the structure and contents of a generic PPL Event Indication and PPL Event Request message of the present invention;

Figure 6 is a block diagram of a PPL Event Indication Acknowledgement and PPL Event Request Acknowledgment message of the present invention.

Figures 7A and 7B are a state diagram of a finite state machine for providing call control processing utilizing the universal API of the present invention to support a highly interactive host telecommunications application requirement;

Figure 7C is an interface diagram of the universal API supporting the call control processing illustrated in Figures 7A and 7B;

Figures 7D and 7E are a diagram of the finite state machine of Figures 7A and 7B in which each series of atomic functions is defined as a primitive;

Figures 7F and 7G are tables showing the correspondence between the atomic functions, primitives and states of Figures 7A-7E;

Figures 8A and 8B are a state diagram of a finite state machine for providing call control processing utilizing the universal API of the present invention to support a limited interactive host telecommunications application requirement;

Figure 8C is an interface diagram of the host-to-switch API generated by the cal control processing illustrated in Figures 8A and 8B;

Figures 8D and 8E are a diagram of the finite state machine of Figures 8A and 8B in which each series of atomic functions is defined as a primitive;

Figures 8F and 8G are tables showing the correspondence between the atomic functions, primitives and states of Figures 8A-8E;

Figure 9 is a functional block diagram illustrating an exemplary process flow to create a PPL Event Indication message;

Figure 10 is a block diagram of the message buffer created by an Layer 4 PPL processor during the creation of the PPL Event Indication message of Figure 9; and

Figure 11 is a functional block diagram illustrating an exemplary process flow to create a PPL Event Request message.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows a commercially available personal computer (PC) 102 which includes a PC central processing unit (CPU) 104 and a hard disk drive 106 interconnected by a PC input/output (I/O) bus 108 and a PC power bus 109. The PC 102 is preferably a PC-AT®, sold by International Business Machines (IBM), or a compatible thereof. Other personal computers having more memory or more powerful CPUs than the PC-AT® may also be used. The PC 102 preferably operates under an application-oriented operating system, such as DOS® or UNIX®.

The PC 102 consists of a chassis or housing in which a motherboard is mounted, along with the disk drive 106 and other optional assemblies such as floppy disk drives, modems and the like. The PC CPU 104 is mounted on the motherboard, which includes a series of edge connectors into which other boards (cards) may be inserted and thereby connected to the PC I/O and power busses 108 and 109.

A programmable telecommunication switch 110 resides within the PC 102. A CPU/matrix card 112 is inserted into one of the slots on the motherboard and thus connected to the busses 108 and 109. The CPU/matrix card 112 is interconnected with a digital (T1) line card 114, a digital (E1) line card 115, a digital signal processing (DSP) card 116, a packet engine card 117, an analog (universal) line card 118 and a terminator card 119 by four busses: a high level data link control (HDLC) or interprocessor bus 120; a time division multiplex (TDM) bus 122; a line card (LC) status/control bus 124; and a timing/control bus 126. A battery/ring voltage bus 128 supplies battery voltage (48VDC) and ringing voltage (109VAC) to the analog line card 118. The terminator card 119 serves to physically terminate busses 120, 122, 124, 126 and 128.

The line cards 114, 115 and 118 and the DSP card 116 are all connected to and receive their basic operating power from the PC power bus 109. Although only one digital (T1) line card 114, one digital (E1) line card 115 and one analog line card 118 are depicted, it should be understood that additional line cards of any type may be added subject to two physical limitations: (1) the maximum switching capacity of the CPU/matrix card 112, and (2) the physical space within the chassis of the PC 102.

An external host 130, which may comprise a separate personal computer, workstation or other computer, may optionally be connected via a communication channel 132 to the CPU/matrix card 112. The CPU/matrix card 112 preferably includes a conventional RS-232 compatible interface for connecting the channel 132. The external host 130 preferably operates under an application-oriented operating system.

If desired, the switch 110 can reside on a passive backplane (no PC CPU 104 or disk 106 present) from which its receives electrical power and be controlled by the external host 130. For example, the present invention may be implemented in other processing platforms such as the expandable telecommunications switch disclosed in copending patent application, serial number 08/207,931, titled Expandable Telecommunications System, assigned to the assignee of the present application and which is hereby incorporated by reference in its entirety.

An external battery/ring voltage supply 131 is connected via a path 133 to the terminator card 119. Supply 131 may comprise, for example, a commercially available power supply.

With the exception of the digital (E1) line card 115, the DSP card 116 and the packet engine card 117, details regarding the construction of the various cards shown in Figure 1 are set forth in U.S. Patent No. 5,321,744, titled Programmable Telecommunications Switch for Personal Computer, assigned to the assignee of the present application and which is hereby incorporated by reference in its entirety. Digital (E1) line card 115 is preferably constructed using similar hardware to that disclosed for T1 line card 114, except for differences in conventional circuitry which allow line card 115 to terminate E1 spans as opposed to T1 spans.

Details regarding the construction of the DSP card 116 and the packet engine card 117 are set forth in U.S. Patent No. 5,349,579, titled Telecommunications Switch With Programmable Communications Services, assigned to the assignee of the present application and which is hereby incorporated by reference in its entirety.

Figure 2 is a layer model of the software used to control the programmable switch 110 of Figure 1. The lefthand column of Figure 2 shows seven layers defined in the Open Systems Interconnection (OSI) reference model. The righthand column of Figure 2 shows five layers used to control switch 2 and their general correspondence to the OSI model.

Referring now to both Figures 1 and 2, the Application Layer 5, which corresponds generally with the Application layer of the OSI model, represents application software which typically runs on either the PC CPU 104 or the external host 130. Application Layer 5 software may be used to implement any of a number of desired telecommunications services such as toll free (800) service, voice mail, automatic call distribution (ACD), to name but a few. Application Layer 5 may communicate with any other layer of the programmable switch through the application program interface (API) of the present invention. When Application Layer 5 resides on external host 130, the API manages communications over communication channel 132. When Application Layer 5 resides on PC CPU 104, the API manages call control processing communications over PC I/O bus 108.

Call Management Layer 104, which corresponds generally with the Presentation, Session and Transport layers of the OSI model, represents software which runs on the CPU/matrix card 12. Call Management Layer 4 is responsible for performing centralized call processing functions and providing a common interface to Application Layer 5 regardless of the type or types of network signalling protocols which may be used within the switch 102. Typically, Call Management Layer 4 performs functions which are required following call setup.

Network Signalling Protocol Layer 3 corresponds generally with the Network layer of the OSI model. The software represented by Network Signalling Protocol

Layer 3 runs either on the CPU/matrix card 112 or on line cards which include their own microprocessors, such as line cards 114 or 115 or packet engine card 117, and is responsible for in and out-of-band network signalling supervision as well as network protocol level control of incoming and outgoing calls.

Link Layer 2 corresponds generally with the Data Link layer of the OSI model. Link Layer 2 software runs on the CPU/matrix card 112, the line cards which include their own microprocessors, the DSP card 116 or the packet engine card 117 (each of which includes its own microprocessor) and is responsible for the detection as well as physical transfer of network signalling information across a network or line interface.

Finally, the Physical Layer 1 corresponds to the Physical layer of the OSI model. Line cards 114, 115 and 118 provide physical T1, E1 and analog electrical interfaces, respectively, to the switch 110.

Figures 3A and 3B are a tabular listing of representative features and functions provided by each of the software Layers 2-5 of Figure 2. The present invention may be used as a development tool to develop suitable software to implement any of the features and functions shown in Figures 3A and 3B. Illustrative examples of the use of the present invention in the context of each of Layers 2-5 are set forth in U.S. Patent No. 5,426,694, assigned to the assignee of the present invention, herein incorporated by reference in its entirety.

Figure 4 is an overall block diagram of a finite state machine development environment, constructed in accordance with a preferred embodiment of the present invention, which enables a customer or user to create and define finite state machines for performing desired telecommunications functions, controlled by one or more applications through the universal API of the present invention. Before considering this Figure in detail, the definitions of certain terms should be addressed.

As used herein, the term *state* refers to a number which represents the current "context" for a particular channel or port. In a preferred embodiment of the present invention, there are three types of states defined: normal, internal and blocking. *Normal* states can be *wait* states (i.e., a SEIZE ACK state, a condition in which further action is suspended until the occurrence of a particular event) or *stable* states (i.e., a conversation is taking place). *Internal* states are used to test conditions and effectively operate as decision branches. Normal and internal states may be specified by a customer or user, in accordance with present invention, to define a finite state machine for performing a desired function. *Blocking* states are generated automatically by the present invention and are used, on a channel-by-channel basis, in connection with the management of off-board resources.

An *event* is a number which identifies a condition which is accepted by a particular state. Data may be associated with an event.

An *atomic function* is one which performs an elementary task such as setting a timer. User-specified data may be associated with an atomic function. A *primitive* is a predetermined sequence of atomic functions which is invoked upon the occurrence of a particular event. Users may create or define primitives from a library of available atomic functions. In a preferred embodiment, each primitive may contain up to 20 atomic functions.

A *state/event table* defines the valid events for a particular state and the primitive which is invoked upon the occurrence of each such event. In a preferred embodiment, a state/event table may contain up to 100 states and up to 20 events per state.

A *primitive table* defines the primitives which are used by a state/event table. In a preferred embodiment, a primitive table may contain up to 200 primitives.

A *protocol* is defined as the association of various types of tables, the least of which is a state/event table and primitive table, and is identified by a *protocol ID* (a number).

An *API protocol* is defined as the host-to-switch control protocol between host applications and software layers of the switch.

A *program protocol language* (PPL) is a programmable environment for managing network signalling protocols and communications services.

A *data block*, such as those denoted by reference numbers 40a, 40n, is assigned for each channel (port) 0...n of the switch. Each data block 40a, 40n contains the following information pertaining to its respective channel: the current state of the channel; a pointer to an active state/event table; a pointer to an active primitive table; a pointer to an assigned state/event table; and a pointer to an assigned primitive table.

In the case of channel 0, the active state/event table and active primitive table pointers are pointing, as indicated by the phantom lines, to tables which are associated with a resident protocol 0, denoted by reference number 442a. The assigned state/event table and assigned primitive table pointers for channel 0 are pointing to tables which are associated with a dynamically loaded, customer-defined protocol 1, denoted by reference number 444a.

Other protocols which are present and available for use are resident protocols 1...n (442b, 442c) and downloaded, customer-defined protocols n+1...m (444b, 444c). The resident protocols 442a-442c represent preprogrammed or "standard" protocols, which are typically provided by a manufacturer with a switch. In contrast, the customer-defined protocols n+1...m are created by a customer or user and may be completely "custom" or "proprietary" in nature.

A layer dependent atomic function library 446 is connected to provide information to a state machine engine 448. State machine engine 448 is also connected to receive the active state/event table pointer and active primitive table pointer from each of data blocks 440a-440n. Also, as denoted by reference number 450, utilities are provided for layer dependent environment support.

The function of the state machine engine 448 is to drive each channel in accordance with its assigned protocol, which is defined by the assigned state/event table and assigned primitive table. Upon the occurrence of a valid event for a normal state, a primitive is invoked in accordance with the entries in the assigned state/event table. The state machine engine 448 uses the atomic function library 446 to perform the atomic functions represented by the invoked primitive.

The state machine engine 448 will drive through any necessary internal states, automatically generating appropriate blocking states, until the channel once again reaches a normal state. At that time, processing by the state machine engine 448 is complete until the occurrence of another valid event.

Each channel is initially assigned one of the customer-defined protocols or one of the preprogrammed protocols. This is accomplished by the transmission of an API message from the Application Layer 5 to the Call Management Layer 4, which in turn issues an appropriate message to Layer 3 which may also be configured in accordance with the API of the present invention. The assigned state/event table pointer and assigned primitive table pointer point to the protocol which was last assigned. Thus, a customer may assign a desired one of the available protocols by simply specifying the appropriate pointers in each data block. In this fashion, the present invention advantageously permits the customer to assign, on a channel-by-channel basis, a desired protocol from among multiple protocols resident within a single switch.

Alternatively, or if the customer elects not to assign protocols to some or all of the channels, default values are preferably provided so that each channel always has a valid protocol (e.g., one of the resident protocols 442a-442c) assigned to it.

The active state/event table and active primitive table pointers, which are provided to the state machine engine 448, point to the protocol which is currently controlling the channel.

The protocol assigned to a particular channel is not necessarily permanent and may be dynamically changed in real time in response to the occurrence of a specified event, as described in detail in connection with Figure 7. Further, because the atomic functions provided by the library 446 represent elementary functions, customers or users are advantageously able to implement desired changes in protocols without substantial, or possibly any, changes to the underlying code. In addition, the environment support utilities are provided to simplify protocol development for the customer or user. The utilities provide ready-to-use resource management functions (e.g., timers) which greatly simplify the state machine logic required to implement desired protocols. Different utilities are preferably provided for each software layer since the resources required by each layer may be different.

In accordance with the present invention, call processing control communications between the Application Layer 5, typically residing on external host 130, and the other layers of switch 102 illustrated in Figure 2, is conducted though the transfer of generic messages of the universal API of the present invention. Specifically, in the preferred embodiment of the universal API of the present invention, a single message type, referred to as the PPL Event Request message, is used to transfer all call control processing commands and data from the host application (Layer 5) to the telecommunications switch (all other software layers).

Likewise, a single message, referred to as the PPL Event Indication message, is used to transfer all call control processing status and data from the telecommunications switch to the host applications. These generic API messages have optional fields and are the only messages necessary to maintain call processing regardless of the application requirements, network signalling protocol requirements, or features presently existing or to be added to the telecommunications switch. The programmable switch of the present invention enables a user to define and assign a desired applications program interface protocol, either "standard" or custom in nature, for performing various switching functions to accommodate any of the above requirements.

Referring to Figure 5, a PPL Event Request message is sent from the host to the switch to initiate a host event on a PPL component with optional ICB data. The PPL Event Request message is the only call control processing message passed from the host to the switch and, in the preferred embodiment, having the format of message 500 illustrated in Figure 5. The PPL Event Request message comprises a number of fields and subfields, each of which is described below.

PPL Event Request message includes a frame byte 502 having a constant value identifying it as the first byte of a frame.

Message length field 504 contains the length of the particular PPL Event Request message. This is necessary due to the ability of the generic API messages of the present invention to include optional fields, changing the length of the message. Typically the length field value does not include the frame byte 502.

A message type field 506 contains a constant value identifying the particular message as a PPL Event Request message. The message type field is constant for all PPL Event Request messages.

Sequence number field 508 is a specific numeric identifier assigned to each PPL Event Request message that is generated by the host application. This value is used to distinguish between different PPL Event Request messages transmitted from the host to the switch. For example, when the host acknowledges the receipt of a PPL Event Request message, it includes the sequence number in its acknowledgement to identify which of the PPL Event Request messages is associated with the status information contained within the acknowledgement.

As noted, every PPL component state machine in a switch is assigned a unique reference number. PPL component ID 510 is a one word field that identifies which PPL component implemented in the switch is referenced by a particular PPL Event Request message 500.

There may be multiple instantiations of a PPL component state machine in a switch at any given time. For example, in the preferred embodiment there is an E1 PPL component state machine assigned to each channel. Thus, in the illustrative embodiment wherein a single E1 card supports 256 channels, there may be as many as 256 instantiations of the E1 PPL component state machine, each associated with a distinct channel. In order to selectively provide access to every instantiation of a PPL component, the universal API of the present invention provides the ability to perform multiple levels of addressing. Thus, once the PPL component has been identified in the PPL component ID field 510, an address element field 514 is provided to identify which instantiation(s) of that PPL component state machine is(are) being referenced. As shown in Figure 5, the PPL Event Request message provides the ability to include any number of address element fields 514, and thus may simultaneously communicate with multiple instantiations of a single PPL component state machine. The total number of address element fields 514 included in a PPL Event Request message is provided in address element count field 512.

To accommodate the additional levels of addressing noted above, address element field 514 contains a number of subfields for further identifying which state machine instantiation is to receive the PPL Event Request message. Specifically, an address element type field 516 is provided to reference the hierarchial components of the switch that may contain or be associated with the desired state machine instantiation. In the above example of an E1 PPL state machine instantiation, the address element type field 516 indicates which span and channel the state machine instantiation is associated with. An address information subfield 520 provides specific addresses for each of the hierarchial components indicated in the address element type field 516.

Since the addressing information contained in field 520 varies in accordance with the type of device addressed, the length of the AE field 514 may vary and thus is provided in length subfield 518. It is considered to be apparent to one skilled in the relevant art to use other addressing schemes appropriate for a particular PPL component state machine and switch architecture. It should also be noted that, in the above example, a single state machine instantiation exists for each channel since the PPL component state machine is assigned to each channel individually. However, it is considered to be apparent to one skilled in the relevant art that a particular state machine may be configured to manage any number of channels.

The multiple levels of addressing provide the universal API PPL Event Request message with a flexible addressing scheme. This enables a host application, using a single PPL Event Request message, to address a range of state machine instantiations having a common PPL component ID to generate a particular event at all addressed state machines.

Each PPL event has a unique ID relative to each PPL component. The PPL event ID field 522 provides the switch with a user-defined PPL event ID that the switch recognizes as being associated with the particular request. The recipient PPL component maps the unique PPL event ID to a PPL event that is unique to that PPL component.

Each PPL Event Request message may also contain one or more data fields in the form of information control blocks (ICB)s. ICBs are defined for each PPL component based upon the software layer and the communications protocol supported by that PPL component. Thus, any signalling information may be passed between the host and switch using the generic, programmable messages of the present invention.

Also referring to Figure 5, a PPL Event Indication message is sent from the switch to the host by a PPL component to report an event at the ports to the host with optional ICB data. The PPL Event Indication message is the only call control processing message passed from the switch to the host and in the preferred embodiment, has the same format as the PPL Event Request message illustrated in Figure 5. Except as noted below, the fields of the PPL Event Indication message are identical to and perform the same functions as, the analogous fields of the PPL Event Request message discussed above.

As noted above, there may be multiple instantiations of a PPL component state machine. For the PPL Event Indication message, the address element field(s) indicate which instantiation of a particular state machine is actually invoking the atomic function that generates the PPL event indication message.

In the PPL Event Indication message, the PPL event ID field 522 is a specific value representing the occurrence of a specific event in the switch that results in the PPL Event Indication message being sent from the PPL component state machine. As noted, this is managed with an atomic function that is programmed to send the particular PPL Event Indication message in response to the occurrence of a particular event, the PPL Event ID included in the message being programmed by the user.

It is considered to be obvious to one skilled in the relevant art to configure all transfers of information in the switch using the universal API of the present invention, including all layer-to-layer communications. For example, the exemplary communications described in the above-incorporated U.S. Patent No. 5,426,694 may be replaced with the universal API messages of the present invention.

The PPL components can be layer specific, function specific, interface specific, protocol specific, or channel specific. This enables a host Layer 5 telecommunications application to be as interactive as desired or necessary, accessing each layer of the switch and managing each PPL component regardless of where the component is located. An application can therefore use the universal API interface to manage any PPL component. This provides a consistent and predictable means for managing every PPL component in the switch, regardless of what level of processing is being performed, ranging from, for example, a very detailed signalling analysis, to network signalling, to high-level call routing, to call management connection functions.

In the preferred embodiment of the present invention, the manner in which the data is identified and passed to the host includes the implementation of one or more atomic functions configured to store and retrieve data of a certain type to specific memory locations in conjunction with one or more atomic functions that generate a generic PPL Event Indication providing the host with all previously stored data.

However, as one skilled in the art would find apparent, there are numerous ways in which atomic functions may be configured to pass data in the PPL Event Indication message. For example, a separate atomic function may be implemented to transfer specific types of data in a PPL event indication message.

The short-hand notation for depicting the PPL Event Request and the PPL Event Indication messages is shown in on the bottom of Figure 5.

Referring to Figure 6, the telecommunications switch responds to the PPL Event Request with a PPL Event Request Response message having the format of message 600. Similarly, the host applications responds to the PPL Event Indication message with a PPL Event Indication Acknowledge message, also having the format illustrated in Figure 6. Generic acknowledgement message 600 includes a frame byte 602, length byte 604, message type 606, and sequence number 608, all of which perform the same function as the corresponding fields in the PPL Event Request message 500. In addition, a status field 610 provides the recipient with message-specific status information. The short-hand notation for depicting the PPL Event Request Acknowledge and the PPL Event Indication Acknowledge messages is shown in Figure 6.

Referring to Figures 7A-8G, two examples of the utilization of the universal API of the present invention to perform interactive voice processing functions are provided below. The first example illustrates a universal API for managing host-to-switch communications when the telecommunications switch is controlled by a highly interactive host application Layer 5 to perform interactive voice announcements. The second example illustrates a universal API for managing host-to-switch communications when the host application Layer 5 has limited interaction with the telecommunications switch to perform the same function. These examples illustrate the ability of the universal API to accommodate various applications requirements.

In the following Figures, a state is depicted as a circle, an atomic function is depicted as a rectangular box, and an event is represented by a word abbreviation located along a path leading out of a state. Information shown in parentheses in an atomic function represents arguments or data that are associated with that function.

Reference numbers are provided below in parentheses when necessary to avoid confusion with other numeric descriptors.

Figures 7A-7B illustrate an example of an application of the present invention in Call Processing Layer 4 with a high level of interaction required by the host application layer 5. In this example, the present invention is used to implement a protocol for providing host application decisionmaking throughout the performance of an interactive voice response to an incoming call.

The protocol begins with the associated channel (channel 1) in normal state NS0, which is the IDLE state 702. Upon the occurrence of the event of layer 3 transmitting to layer 4 a setup message ((50)L4PPLevL3_SETUP_INDICATION)), the atomic function af35 is performed. As noted in its descriptor, the Layer 4 PPL event (L4PPLev) is received from network signalling protocol layer 3 (L3), reporting that it has detected an incoming call (SETUP_INDICATION). The number 50 in the parenthetical preceding the message descriptor is the PPL event ID assigned to that event by the Layer 4 PPL. Thus, when Layer 4 is notified of an incoming call, represented by a PPL event ID of 50, the PPL component state machine in Figure 7A leaves idle state 702 and performs atomic function af35 (704).

Atomic function af35 (704) operates to notify the host application (Layer 5) of the event, assigning to the event a PPL event ID of 1. The host application interprets this PPL event ID (the number 1) as a notification of an incoming call. Referring to Figure 7C, atomic function 35 (704) generates a PPL Event Indication message 701 to notify the host of the incoming call. This PPL Event Indication message has the following format:

PPL Event Ind (L4PPL, ch1, 1)

wherein the PPL component ID indicates the Layer 4 PPL component (L4PPL), the instantiation of the Layer 4 PPL component state machine addressed by this message is the instantiation associated with channel 1 (ch1), and the PPL event ID (1) indicates that an incoming message has been received while the PPL component state machine has been in the idle state NS0.

As shown, the arguments associated with atomic function af35 (704) specify a Layer 4 PPL event ID. Note that more generally, atomic function af35 is a PPL Send Event Indication message atomic function, used whenever a PPL Event Indication message is to be sent to the host Layer 5, each message having arguments for indicating the unique PPL event ID associated with the occurrence of a different event. The host responds with a PPL Event Indication Acknowledge message 703 having the general format:

PPL Event Ind Ack (sequence #, status)

wherein the sequence number is the sequence number provided in the PPL Event Indication message 701, and the status indicates the status of the associated PPL event indication message. For purposes of this and the following examples, the PPL Event Indication Acknowledge messages all indicate that the immediately previous PPL Event Indication message was successfully received.

After the telecommunications switch provides the host with notification of an incoming call utilizing the PPL Event Indication message of the present invention, the Layer 4 PPL component state machine enters normal state NS1, which is a WAIT state 706, during which the Layer 4 PPL component waits for the host application to respond to the notification. The host sends a Layer 5 PPL Event Request message 705 (see Figure 7C) with an event ID of 1, indicating that it is requesting that the switch proceed with the call received on channel 1. Message 705 has the following format:

PPL Event Req (L4PPL, ch1, 1)

indicating that the switch is to respond to the incoming call received on channel 1. A PPL Event Request message having a PPL Event ID of 1 is interpreted by the Layer 4 PPL component state machine as an event. As illustrated in Figure 7A, the receipt of this PPL Event Request message is assigned by the Layer 4 PPL component state machine a Layer 4 unique PPL event ID of 501, indicating that a Layer 5 PPL Event Request (with a PPL Event ID of 1) has occurred.

In response to PPL event 501, the Layer 4 PPL component state machine performs 5 atomic functions: atomic function af60 (708), atomic function af62 (710), atomic function af140 (712), atomic function af212 (714) and atomic function af50 (716). Atomic function af60 is an atomic function that generates a generic PPL Event Request Acknowledge message in accordance with the present invention. This atomic function af60 may be used whenever a PPL component of the switch is to acknowledge the receipt of a PPL Event Request message. The argument number 16 represents an acknowledgement status that the PPL Event Request message was successfully received. This atomic function af60 (708) generates the PPL Event Request Acknowledge message 707, having the same general format as the PPL Event Indication Acknowledge message described above. The PPL Event Request Acknowledge message 707 indicates that the above incoming message has been successfully received.

Atomic functions af62 (710) and atomic function af140 (712), serve, respectively, to send a connect message (to answer the call) to Layer 3 and to send a message to allocate a DSP resource for interactive digit string collection. Atomic function af212 (714) plays an opening announcement to the caller. As shown, there are two arguments to af212: an announcement ID and an announcement control option. af212 (714) was selected to play an opening announcement. Atomic function af50 (716) is performed to set a timer to wait for a selected period of time for receipt of incoming digits, entered in response to the announcement played by atomic function af212 (714). As shown, the first argument indicates that the multi-purpose timer to be used for performing this function is timer1. The second argument indicates the number of 1000 ms units the timer is to count. Here, the second argument is 10, indicating that timer1 will count for 10 seconds. Thus, atomic function af50 (716) enables timer1 to expire in 10 seconds, during which time the Layer 4 PPL component enters normal state S2, which is WAIT state 718, wherein the PPL state machine waits for a digit to be detected on channel 1.

If the next PPL event is the expiration of timer1 ((191) PPLevTIMER1) indicating that no digits were received with the 10 second period, atomic function af35 (720) is performed to inform the host that no digits were received. The receipt of a

PPLevTIMER1 message is assigned a PPL event ID of 191 by Layer 4 PPL component. As noted, atomic function 35 generates the PPL Event Indication message of the present invention. Here, however, a PPL Event ID of 4 is included in the PPL Event Indication message, indicating that there has been a failure to detect digits on the selected channel. The format of this PPL Event Indication message is, therefore:

PPL Event Ind (L4PPL, ch1, 4)

indicating that no digits have been detected on the channel associated with the channel 1 instantiation of the Layer 4 PPL component while the Layer 4 PPL component was in the wait state 718.

Since the interface diagram of Figure 7C illustrates the universal API protocol associated with the successful receipt of digits and subsequent processing of the call announcement, this message is not illustrated in Figure 7C. Processing then continues with a series of atomic functions not shown where, under host application control through the implementation of the universal API of the present invention, the telecommunications switch performs various functions in response to the failure to detect digits on channel 1.

If the next event to occur while the Layer 4 PPL component state machine is in wait state 718 is the receipt of a message indicating that digits have been detected on channel 1, ((66)L4PPLevDSP_RESULT_DIGITS), atomic function af47 (722) is performed. The receipt of this message is assigned a unique PPL Event ID of 66. Thus, when Layer 4 is notified that digits have been received, the Layer 4 PPL component state machine leaves wait state S2 (718) and performs atomic function af47 (722). Atomic function af47 disables the PPL multipurpose timer (timer1) selected by atomic function af50 (716), as indicated in the argument to the atomic function. Atomic function af53 (724) stores the received digits in a selected general purpose register. Here, af53 (724) stores the received digit in general purpose register 1.

In accordance with the present invention, atomic function af36 (726) is an atomic function configured to send a PPL Event Indication message with the contents of a selected general purpose register (argument 2), with a PPL event ID (argument 1).

Here, atomic function af36 (726) sends the contents of the general purpose register 1 to the Layer 5 host application as a PPL Event Indication message 709 having an Event ID of 2. PPL Event Indication message 709 has the format

PPL Event Ind (L4PPL, ch1, 2, digit)

wherein L4PPL is the PPL component ID, ch1 is the address element, 2 is the PPL event ID, and "digit" is the received digit. This PPL Event Indication message exemplifies the capability of the universal API of the present invention to transfer data as well as commands utilizing a single generic PPL Event Indication message format. The host responds with a PPL Event Indication Acknowledgement message 711, indicating that the PPL Event Indication message 709 was successfully received. Atomic function af147 (728) is then performed to cancel digit reception by disconnecting the DTMF receiver from channel 1.

The Layer 4 PPL component state machine then enters state S4 which is a WAIT state 730, wherein the Layer 4 PPL component state machine will wait indefinitely for the host application Layer 5 to direct the Layer 4 PPL component state machine how to respond to the digit that was received. As shown in Figure 7B, in the exemplary embodiment, the host application may send the Layer 4 PPL component any one of 3 different responses, having PPL Event ID 504, 505, and 506.

If a PPL Event Request message 713 having a PPL event ID of 4 is received by the Layer 4 PPL component state machine, ((504)PPLevL5_EVENT_REQ_4) the Layer 4 PPL component state machine assigns a Layer 4 unique PPL event ID 504 to it, indicating that Layer 5 provided a PPL Event Request message having a PPL event ID of 4. PPL Event Request message 711 directs the Layer 4 PPL component state machine to play a specific outgoing announcement. The format of PPL Event Request message 713 is:

PPL Event Req (L4PPL, ch1 , 4)

wherein the PPL component ID indicates that the message is directed towards the Layer 4 PPL component (L4PPL), the address element indicates that channel 1 is the channel by which the communication is occurring (ch1), and the PPL event ID (4) indicates that a specific additional outgoing announcement is to be played on the identified channel.

In response to PPL event 504, Layer 4 performs 4 atomic functions: atomic function af60 (732), atomic function af140 (734), atomic function af212 (736) and atomic function af50 (738). Atomic function af60 (732) is an atomic function that generates a generic PPL Event Request Acknowledge message in accordance with the present invention. As noted, atomic function af60 is used whenever a PPL component is to acknowledge the receipt of a PPL Event Request message. The argument number 16 represents an acknowledgement status that the PPL Event Request message was successfully received. This atomic function generates the PPL Event Request Acknowledge message 764, having the general format described above.

Atomic function af140 (734) serves to allocate a DSP resource for interactive digit string collection to channel 1. Atomic function af212 (736) plays an additional outgoing announcement on channel 1. An announcement ID of 3 is indicated by the first argument; no options were selected according to the second argument. Atomic function af50 (738) is performed to set timer1 to wait for a 10 seconds for receipt of incoming digits. The PPL component enters state S5 (740) to wait for the incoming digit for the selected period of time.

The performance of atomic function af212 (736) results in the playing of an announcement to the caller. As shown, there are two arguments to af212: the announcement ID and announcement control options. Atomic function af212 (736) was selected to play an outgoing announcement.

Atomic function af50 (738) is performed to set a timer to wait for a selected period of time for receipt of incoming digits, entered in response to the announcement played by atomic function af212 (736). In accordance with the arguments, atomic function af212 (736) sets timer1 to expire in 10 seconds. During this period, the Layer 4 PPL component state machine enters state S5, which is a WAIT state 740 wherein the state machine waits for digits to be received.

In this exemplary embodiment, the host may have alternatively responded with either a PPL Event Request having a PPL event ID of 5 or 6 indicating to the Layer 4 PPL Component to perform other functions not shown. In both cases, the PPL component state machine performs atomic function af60 (731,733, respectively), indicating that the respective PPL Event Request message was successfully received.

If the next event is the expiration of timer1((191) PPLevTIMER1), the protocol again performs an atomic function af35. Atomic function af35 (742) is performed to inform the host that no digits were received within the allotted time. As noted, atomic functions af35 are configured to generate a PPL Event Indication message in accordance with the present invention. Here, a PPL Event ID of 4 is included in the PPL Event Indication message by atomic function af35 (742), indicating that there has been a failure to detect digits on the selected channel. The format of this PPL Event Indication message is:

PPL Event Ind (L4PPL, ch1, 4)

indicating that for the channel 1 instantiation of the Layer 4 PPL Component, no digits were detected within the allotted time. Since the interface diagram of Figure 7C illustrates the API protocol associated with the successful processing of the call announcement sequence, this message is not illustrated in that Figure.

If the next PPL event is the expiration of timer1 ((191) PPLevTIMER1) indicating that no digits were received within the 10 second period, atomic function af35 (742) is performed to inform the host that no digits were received by generating the PPL Event Indication message of the present invention with a PPL Event ID of 4, the format of which is:

PPL Event Ind (L4PPL, ch1, 4)

For reasons given above, this is not shown in Figure 7C. Processing then continues with a series of atomic functions not shown where, under host ampliation control through the implementation of the universal API of the present invention, the telecommunications switch performs various functions in response to the failure to detect digits on channel 1.

If the next event to occur while the Layer 4 PPL component state machine is in wait for digit state 740, is the receipt of a message indicating that digits have been detected on channel 1, ((66)L4PPLevDSP_RESULT_DIGITS), atomic functions af47 (744), af53 (746) and af36(748) are performed to disable the PPL multipurpose timer (timer1) previously selected, storing the received digits in a selected general purpose register, and sending a PPL Event Indication Message 717, respectively.

In accordance with the present invention atomic function af36 (748) is an atomic function configured to send a PPL Event Indication message with the contents of general purpose register 1 with a PPL event ID of 3. Here, atomic function af36 (748) sends the contents of the general purpose register 1 to the Layer 5 host application as a PPL Event Indication message 717 having an Event ID of 3. PPL Event Indication message 717 has the format:

PPL Event Ind (L4PPL, ch1, 3, digit)

wherein L4PPL is the PPL component ID, ch1 is the address element, 3 is the PPL event ID, and "digit" is the received digit. This event ID indicates that the returned digit is in response to an af212 atomic function playing an outgoing announcement having at announcement ID of 3. The host responds with a PPL Event Indication Acknowledgement message 719, indicating that the PPL Event Indication message 711 was successfully received.

Referring now to Figure 7D, it may be seen that the each sequence of atomic functions shown in Figures 7A-7B has been defined as a primitive. In effect, each primitive provides a shorthand way to identify a desired sequence of atomic functions to invoke. The table of Figure 7D lists in tabular format the sequence of atomic functions for each primitive.

Figure 7E is a state/event table that defines the relationships between the states, events and primitives of Figure 7D. In accordance with a preferred embodiment of the present invention, a customer wishing to create the protocol depicted in Figures 7A-

7B, would need only define the tables shown in Figure 76D and 7E. Those tables would then be downloaded to the switch 102 (Figure 1) through a series of messages from the host device.

Referring to Figures 8A-8G, a second example of the universal API of the present invention configured to manage host-to-switch communications is illustrated. IN this example, the host application Layer 5 has limited interaction with the telecommunications switch while performing these functions. Specifically, the telecommunications switch is configured to automatically respond to the digits that are entered. In contrast to the previous example, the Layer 4 PPL state machine includes internal states responsive to prompts internally generated during digit collection. These aspects of the switch replace the atomic functions generating PPL Event Indication messages to the host providing the received digit, and the subsequent wait states wherein the switch waits for the host to supply it with a PL Event Request message.

Figures 8A-8B illustrate an example of an application of the present invention in Call Processing Layer 4 with a limited level of interaction required by the host application Layer 5 to implement a protocol for providing limited host application decisionmaking in the performance of an interactive voice response to an incoming call.

The protocol begins with the associated channel (channel 1) in normal state S0, which is the IDLE state 702. Upon the occurrence of the event of layer 3 transmitting to layer 4 a setup message ((50)L4PPLevL3_SETUP_INDICATION)), the PPL component state machine in Figure 8A leaves idle state 802 and performs atomic function af35 (804).

Atomic function af35 (804) operates to notify the host application (Layer 5) of the event, assigning to the event a PPL event ID of 1. The host application interprets this PPL event ID value of 1 as a notification of an incoming call. Referring to Figure 8C, atomic function 35 (804) generates a PPL Event Indication message 801 to notify the host of the incoming call. This PPL Event Indication message has the same format as PPL Event Indication message 701, and indicates that the channel 1 instantiation of the Layer 4 PPL component state machine addressed by this message received an incoming message while the Layer 4 PPL component state machine was in the idle state.

The host responds with a PPL Event Indication Acknowledge message 702 having the general format described above, indicating that the previous PL Event Indication message was successfully received.

After the telecommunications switch provides the host with notification of an incoming call utilizing the PPL Event Indication message of the present invention, the Layer 4 PPL component state machine enters normal state S1, which is the WAIT state 706, during which the Layer 4 PPL component waits for the host application to respond to the notification. The host sends a Layer 5 PPL Event Request message 705 with an event ID of 1, indicating that it is requesting that the switch proceed with the call received on channel 1. This message has the format described above, indicating that an incoming message has been received on channel 1 for that instantiation of the Layer 4 PPL component while the Layer 4 PPL component state machine has been in the idle state.

The receipt of this PPL Event Request message is identified by the Layer 4 PPL component state machine as a PPL event and is assigned a Layer 4 unique PPL event ID of 501, indicating that a Layer 5 PPL Event Request (1) has occurred.

In response to PPL event 501, the Layer 4 PPL component state machine performs 5 atomic functions: atomic function af60 (808), atomic function af62 (810), atomic function af140 (812), atomic function af212 (814) and atomic function af50 (816). As noted, atomic function af60 is used whenever a PPL component is to acknowledge the receipt of a PPL Event Request message. The argument number 16 represents an acknowledgement status that the PPL Event Request message was successfully received. This atomic function af60 (808) generates the PPL Event Request Acknowledge message 807, having the same general format as the PPL Event Indication Acknowledge message described above. The PPL Event Request Acknowledge message 807 indicates that the above incoming message has been successfully received.

Atomic functions af62 (810), af140 (812), af212 (814) and af50 (816) perform the same function as the analogous atomic functions described above with reference to

Figure 7A. Atomic function af50 (816) enables timer1 to expire during which time the Layer 4 PPL component enters normal state S2, which is WAIT state 818, wherein the PPL state machine waits for a digit to be detected on channel 1.

As in the above example, if the next PPL event is the expiration of timer1 ((191) PPLevTIMER1) indicating that no digits were received within the selected waiting period, atomic function af35 (820) is performed.

If the next event to occur while the Layer 4 PPL component state machine is in wait state 818 is the receipt of a message indicating that digits have been detected on channel 1, ((66)L4PPLevDSP_RESULT_DIGITS), atomic functions af47 (822), af53 (824), and af47 (828) are performed. These atomic functions performs similar functions to the analogous atomic functions described above with reference to Figures 7A and 7B. Note that an atomic function analogous to af36 (726) is not invoked. Thus, the received digit is not provided to the host application.

Atomic function af28 (829) is performed to test the value of the digit stored in the general purpose register used in atomic function af63 (824) to store the received digit. The Layer 4 PPL component state machine enters internal state IS3 which is a TEST state 830, wherein the Layer 4 PPL component state machine tests the value of the digit that was received and stored in general purpose register 1. As shown in Figure 7B, in the exemplary embodiment, the tested digit may have any one of 3 different values, each generating an internal event having PPL Event ID 200, 201, and 202.

If a PPL Internal Event message having a PPL event ID of 0 ((200)PPLevINT_EVENT_0) is provided to the Layer 4 PPL component state machine, the Layer 4 PPL component state machine assigns a Layer 4 unique PPL event ID 200 to it to indicate that the internal event having a PPL event ID of 0 was received.

In response to PPL event 200, the Layer 4 PPL component state machine performs 3 atomic functions af140 (834), af212 (836) and atomic function af50 (838), each of which perform functions similar to the analogous atomic functions described above with reference to Figures 7A and 7B. Note that an atomic function analogous to af60 (732) is not performed since the switch tests the incoming digit itself, and does not wait for a host generated PPL Event Request message. Therefore, no acknowledgement is required to be generated.

The Layer 4 PPL component state machine then enters normal state NS4, which is a WAIT state 840 wherein the state machine again waits for digits to be received.

If no digits are received, the next event is the expiration of timer1((191) PPLevTIMER1), the protocol performs an atomic function af35 (842) to inform the host that no digits were received within the allotted time. Processing then continues with a series of atomic functions not shown where, under host ampliation control through the implementation of the universal API of the present invention, the telecommunications switch performs various functions in response to the failure to detect digits on channel 1.

If the next event to occur while the Layer 4 PPL component state machine is in wait for digit state 840, is the receipt of a message indicating that digits have been detected on channel 1, ((66)L4PPLevDSP_RESULT_DIGITS), atomic functions af147 (844), af53 (846) are performed. These atomic functions perform similar functions to the analogous atomic functions described above with reference to Figures 7A and 7B. Further, atomic function af28 (847) is performed to test the value of the now second received digit stored in general purpose register 1. A function analogous to atomic function af36 (748) is not performed, thereby not providing the host with a PPL Event Indication message.

Referring now to Figure 8D-8E, it may be seen that the each sequence of atomic functions shown in Figures 8A-8B has been defined as a primitive. In effect, each primitive provides a shorthand way to identify a desired sequence of atomic functions to invoke. The table of Figure 8F lists in tabular format the sequence of atomic functions for each primitive.

Figure 8F is a state/event table that defines the relationships between the states, events and primitives of Figure 8D. In accordance with a preferred embodiment of the present invention, a customer wishing to create the protocol depicted in Figures 8A-8B, would need only define the tables shown in Figure 8D and 8E. Those tables would then be downloaded to the switch 102 (Figure 1) through a series of messages from the host device.

Referring to Figures 9-11, a Layer 4 PPL component 901 is executed as part of a Layer 4 PPL processor 902. As noted above, there may be multiple instantiations of a PPL component operating simultaneously, each of which has an associated state machine and tables. All instantiations of a the Layer 4 PPL component 901 are executed on a PPL state machine engine 1104. Layer 4 PPL processor 902 also includes a Layer 4 PPL message processor 1102 for receiving and processing internal PPL Event Request messages 1106. Each PPL processor such as Layer 4 PPL processor 902 may contain any number of PPL components. In the exemplary embodiment shown in Figures 9 and 11, the Layer 4 PPL processor 902 contains a single Layer 4 PPL component 901.

Figure 9 illustrates the process flow related to the invocation and execution of an atomic function to create a PPL Event Indication message. For exemplary purposes, Figure 9 illustrates the functions preformed in relation to the processing of atomic function af35 (704) of primitive #1 (750) to create PPL Event Indication message 701. Atomic function af35 (704) is part of the Layer 4 PPL component 901.

Layer 4 PPL processor 902 resides on CPU/matrix card 112 in the illustrative embodiment discussed above, and invokes atomic functions in accordance with the state/event and primitive tables to perform various functions, including the functions discussed above with reference to the Call Management Layer 4 in Figure 2. As noted, Call Management Layer 4 is responsible for performing centralized call processing functions and providing a common interface to Application Layer 5.

In the preferred embodiment of the present invention, the functions performed by the Layer 4 PPL processor 902 are implemented in a publicly available, proprietary operating system referred to as PSOS, available from Integrated Systems, Inc., Santa Clara, California, USA. However, as will become apparent to one skilled in the relevant art, the present invention may be implemented in any commonly known software program and in any software language now or later developed.

Generally, the Layer 4 PPL processor 902 invokes atomic functions that generate internal representations of the PPL Event Indication message. The internal message is passed to a communications processor 906, also residing on the CPU/matrix card 112, for translation into a PPL Event Indication message of the universal API of the present invention.

When Layer 4 PPL processor 902 executes a primitive of a PPL component state machine, it invokes each of the atomic functions associated with that primitive, as indicated by the primitive table 780 discussed above. In the example discussed above with reference to Figures 7A and 7B, atomic function af35 (704) is the only atomic function included in primitive #1 (750). As noted, atomic function 35 is a PPL Send Event Indication atomic function used whenever a PPL Event Indication is to be sent to the host, each occurrence of the atomic function having a different PPL event ID to indicate the occurrence of a different event.

A number of functions, each of which is described below, are performed by the Layer 4 PPL atomic function af35 (704) to create the PPL Event Indication message 701 for transmission to a Layer 5 host application. Referring to Figure 10, layer 4 PPL processor 902 allocates a message buffer 1050 to "attach" to the internal representation of the PPL Event Indication message 904 generated by the atomic function af35 (704). The message buffer is used by the PSOS operating system to store the necessary information for creation of the PPL Event Indication message 701. A pointer to that message buffer is obtained through the PSOS operating system when the buffer is allocated.

Once the message buffer is allocated, destination and source ID fields 1052, 1054 are loaded. The contents of these two fields is determined by the relative location of the transmitting and receiving elements. In addition to enabling a PPL component to communicate with Layer 5 applications residing on the host, the universal API of the present invention may be implemented to manage communications between any two instantiations of any PPL components residing in the same or different PPL processors.

When the universal API is utilized to achieve communications between PPL components that are located in, or "owned", by the same PPL processor, then the source and destination ID fields are loaded with the PPL component ID. Otherwise, the source and destination ID fields are loaded with the processor virtual ID, and the message type field 1058 is used by the destination PPL component or application to direct the message to the appropriate instantiation of the desired PPL component residing in the destination PPL processor. The message type field 1058 contains a unique message type identifier that is associated with a specific PPL component.

The Layer 4 PPL processor 902 also loads a PPL event ID into the associated field 1056 of the message buffer, the event ID identified in the PPL primitive table 780 provided to atomic function af35 (704). In the example illustrated in Figure 7, atomic function af35 (704) indicates the detection of an incoming call during idle state S0, and is assigned a PPL event ID of 1.

An ICB count field 1062 is loaded with the number of trailing ICB data fields 1064, if any.

The Layer 4 PPL processor 902 transfers the data buffer 1050 to the PPL Event Indication message 904. This is accomplished by invoking a function that attaches the allocated buffer 1050 to the PPL Event Indication message 904 by providing the communications processor 906 with a pointer to the data buffer 1050. The communications processor 906 reformats the API messages of the present invention from the internal representation usable by the PPL processor 902 to the format shown in Figure 5 for transmission to the host application. Communications processor 906 performs well known translating operations typical of message handling communications processors, and is considered to be well known in the art. Communications processor 906 then transmits the PPL Event Indication message 701 to an applications program located in host computer 130 via the API interface 908.

The scheme discussed above with respect to the Layer 4 PPL processor 902 is shown below by the following pseudo-code. It is envisioned that this pseudo-code can be used to generate source code for the present invention in any suitable language, such as C, C++ or PASCAL:

```
1.    allocate psos msg data buffer (ppl_data_buff);
2.    psos_msg.ppl_component=L4PPL;
3.    psos_msg.event_id=event_id;
4.    psos_msg.destination = HOST;
5.    psos_msg.source = L4PPL;
6.    psos_msg.timeslot_addr = CHANNEL 1;
```

7. l4ppl_send_msg (psos_msg, comm queue);

Figure 11 illustrates the process flow related to the receipt and processing of a PPL Event Request message. For exemplary purposes, Figure 11 illustrates the functions related to the processing of PPL Event Request message 705 received at wait state S1 (706), invoking primitive 2 atomic functions as shown in primitive table 780.

The communications processor 1006 performs the inverse operation of that performed above with respect to the PPL Event Indication message. That is, the communications processor 1006 receives the API version of the PPL Event Request message 705 over API 1008 and translates it into an internal PSOS PPL Event Request message 1106. Communications processor 1006 transmits the PPL Event Request message 1106 to the Layer 4 PPL processor 1002. A Layer 4 PPL message processor 1102 receives and processes the internal PPL Event Request message 1106 and generates a distinct Layer 4 PPL event for the Layer 4 PPL state machine engine 1104.

The Layer 4 PPL message processor 1102 converts the PPL event ID 522 of message 705 into a Layer 4 unique PPL event ID for the Layer 4 PPL state machine 1104 by adding a layer 5 event request base value of 500 to the PPL event ID. Thus, in the exemplary embodiment, the Layer 4 PPL message processor 1102 adds a base value of 500 to the PPL Event Request message PPL event ID of 1 to result in a Layer 4 unique PPL event ID of 501.

Once the PPL Event Request message is mapped to a Layer 4 unique PPL event ID, a pointer is derived to the selected channel's PPL data based upon the address element value in the message that contained a logical span and channel ID. In other words, the Layer 4 PPL message processor 1102 converts the logical address into a physical address, i.e.., a physical time slot in switch 102. Then the PPL state machine engine is invoked, typically as a function call, with the channel pointer for the PPL component instantiation data block and a pointer to the data block associated with the PPL Event Request message 1106 that was received from the communications processor 1006.

The Layer 4 PPL component state machine engine 1104 processes the Layer 4 unique PPL event ID, searching the state/event table 790 for that PPL Event ID for the present state. If a matching event is found, the state machine engine 1104 invokes the identified primitive in the state/event table, retrieving from primitive table 780 the atomic functions associated with the primitive ID.

Thus, in the illustrative embodiment, the Layer 4 PPL component state machine engine 1104 processes PPL event 501, locating the PPL Event ID of 501 for the present state S1 (706) in the state/event table 790 and invoking the atomic functions associated with primitive #2. The PPL state machine engine 1104 enters the state indicated in the Layer 4 PPL state/event table 790 after processing all the atomic functions associated with primitive 2.

Pseudo-code for Layer 4 PPL message processor 1102 as contemplated by embodiments of the present invention is disclosed below:

```
1.    ppl_event=psos_msg.ppl_data_buff®ppl_event + ppl_L5_event_req_base
2.    ppl_chan_ptr = ppl_data [psos_msg.hdr.timeslot_addr]
3.    ppl_stmch(ppl_chan_ptr, ppl_event, psos.msg)
```

It should be understood that embodiments of the present invention can be implemented in hardware, software or a combination thereof. In such embodiments, the various components and steps would be implemented in hardware and/or software to perform the functions of the present invention. Any presently available or future developed computer software language and/or hardware components can be employed in such embodiments of the present invention. In particular, the pseudo-code discussed above can be especially useful for creating the software embodiments.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention. Furthermore, the terms and expressions which have been employed are used as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention claimed.

CLAIMS

1. A telecommunications system, including:
a host device;
a programmable telecommunication switch, connected in communicating relationship with and responsive to said host device, for performing call processing functions related to communication paths established between various ones of a plurality of channels; and
a universal applications program interface (API) having standardized messages for communication between said telecommunications switch and said host device.

2. The system of claim 1, wherein said universal API comprises:
a single message type, referred to as a programmable protocol language (PPL) event request message, for transferring all call control processing commands and data from said host device to said telecommunications switch; and
a single message type, referred to as the PPL event indication message, for transferring all call control processing status and data from said telecommunications switch to said host device.

3. The system as in claim 2, wherein said telecommunications switch further comprises one or more instantiations of one or more finite state machines, each of said one or more finite state machines representing one of said one or more protocols and comprising,
one or more libraries each containing one or more predetermined functions;
one or more predetermined logical states;
at least one predetermined event associated with each said one or more predetermined logical states, each said at least one predetermined event uniquely identified relative to each said one or more PPL component state machines; and
wherein upon an occurrence of one of said one or more predetermined events, a predetermined primitive associated with the occurring event is invoked, said

predetermined primitive comprising a predetermined series of one or more said predetermined functions.

4. The system as in claim 3, wherein
said switch further comprises one or more state machine engines,
wherein each of said one or more state machines is configured to be interpreted by one or more state machine engines.

5. The system of claim 3, wherein said PPL event request message comprises:
a PPL component ID for identifying which of said one or more state machines is referenced by a particular PPL event request message;
one or more address elements, each identifying one of said one or more instantiations of said state machine identified in said PPL component ID field; and
a user-defined PPL event ID representing an associated one of said at least one predetermined events associated with the particular state machine identified in said PPL component ID field.

6. The system of claim 5, wherein said PPL event request message further comprises:
an address element type associated with said address element, for referencing components of said telecommunications switch associated with said state machine instantiation identified by said associated address element; and
a component address of each of said telecommunications switch components identified by said address element type.

7. The system of claim 5, wherein said PPL event request message further comprises:
one or more data fields associated with each of said one or more state machines, for transferring call control processing information from said host device to said telecommunications switch.

8. The system of claim 3, wherein said PPL e.ent indication message comprises: a PPL component ID for identifying which of said one or more state machines is referenced by a particular PPL event indication message; one or more address elements, each identifying one of said one or more instantiations of said state machine has invoked the function that generates said PPL event indication message; and a user-defined PPL event ID representing an occurrence of a specific one of said at least one event in said telecommunications switch that results in a particular PPL event indication message being generated by said state machine.

9. The system of claim 8, wherein each said PPL event indication message is generated by one of said one or more functions configured to send a PPL event indication message in response to the occurrence of a particular event, and wherein each said one or more address element fields comprises: an address element type referencing PPL components of said telecommunications switch associated with said state machine instantiation identified by said one or more address elements; and a PPL component address of each of said PPL components identified by said address element type.

10. The system of claim 8, wherein said PPL event indication message further comprises: one or more data fields associated with each of said one or more state machines, for transferring call control processing information from said host device to said telecommunications switch.

11. A telecommunications system, including: a host device; a programmable telecommunication switch, connected in communicating relationship with and responsive to said host device, for performing call processing

functions related to communication paths established between various ones of a plurality of channels; and

means for effecting communications between said switch and said host using a programmable universal applications program interface (API) including standardized messages for transmitting information between said host and said switch.

12. The system of claim 11, wherein said API is configured to be customized to meet telecommunications application and network signaling protocol requirements.

13. The system of claim 11, wherein said API comprises:

a first predetermined message format for all messages transferring call control processing information from said host device to said telecommunications switch; and

a second predetermined message format for all messages transferring call control processing information from said telecommunications switch to said host device.

14. The system as in claim 13, wherein said telecommunications switch further comprises:

one or more programmable protocol language (PPL) component state machines, each of which represents one of said one or more protocols for performing said call processing functions, said one or more state machines responsive to one or more predetermined events associated with said state machine.

15. The system as in claim 14, wherein

said switch further comprises one or more state machine engines, and wherein

each said one or more finite state machines comprises one or more libraries of predetermined functions,

wherein each of said one or more finite state machines is configured to be interpreted by one of said one or more state machine engines.

16. The system as in claim 15, wherein each of said one or more state machines is defined by a functional combination of a state/event table and a primitive table, wherein

said state/event table defines one or more predetermined logical states and at least one of said one or more predetermined events associated with each said one or more predetermined logical states, and wherein

said primitive table defines one or more primitives each of which comprises a predetermined series of one or more said predetermined functions, whereby upon an occurrence of one of said one or more predetermined events, a predetermined primitive associated with the occurring event is invoked.

17. The system of claim 14, wherein said first predetermined message format is a variable length PPL event request message comprising:

a PPL component ID for identifying which of said one or more PPL component state machines is referenced by a particular PPL event request message.

18. The system of claim 14, wherein said telecommunications switch further comprises:

one or more instantiations of each of said one or more PPL component state machines.

19. The system of claim 18, wherein said first message format is a variable length PPL event request message comprises:

a PPL component ID identifying which of said one or more PPL component state machines is referenced by a particular PPL event request message; and

one or more address elements, each identifying one of said one or more instantiations of said PPL component state machine identified by said PPL component ID.

20. The system of claim 19, wherein each said one or more address elements comprises:

an address element type for referencing components of said telecommunications switch associated with said state machine instantiation identified by said one or more address elements; and

PPL component address information providing specific addresses for each of said PPL components identified by said one or more address elements.

21. The system as in claim 18, wherein said PPL event request message comprises a programmable variable addressing scheme to address a desired one or more of said at least one instantiation of each of said plurality of PPL component state machines.

22. The system of claim 19, wherein,

each said one or more events is uniquely identified relative to each said one or more PPL component state machines, and further wherein,

said PPL event request message further comprises a PPL event ID field containing a user-defined event ID representing an associated event unique to a particular PPL component state machine identified in said PPL component ID field.

23. The system of claim 22, wherein said PPL event request message further comprises:

one or more data fields associated with each of said one or more PPL component state machines, for transferring call control processing information from said host to said switch.

24. The system of claim 14, wherein said second predetermined message format is a variable length PPL event indication message comprises:

a PPL component ID for identifying which of said one or more PPL component state machines is referenced by a particular PPL event indication message.

25. The system as in claim 18, wherein said PPL event indication message comprises a programmable variable addressing scheme to address a desired one or

more of said at least one instantiation of each of said plurality of PPL component state machines.

26. The system of claim 18, wherein said first message format is a variable length PPL event indication message comprises:

a PPL component ID identifying which of said one or more PPL component state machines is referenced by a particular PPL event indication message; and

one or more address elements, each identifying one of said one or more instantiations of said PPL component state machine has invoking the function that generates said PPL event indication message.

27. The system of claim 26, wherein said PPL event indication message is generated by one of said one or more functions configured to send the particular PPL event indication message in response to the occurrence of a particular event, and wherein each said one or more address element fields comprises:

an address element type subfield for referencing components of said switch associated with said state machine instantiation identified in said one or more address element fields; and

an address information subfield provides specific addresses for each of the hierarchical components indicated in said address element type field.

28. The system of claim 26, wherein,

each said one or more events is uniquely identified relative to each said one or more PPL component state machines, and further wherein,

said PPL event indication message further comprises a PPL event ID field containing a user-defined event ID representing the occurrence of a specific event in said switch that results in a particular PPL event indication message being generated by said PPL component state machine.

29. The system of claim 23, wherein said PPL event indication message further comprises:

one or more data fields associated with each of said one or more PPL component state machines, for transferring call control processing information from said host to said switch.

30. The system of claim 11, wherein said call processing functions include dynamically connecting or disconnecting communication paths between various ones of a plurality of channels.

31. A functionally-layered programmable telecommunication switch including:

controllable-switching means for dynamically connecting or disconnecting communication paths between various ones of a plurality of channels in response to messages generated by a telecommunications services application;

one or more instantiations of a plurality of programmable protocol language (PPL) component state machines, each of which is associated with a PPL component of said telecommunications switch and each of which represents one of a plurality of protocols configured to perform call processing functions with respect said plurality of channels, wherein said plurality of PPL component state machines are functionally associated with the functional layers of the telecommunications switch including said PPL components; and

a programmable universal applications program interface (API) for transferring standardized messages between said functional layers and between said functional layers and said telecommunications services application.

32. The telecommunications switch of claim 31, wherein said functional layers of said telecommunication switch comprise:

an application layer comprising said telecommunications service applications configured to operate in conjunction with one or more of said functional layers to perform telecommunications service functions.

33. The telecommunications switch of claim 32, wherein said application layer resides in said telecommunications switch and further wherein said universal API

defines communications that occur over a bus internal to said telecommunications switch.

34. The telecommunications switch of claim 32, wherein said functional layers further include an application layer residing in a host computer system coupled to said telecommunications switch, and wherein said API defines communications that occur over a communication channel coupling said telecommunications switch and said host device.

35. The telecommunications switch of claim 32, wherein said telecommunications services provided by said telecommunication service application includes toll-free service functions.

36. The telecommunications switch of claim 32, wherein said telecommunications service provided by said telecommunication service application includes voice mail service functions.

37. The telecommunications switch of claim 32, wherein said telecommunications service provided by said telecommunication service application includes automatic call distribution service functions.

38. The telecommunications switch of claim 32, wherein said call processing function performed by said telecommunication service application includes interactive voice-response functions.

39. The telecommunications switch of claim 32, wherein said call processing function performed by said telecommunication service application includes personal communications services functions.

40. The telecommunications switch of claim 32, wherein said call processing function performed by said telecommunication service application includes tone generation functions.

41. The telecommunications switch of claim 32, wherein said call processing function performed by said telecommunication service application includes call conferencing functions.

42. The telecommunications switch of claim 32, wherein said call processing function performed by said telecommunication service application includes call management functions.

43. The telecommunications switch of claim 32, wherein said call processing function performed by said telecommunication service application includes call progress tone control functions.

44. The telecommunications switch of claim 32, wherein said call processing function performed by said telecommunication service application includes inbound call routing and queuing functions.

45. The telecommunications switch of claim 31, wherein said functional layers comprise:

a call management layer for performing centralized call processing functions.

46. The telecommunications switch of claim 45, wherein said centralized call processing functions performed by said call management layer includes recorded announcement control functions for interactive voice response application support.

47. The telecommunications switch of claim 45, wherein said centralized call processing functions performed by said call management layer includes reconnection and transfer functions.

48. The telecommunications switch of claim 45, wherein said centralized call processing functions performed by said call management layer includes the provision of multiple call management features.

49. The telecommunications switch of claim 45, wherein said centralized call processing functions performed by said call management layer includes conferencing connection management functions.

50. The telecommunications switch of claim 31, wherein said functional layers comprise:

a network signaling protocol layer for performing network signaling functions.

51. The telecommunications switch of claim 50, wherein said network signally functions performed by said network signalling protocol layer includes in- and out-of-band network signalling supervision.

52. The telecommunications switch of claim 50, wherein said network signalling functions performed by said network signalling protocol layer includes network protocol level control of incoming and outgoing calls.

53. The telecommunications switch of claim 31, wherein said functional layers comprise:

a link layer for detecting and transferring network signaling information across a network or line interface.

54. The telecommunications switch of claim 53, wherein said link layer runs on a CPU/matrix card.

55. The telecommunications switch of claim 53, wherein said link layer runs on line cards.

56. The telecommunications switch of claim 53, wherein said functions performed by said link layer include T1 robbed bit signal scanning.

57. The telecommunications switch of claim 53, wherein said functions performed by said link layer include E1 channel associated signaling scanning.

58. The telecommunications switch of claim 53, wherein said functions performed by said link layer include T1/E1 line interface frame alarm control.

59. The telecommunications switch of claim 53, wherein said functions performed by said link layer include DSP tone generation control.

60. The telecommunications switch of claim 53, wherein said functions performed by said link layer include DSP recorded voice announcement control.

61. The telecommunications switch of claim 31, said functional layers comprise:

a physical layer implemented in line cards providing physical and electrical network and line interfaces to the switch.

62. The system of claim 31, wherein said API comprises:

predetermined message formats for all messages transferring call control processing commands, status and data between said functional layers.

63. The switch as in claim 31, wherein each said one or more PPL component state machines comprises,

one or more libraries each containing one or more predetermined functions;

one or more predetermined logical states;

at least one predetermined event associated with each said one or more predetermined logical states, each said at least one predetermined event uniquely identified relative to each said one or more PPL component state machines; and wherein upon an occurrence of one of said one or more predetermined events, a predetermined primitive associated with the occurring event is invoked, said primitive comprising a predetermined series of one or more said predetermined functions.

64. The switch as in claim 63, wherein

said switch further comprises one or more state machine engines, and wherein

each said one or more component state machines comprises one or more libraries of predetermined functions,

wherein said each said one or more component state machines is configured to be interpreted by one or more state machine engines.

65. The switch as in claim 63, each said one or more finite state machines comprising,

one or more libraries each containing one or more predetermined functions;

one or more predetermined logical states;

at least one predetermined event associated with each said one or more predetermined logical states, each said at least one predetermined event uniquely identified relative to each said one or more PPL component state machines; and

a predetermined series of one or more said predetermined functions,

wherein upon an occurrence of one of said one or more predetermined events, a predetermined primitive associated with the occurring event is invoked.

66. The switch as in claim 65, wherein each of said one or more state machines is defined by a functional combination of a state/event table and a primitive table, wherein

said state/event table defines one or more predetermined logical states and at least one of said one or more predetermined events associated with each said one or more predetermined logical states, and wherein

said primitive table defines one or more primitives each of which comprises a predetermined series of one or more said predetermined functions.

67. The switch as in claim 65, wherein

said switch further comprises one or more state machine engines, and wherein wherein said each said one or more finite state machines is configured to be interpreted by one or more state machine engines.

68. The switch of claim 65, wherein said PPL event request message comprises:

a PPL component ID for identifying which of said one or more PPL component state machines is referenced by a particular PPL event request message;

one or more address element fields, each identifying one of said one or more instantiations of said PPL component state machine identified in said PPL component ID field; and

a PPL event ID field containing a user-defined event ID representing an associated event unique to a particular PPL component state machine identified in said PPL component ID field.

69. The switch of claim 68, wherein each said one or more address element fields comprises:

an address element type subfield for referencing components of said switch associated with said state machine instantiation identified in said one or more address element fields; and

an address information subfield provides specific addresses for each of the hierarchical components indicated in said address element type field.

70. The switch of claim 68, wherein said PPL event request message further comprises:

one or more data fields associated with each of said one or more PPL component state machines, for transferring call control processing information from said host to said switch.

71. The switch of claim 65, wherein said PPL event indication message comprises:

a PPL component ID for identifying which of said one or more PPL component state machines is referenced by a particular PPL event indication message;

a PPL component ID field for identifying which of said one or more PPL component state machines is referenced by a particular PPL event indication message;

one or more address element fields, each identifying one of said one or more instantiations of said PPL component state machine has invoking the function that generates said PPL event indication message; and

a PPL event ID field containing a user-defined event ID representing the occurrence of a specific event in said switch that results in a particular PPL event indication message being generated by said PPL component state machine.

72. The switch of claim 71, wherein said PPL event indication message is generated by one of said one or more functions configured to send the particular PPL event indication message in response to the occurrence of a particular event, and wherein each said one or more address element fields comprises:

an address element type subfield for referencing components of said switch associated with said state machine instantiation identified in said one or more address element fields; and

an address information subfield provides specific addresses for each of the hierarchical components indicated in said address element type field.

73. The switch of claim 71, wherein said PPL event indication message further comprises:

one or more data fields associated with each of said plurality PPL component state machines, for transferring call control processing information between said functional layers, said data blocks defined for each said plurality of PPL components based upon which of said functional layers said PPL component state machine is associated with and the communications protocol supported by that PPL component state machine.

74. A universal applications program interface (API) for standardized interactive call processing communications between functional layers of a telecommunications system including a telecommunications switch and a host device coupled to the switch, including:

a first programmable message for transferring all call control processing commands and data from said host to said functional layers of said telecommunications switch; and

a second programmable message for transferring all call control processing status and data from said functional layers of said telecommunications switch to said host.

75. The API of claim 74, wherein the telecommunications switch comprises:

one or more instantiations of one or more PPL component state machines each of which represents a call processing protocol, each said one or more finite state machines comprising,

one or more libraries each containing one or more predetermined functions;

one or more predetermined logical states;

at least one predetermined event associated with each said one or more predetermined logical states, each said at least one predetermined event uniquely identified relative to each said one or more PPL component state machines; and

wherein upon an occurrence of one of said one or more predetermined events, a predetermined primitive associated with the occurring event is invoked, said primitive comprising a predetermined series of one or more said predetermined functions,

wherein said one or more predetermined events includes receipt of said first programmable message and wherein at least one of said one or more predetermined functions generates said second programmable message.

76. The API as in claim 75, wherein

said telecommunications switch further comprises one or more state machine engines, and wherein each said one or more PPL component state machines comprises one or more libraries of said one or more predetermined functions, and wherein

each said one or more PPL component state machines is configured to be interpreted by said one or more state machine engines.

77. The switch as in claim 75, wherein said API further comprises:

an acknowledge message including a status field providing the recipient with message-specific status information,

wherein said host device transmits said acknowledge message to said telecommunications switch upon receipt of said first programmable message and wherein at one of said one or more predetermined functions is configured to transmit said acknowledge message to said host device upon receipt of said second programmable message.

78. A method for developing call-associated protocols for performing call processing functions related to communication paths established between various ones of a plurality of channels in a programmable telecommunications switch, said call processing function associated with the functions performed by a particular functional layer of said switch, the method including the steps of:

(a) creating one or more state/event tables each of which defines,

a plurality of predetermined logical states,

one or more predetermined events associated with each of said plurality of predetermined logical states, said one or more predetermined events including receipt of one or more application program interface (API) messages generated at the same or different functional layer as said created call-associated protocol, and

a primitive associated with each said one or more predetermined events, wherein said primitive is invoked upon an occurrence of said one or more associated events;

(b) creating one or more primitive tables each of which defines a predetermined series of predetermined layer-dependent functions for each said primitive, one or more of said predetermined functions generating an API message to said functional layer; and

(c) creating one or more protocols each of which is represented by a predetermined association of one or more of said state/event tables and one or more of said one or more primitive tables.

79. The method of claim 78, further comprising the steps of:

(d) storing said one or more call-associated protocols stored within said programmable telecommunications switch; and

(e) executing said one or more call-associated protocols within said telecommunications switch.

80. The method as in claim 78, wherein each of said one or more protocols is represented by a finite state machine having access to a comprising a library containing definitions of said predetermined functions, and configured to be interpreted by a state machine engine, said state machine engine operating in response to said pointers.

81. A functionally-layered programmable telecommunication switch including:

a layer-specific processor having a state machine engine configured to execute an instantiation of a PPL component state machine representing a call processing protocol associated with a communications channel in the switch, said state machine invoking one or more predetermined functions in accordance with a current state and the occurrence of a predetermined event,

wherein said one or more predetermined functions includes generating a first application program interface (API) message having a first predetermined message format for all messages transferring call control processing information from said state machine; and

wherein said predetermined event is one of a plurality of events including the receipt of a second API message having a second predetermined message format for all messages transferring call control processing to said state machine.

82. The switch of claim 81, wherein said layer-specific processor is configured to process said first and second API messages in an internally-represented form, and wherein said switch further comprises:

a communications processor, coupled to said layer-specific processor, configured to convert between internally-represented API message form and said universal standardized API message form, and further configured to transmit said first universal API message.

83. The switch of claim 82, wherein said system includes a host configured to support applications residing in an application layer and further wherein said API messages are transmitted from the switch to the host and vice versa.

84. The switch of claim 81, wherein said processor comprises:

an atomic function message buffer including a destination identification field and a source identification field containing respective addresses of a source and receiving PPL component instantiation residing in the same or different PPL processors; and

means for attaching said message buffer to said internal representation of said PPL event indication message generated by said atomic function.

85. The switch of claim 84, wherein said message buffer further comprises:

a PPL event identification field identifying the event that generated said atomic function.

86. The switch of claim 84, wherein said message buffer further comprises:

one or more data fields containing information associated with said event and said atomic function for a receiving instantiation.

87. The switch of claim 83, wherein said plurality of PPL component state machines are layer specific.

88. The switch of claim 83, wherein said plurality of PPL component state machines are function specific.

89. The switch of claim 83, wherein said plurality of PPL component state machines are interface specific.

90. The switch of claim 83, wherein said plurality of PPL component state machines are protocol specific.

91. The switch of claim 83, wherein said plurality of PPL component state machines are protocol specific.

92. A method for communicating between two layers of a functionally-layered programmable telecommunication switch system utilizing a standardized universal application program interface (API), the method including the steps of :

(1) invoking one or more instantiations of a layer-specific program protocol language (PPL) component state machine at a layer-specific PPL processor having a state machine engine, each of said one or more instantiations representing a call processing protocol;

(2) invoking atomic functions in accordance with state/event and primitive tables defining said state machine and stored in the processor to perform various functions, said atomic functions generating internal representations of a API event indication message; and

(3) transferring said internally-represented PPL event indication message to a communications processor coupled to said processor for translation into a universal standardized PPL event indication message.

93. The method of claim 92, further comprising the step of:

(4) transmitting said universal API message to another PPL component state machine instantiation residing in the same or different PPL processor.

94. The method of claim 92, wherein said system includes a host supporting applications residing in an application layer and wherein the method further comprises the step of:

(4) transmitting said universal API message to an application located on the host.

95. The method of claim 93, further comprising the steps of:

(5) creating an atomic function message buffer, by said processor, including a destination identification field and a source identification field containing respective addresses of said source and receiving PPL component instantiation; and

(6) attaching said message buffer to said internal representation of said PPL event indication message generated by said atomic function.

96. The method of claim 95, wherein said message buffer further comprises:

a PPL event identification field identifying the event that generated said atomic function.

97. The method of claim 95, wherein said message buffer further comprises:

one or more data fields containing information associated with said event and said atomic function for a receiving instantiation.

98. The method of claim 92, further comprising the steps of:

(4) receiving at said communications processor, a universal API PPL event request message;

(5) translating at said communications processor, said universal API PPL event request message into an internally-represented PPL event request message;

(6) transmitting said internally-represented PPL event request message to said layer-specific PPL processor;

(7) receiving and processing, at said layer-specific PPL processor, said internally-represented PPL event request message; and

(8) converting a PPL event ID value included in said internally-represented PPL event request message into a layer-specific unique PPL event identification value for said layer-specific state machine; and

(9) processing the layer-unique PPL event identification value by said layer-specific PPL component state machine engine.

99. The method of claim 98, wherein said step (9) comprises the steps of:

(a) searching said state/event table for that PPL event identification value for the present state of said state machine;

(b) when a matching event is found, invoking the identified primitive in the state/event table, retrieving from primitive table the atomic functions associated with the primitive ID;

(c) invoking an identified primitive in the state/event table; and

(d) retrieving from primitive table the atomic functions associated with the primitive ID.

100. A telecommunications system substantially as herein described with reference to the accompanying drawings.

101. A functionally-layered programmable telecommunications switch substantially as herein described with reference to the accompanying drawings.

102. An API for standardized interactive call processing communications between functional layers of a telecommunication system substantially as herein described with reference to the accompanying drawings.

103. A method for developing call-associated protocols substantially as herein described with reference to the accompanying drawings.

104. A method for communicating between two layers of a functional-layered programmable telecommunication switch system substantially as herein described with reference to the accompanying drawings.

DATED: 21 February 2000
PHILLIPS ORMONDE & FITZPATRICK
Attorneys for:
EXCEL SWITCHING CORPORATION

FIG. 1

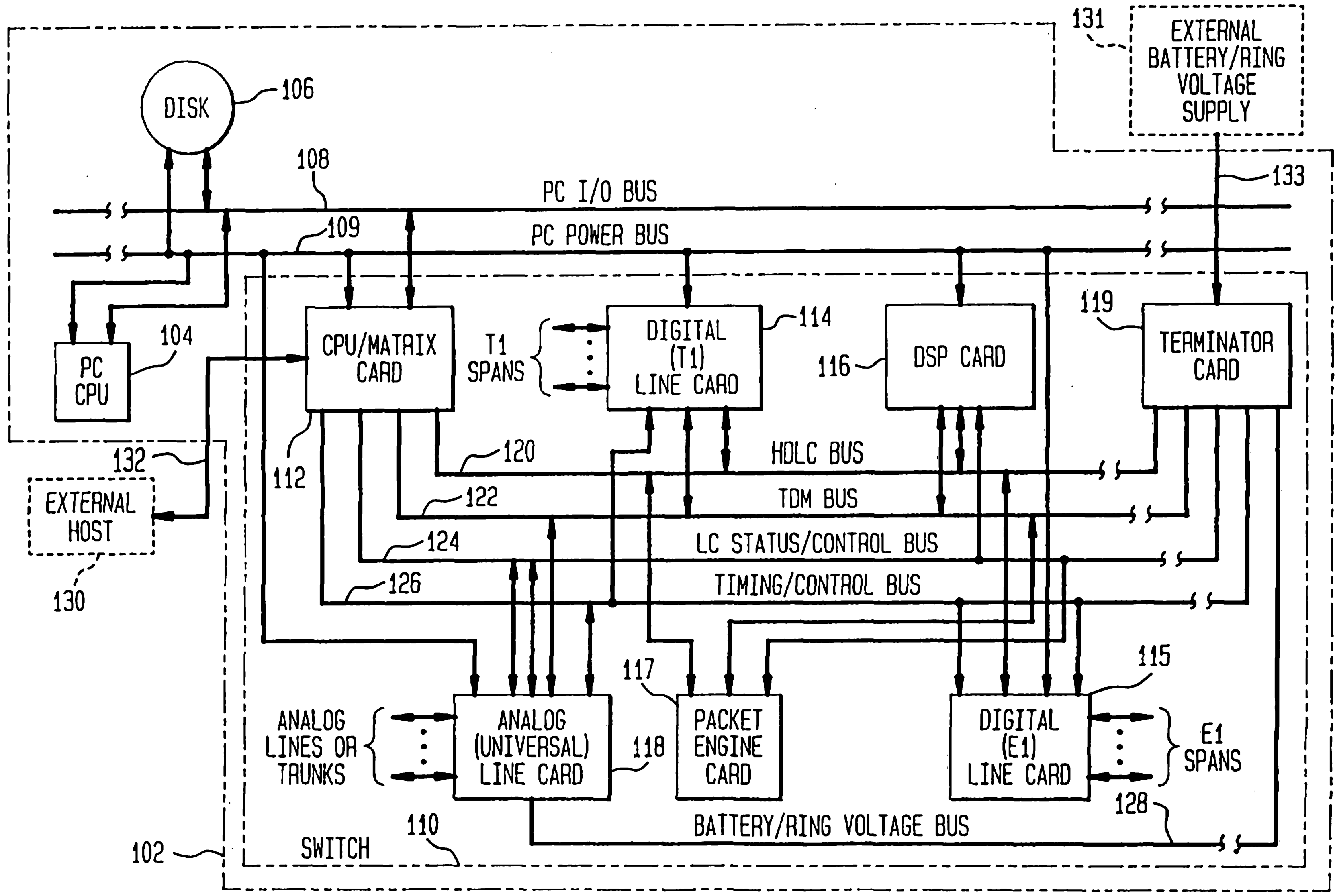

131
EXTERNAL BATTERY/RING VOLTAGE SUPPLY
DISK
106
108
PC I/O BUS
133
109
PC POWER BUS
104
PC CPU
CPU/MATRIX CARD
T1 SPANS
DIGITAL (T1) LINE CARD
114
116
DSP CARD
119
TERMINATOR CARD
132
112
120
HDLC BUS
EXTERNAL HOST
122
TDM BUS
130
124
LC STATUS/CONTROL BUS
126
TIMING/CONTROL BUS
117
115
ANALOG LINES OR TRUNKS
ANALOG (UNIVERSAL) LINE CARD
118
PACKET ENGINE CARD
DIGITAL (E1) LINE CARD
E1 SPANS
128
110
BATTERY/RING VOLTAGE BUS
102
SWITCH

FIG. 2

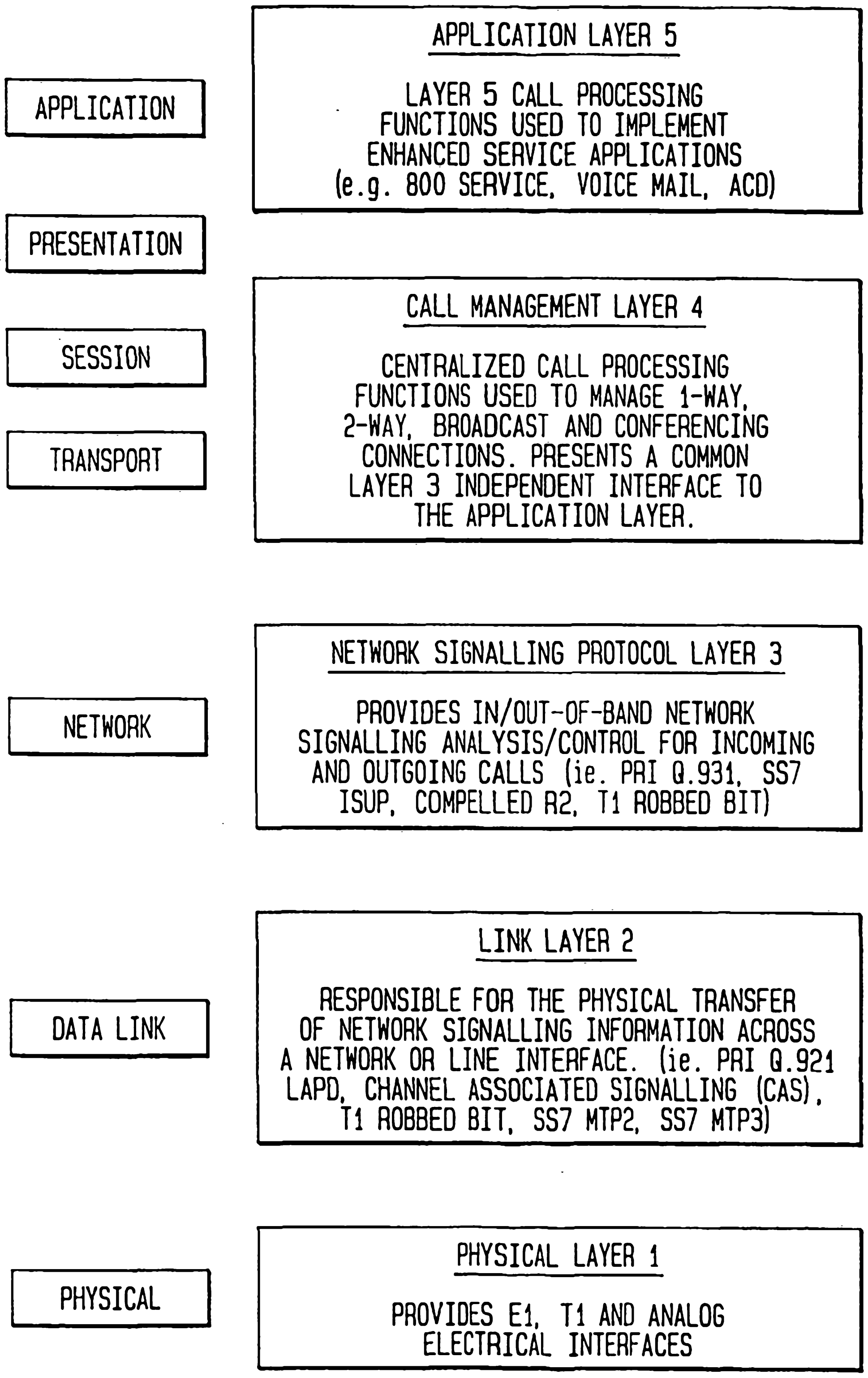

APPLICATION
PRESENTATION
SESSION
TRANSPORT
NETWORK
DATA LINK
PHYSICAL
APPLICATION LAYER 5
LAYER 5 CALL PROCESSING FUNCTIONS USED TO IMPLEMENT ENHANCED SERVICE APPLICATIONS (e.g. 800 SERVICE, VOICE MAIL, ACD)
CALL MANAGEMENT LAYER 4
CENTRALIZED CALL PROCESSING FUNCTIONS USED TO MANAGE 1-WAY, 2-WAY, BROADCAST AND CONFERENCING CONNECTIONS. PRESENTS A COMMON LAYER 3 INDEPENDENT INTERFACE TO THE APPLICATION LAYER.
NETWORK SIGNALLING PROTOCOL LAYER 3
PROVIDES IN/OUT-OF-BAND NETWORK SIGNALLING ANALYSIS/CONTROL FOR INCOMING AND OUTGOING CALLS (ie. PRI Q.931, SS7 ISUP, COMPELLED R2, T1 ROBBED BIT)
LINK LAYER 2
RESPONSIBLE FOR THE PHYSICAL TRANSFER OF NETWORK SIGNALLING INFORMATION ACROSS A NETWORK OR LINE INTERFACE. (ie. PRI Q.921 LAPD, CHANNEL ASSOCIATED SIGNALLING (CAS), T1 ROBBED BIT, SS7 MTP2, SS7 MTP3)
PHYSICAL LAYER 1
PROVIDES E1, T1 AND ANALOG ELECTRICAL INTERFACES

FIG. 3A

APPLICATION LAYER (LAYER 5)

- **MATRIX/LINE CARD MANAGEMENT**
  - DOWNLOAD CONTROL
  - ALARM PROCESSING
  - REDUNDANT MATRIX CONTROL
- **CONFIGURATION MANAGEMENT**
  - MATRIX CONFIGURATION
  - LINE CARD CONFIGURATION
- **HIGH LEVEL (LAYER 5) CALL PROCESSING**
  - INTERACTIVE DIGIT COLLECTION
  - RECORDED ANNOUNCEMENT CONTROL FOR INTERACTIVE VOICE RESPONSE APPLICATION SUPPORT
  - BROADCASTING/CONFERENCING CONTROL
  - INBOUND CALL ROUTING/QUEUEING
  - OUTBOUND CALL INITIATION WITH DIGIT OUTPULSING
  - ADDRESS DIGIT ROUTING TO CHANNELS/CHANNEL GROUPS
  - CALL HUNTING FOR OUTBOUND CHANNEL SELECTION
  - CALL PROGRESS TONE CONTROL FOR INBOUND/ OUTBOUND CALLS
  - MULITPLE CALL MGMT FEATURES (TRANSFER, HOLD, CON- FERENCING, CALLBACK, FORWARDING, ETC.)
  - CALL DETAIL RECORDING

CALL MANAGEMENT LAYER (LAYER 4)

INTERACTIVE RECORDED ANNOUNCEMENT CONTROL (USER DIGIT DRIVEN)
LAYER 4/APPLICATION LAYER (LAYER 5) INITIATED CALL PARK
1-WAY/2-WAY/CONFERENCE CONNECTION MANAGEMENT
RECONNECTION (TRANSFER)
LAYER 4 OUTGOING OUTSEIZE INITIATION FOR 2-WAY CONNECTIONS
MULTIPLE CALL MGMT FEATURES (TRANSFER, HOLD, CONFERENCING, CALLBACK, FORWARDING, ETC.)
CUSTOMIZATION OF INSEIZE COMPLETION REPORT SENT TO THE APPLICATION LAYER (LAYER 5)

NETWORK PROTOCOL LAYER (LAYER 3)

- **IN BAND LINE/ADDRESS SIGNALLING CONTROL**
  - E&M INTERFACE
  - LOOPSTART, GROUNDSTART TRUNK INTERFACES
  - LOOPSTART, GROUNDSTART LINE INTERFACES
  - MULTI-WINK MFR1 FEATURE GROUP D
  - DTMF DIALED NUMBER INDENTIFICATION SERVICES (DNIS)
  - COMPELLED R2 FOR INTERNATIONAL E1 INTERFACES
  - IN BAND/EXTENDED IN BAND/MULTI-WINK COIN SIGNALLING
  - CUSTOM T1/E1 SERVICE CARD INTERFACES
- **OUT OF BAND SIGNALLING CONTROL**
  - ISDN PRIMARY RATE LAYER 3 Q.931
  - SS7 ISDN USER PART (ISUP)

FIG. 3B

LINK LAYER (LAYER 2)

- T1 ROBBED BIT SIGNALLING SCANNING
- E1 CHANNEL ASSOCIATED SIGNALLING SCANNING
- T1/E1 LINE INTERFACE FRAME ALARM CONTROL
- DSP TONE RECEPTION CONTROL
  - IN BAND ADDRESS SIGNALLING (MFR1, MFR2, DTMF)
  - CALL PROGRESS ANALYSIS
- DSP TONE GENERATION CONTROL
  - IN BAND ADDRESS SIGNALLING (MFR1, MFR2, DTMF)
  - CALL PROGRESS TONE GENERATION
  - CUSTOM CALL PROGRESS TONE GENERATION
- SS7 MTP2/MTP3
- DSP RECORDED VOICE ANNOUNCEMENT CONTROL
- DSP CONFERENCE GENERATION CONTROL
- GENERIC DSP FUNCTION CONTROL
  - DSP PROCESSOR TO MFDSP MAIN PROCESSOR DSP CONTROL/ INFORMATIONAL MESSAGES
  - MFDSP MAIN PROCESSOR TO DSP PROCESSOR CONTROL/ INFORMATIONAL MESSAGES
  - MFDSP MAIN PROCESSOR DSP FUNCTION ANALYSIS/CONTROL
- LAPD Q.921

FIG. 4

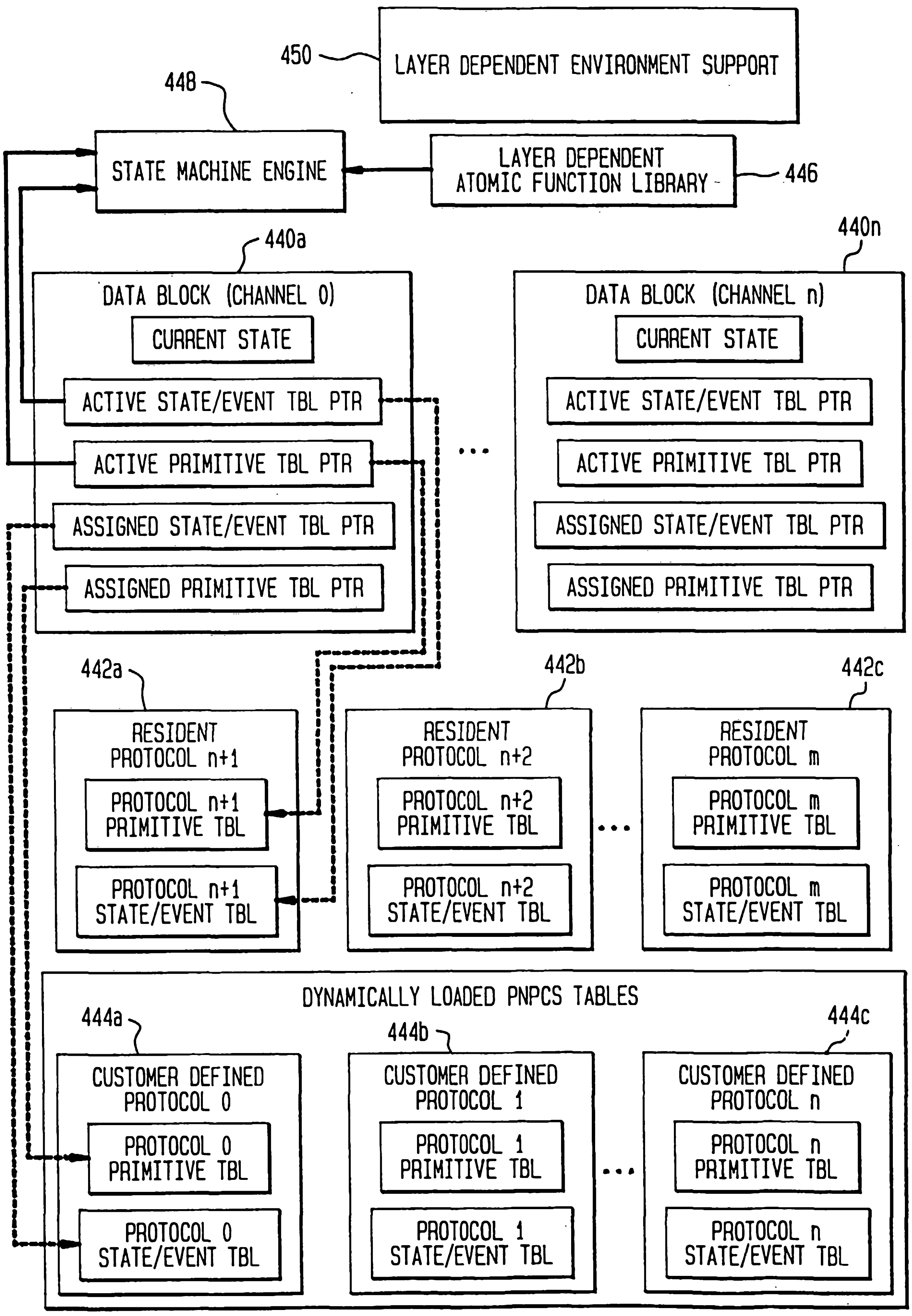
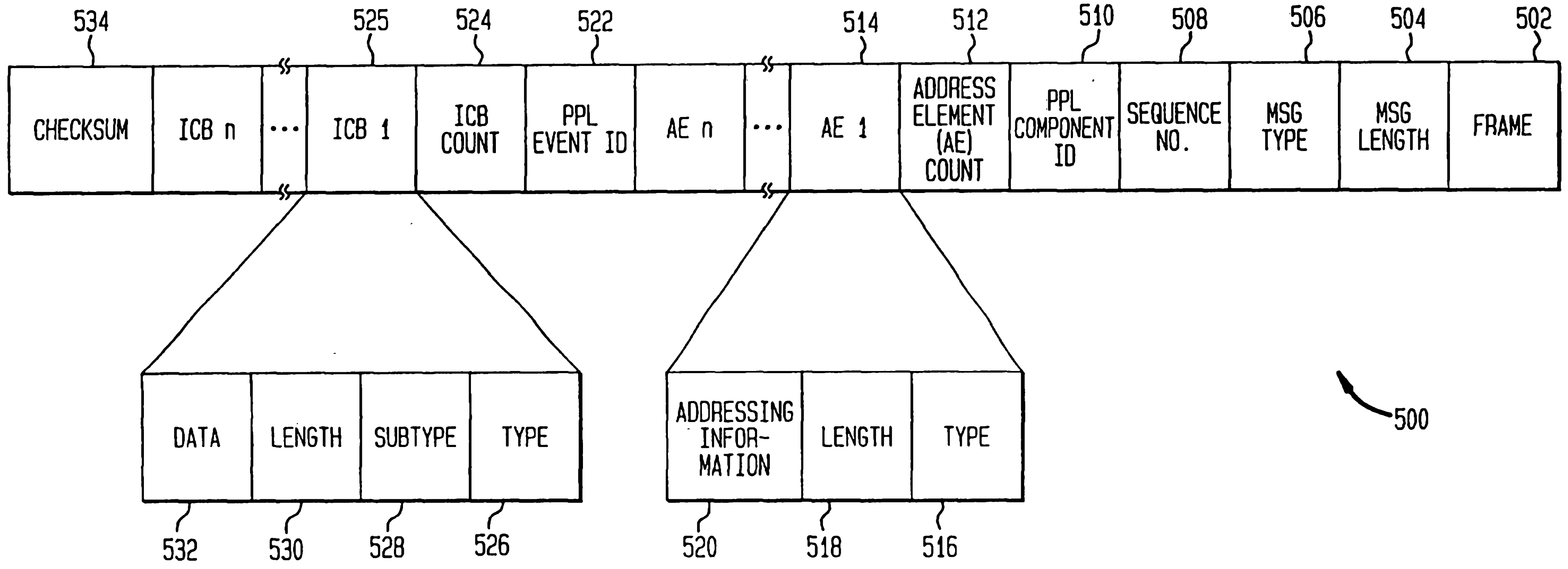
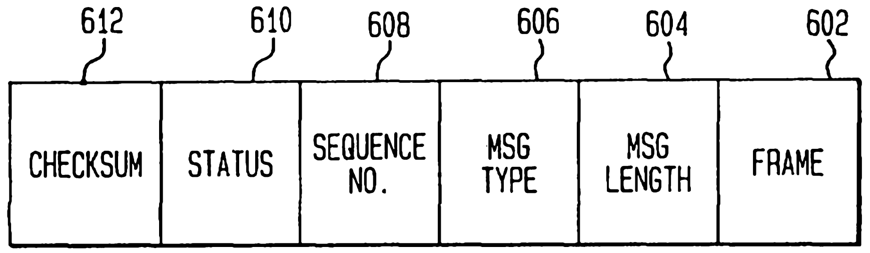

450
LAYER DEPENDENT ENVIRONMENT SUPPORT
448
STATE MACHINE ENGINE
LAYER DEPENDENT ATOMIC FUNCTION LIBRARY
446
440a
DATA BLOCK (CHANNEL 0)
CURRENT STATE
ACTIVE STATE/EVENT TBL PTR
ACTIVE PRIMITIVE TBL PTR
ASSIGNED STATE/EVENT TBL PTR
ASSIGNED PRIMITIVE TBL PTR
...
440n
DATA BLOCK (CHANNEL n)
CURRENT STATE
ACTIVE STATE/EVENT TBL PTR
ACTIVE PRIMITIVE TBL PTR
ASSIGNED STATE/EVENT TBL PTR
ASSIGNED PRIMITIVE TBL PTR
442a
RESIDENT PROTOCOL n+1
PROTOCOL n+1 PRIMITIVE TBL
PROTOCOL n+1 STATE/EVENT TBL
442b
RESIDENT PROTOCOL n+2
PROTOCOL n+2 PRIMITIVE TBL
PROTOCOL n+2 STATE/EVENT TBL
...
442c
RESIDENT PROTOCOL m
PROTOCOL m PRIMITIVE TBL
PROTOCOL m STATE/EVENT TBL
DYNAMICALLY LOADED PNPCS TABLES
444a
CUSTOMER DEFINED PROTOCOL 0
PROTOCOL 0 PRIMITIVE TBL
PROTOCOL 0 STATE/EVENT TBL
444b
CUSTOMER DEFINED PROTOCOL 1
PROTOCOL 1 PRIMITIVE TBL
PROTOCOL 1 STATE/EVENT TBL
...
444c
CUSTOMER DEFINED PROTOCOL n
PROTOCOL n PRIMITIVE TBL
PROTOCOL n STATE/EVENT TBL

FIG. 5



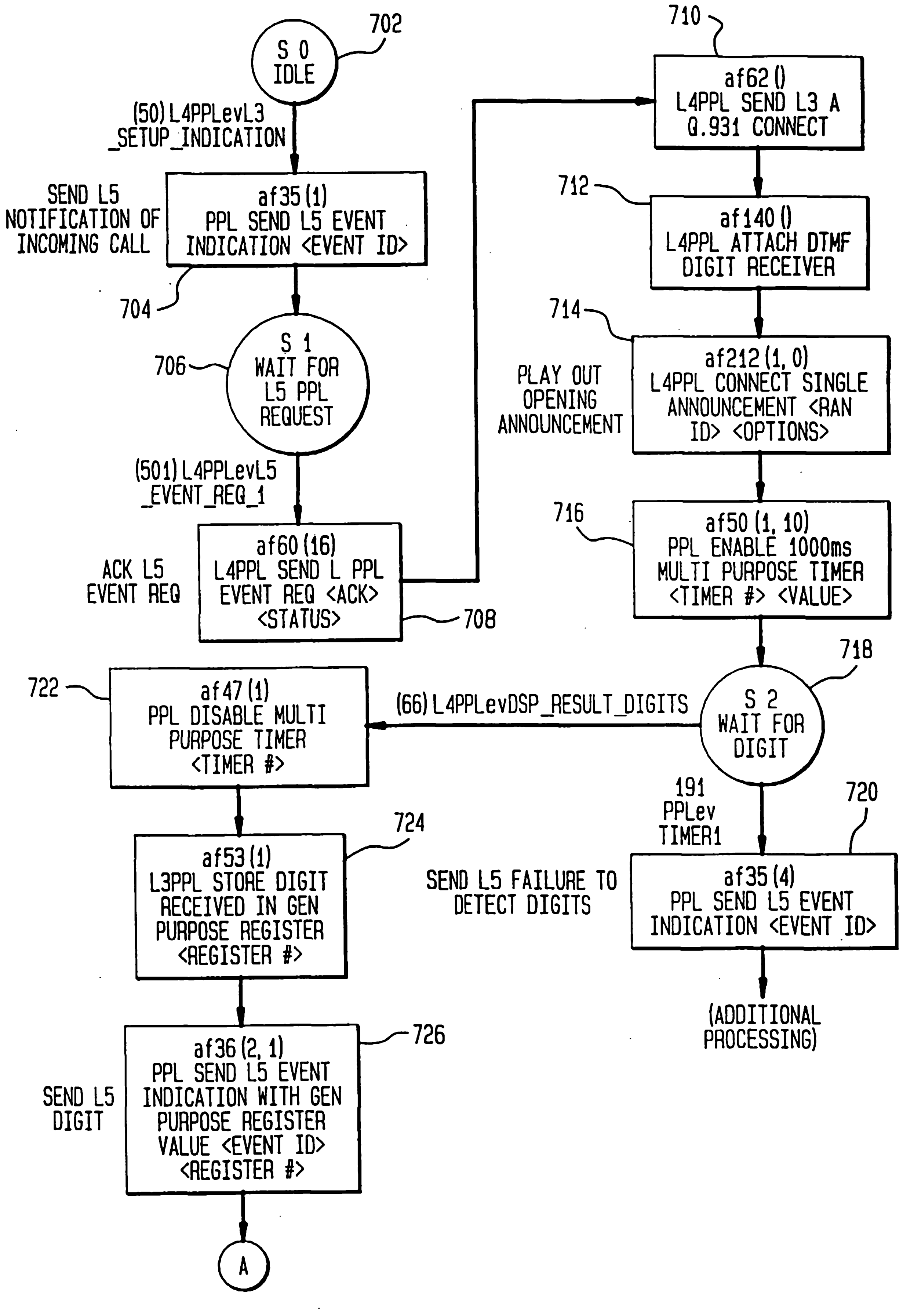
PPL EVENT REQ (PPL COMP. ID, CHANNEL NO., EVENT ID, DATA)
PPL EVENT IND (PPL COMP. ID, CHANNEL NO., EVENT ID, DATA)

FIG. 6



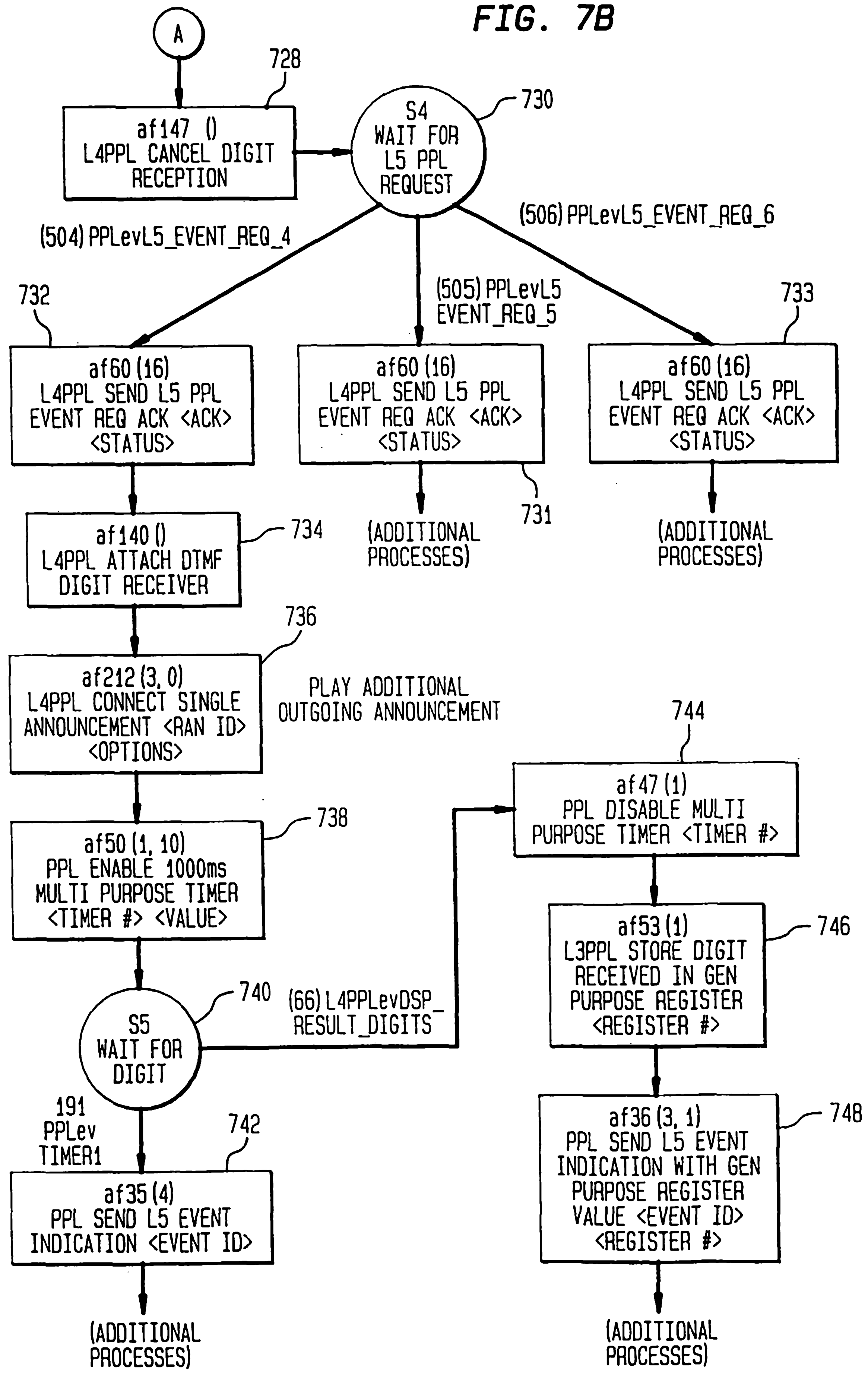
PPL EVENT REQ ACK (SEQUENCE NO, STATUS)
PPL EVENT IND ACK (SEQUENCE NO, STATUS)

FIG. 7A



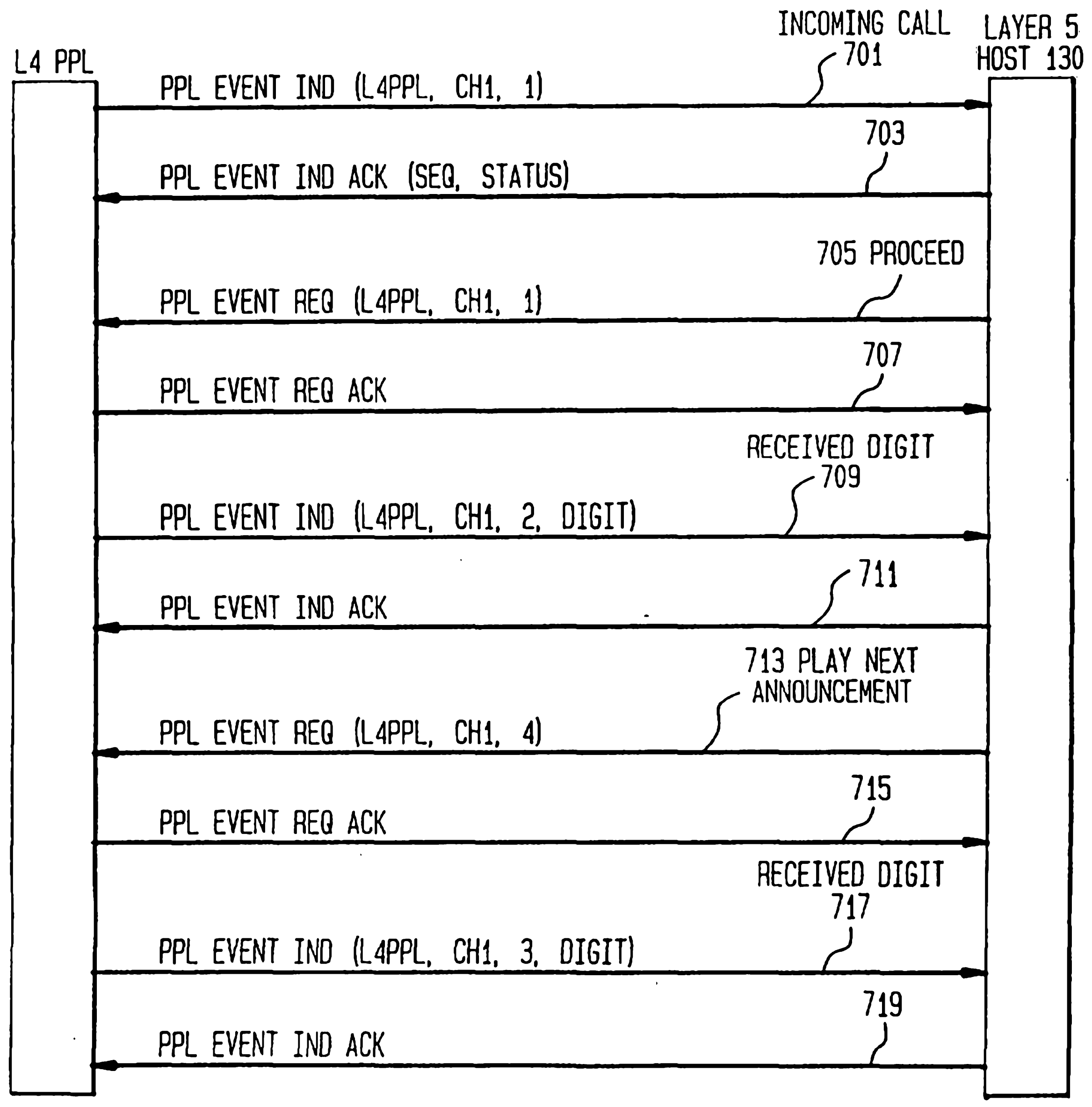
702
S 0 IDLE
(50) L4PPLevL3 _SETUP_INDICATION
SEND L5 NOTIFICATION OF INCOMING CALL
af35 (1) PPL SEND L5 EVENT INDICATION <EVENT ID>
704
706
S 1 WAIT FOR L5 PPL REQUEST
(501) L4PPLevL5 _EVENT_REQ_1
ACK L5 EVENT REQ
af60 (16) L4PPL SEND L PPL EVENT REQ <ACK> <STATUS>
708
710
af62 () L4PPL SEND L3 A Q.931 CONNECT
712
af140 () L4PPL ATTACH DTMF DIGIT RECEIVER
714
PLAY OUT OPENING ANNOUNCEMENT
af212 (1, 0) L4PPL CONNECT SINGLE ANNOUNCEMENT <RAN ID> <OPTIONS>
716
af50 (1, 10) PPL ENABLE 1000ms MULTI PURPOSE TIMER <TIMER #> <VALUE>
718
S 2 WAIT FOR DIGIT
(66) L4PPLevDSP_RESULT_DIGITS
722
af47 (1) PPL DISABLE MULTI PURPOSE TIMER <TIMER #>
724
af53 (1) L3PPL STORE DIGIT RECEIVED IN GEN PURPOSE REGISTER <REGISTER #>
726
SEND L5 DIGIT
af36 (2, 1) PPL SEND L5 EVENT INDICATION WITH GEN PURPOSE REGISTER VALUE <EVENT ID> <REGISTER #>
A
191 PPLev TIMER1
720
SEND L5 FAILURE TO DETECT DIGITS
af35 (4) PPL SEND L5 EVENT INDICATION <EVENT ID>
(ADDITIONAL PROCESSING)

FIG. 7B



A
728
af147 ()
L4PPL CANCEL DIGIT RECEPTION
S4 WAIT FOR L5 PPL REQUEST
730
(504) PPLevL5_EVENT_REQ_4
(505) PPLevL5 EVENT_REQ_5
(506) PPLevL5_EVENT_REQ_6
732
af60 (16) L4PPL SEND L5 PPL EVENT REQ ACK <ACK> <STATUS>
af60 (16) L4PPL SEND L5 PPL EVENT REQ ACK <ACK> <STATUS>
733
af60 (16) L4PPL SEND L5 PPL EVENT REQ ACK <ACK> <STATUS>
731
(ADDITIONAL PROCESSES)
(ADDITIONAL PROCESSES)
af140 () L4PPL ATTACH DTMF DIGIT RECEIVER
734
736
af212 (3, 0) L4PPL CONNECT SINGLE ANNOUNCEMENT <RAN ID> <OPTIONS>
PLAY ADDITIONAL OUTGOING ANNOUNCEMENT
744
af47 (1) PPL DISABLE MULTI PURPOSE TIMER <TIMER #>
af50 (1, 10) PPL ENABLE 1000ms MULTI PURPOSE TIMER <TIMER #> <VALUE>
738
af53 (1) L3PPL STORE DIGIT RECEIVED IN GEN PURPOSE REGISTER <REGISTER #>
746
740
(66) L4PPLevDSP_ RESULT_DIGITS
S5 WAIT FOR DIGIT
191 PPLev TIMER1
742
af35 (4) PPL SEND L5 EVENT INDICATION <EVENT ID>
af36 (3, 1) PPL SEND L5 EVENT INDICATION WITH GEN PURPOSE REGISTER VALUE <EVENT ID> <REGISTER #>
748
(ADDITIONAL PROCESSES)
(ADDITIONAL PROCESSES)

FIG. 7C



L4 PPL
LAYER 5 HOST 130
INCOMING CALL 701
PPL EVENT IND (L4PPL, CH1, 1)
703
PPL EVENT IND ACK (SEQ, STATUS)
705 PROCEED
PPL EVENT REQ (L4PPL, CH1, 1)
707
PPL EVENT REQ ACK
RECEIVED DIGIT 709
PPL EVENT IND (L4PPL, CH1, 2, DIGIT)
711
PPL EVENT IND ACK
713 PLAY NEXT ANNOUNCEMENT
PPL EVENT REQ (L4PPL, CH1, 4)
715
PPL EVENT REQ ACK
RECEIVED DIGIT 717
PPL EVENT IND (L4PPL, CH1, 3, DIGIT)
719
PPL EVENT IND ACK

FIG. 7D

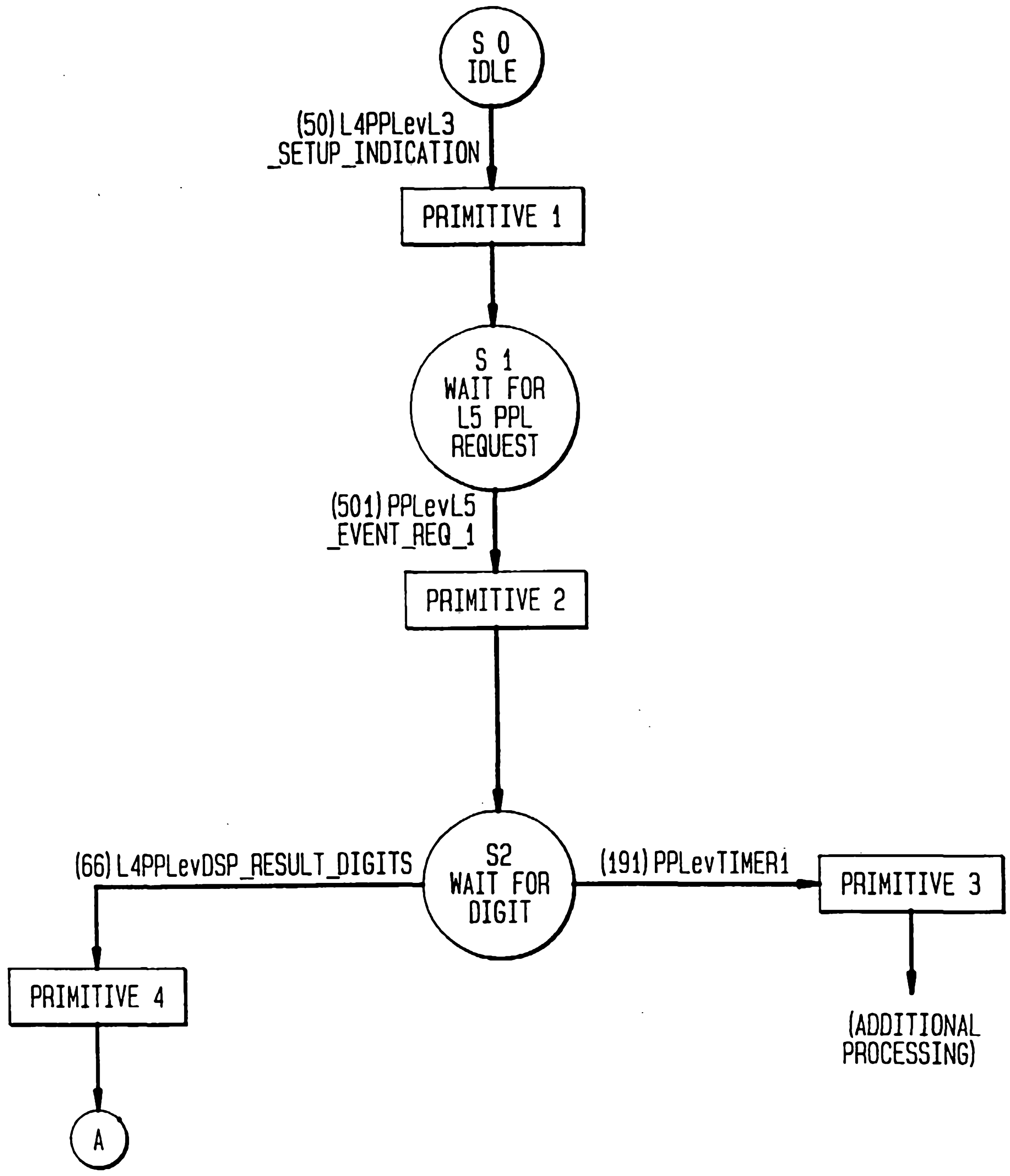

S 0
IDLE
(50) L4PPLevL3 _SETUP_INDICATION
PRIMITIVE 1
S 1
WAIT FOR
L5 PPL
REQUEST
(501) PPLevL5 _EVENT_REQ_1
PRIMITIVE 2
S2
WAIT FOR
DIGIT
(66) L4PPLevDSP_RESULT_DIGITS
(191) PPLevTIMER1
PRIMITIVE 3
(ADDITIONAL PROCESSING)
PRIMITIVE 4
A

FIG. 7E

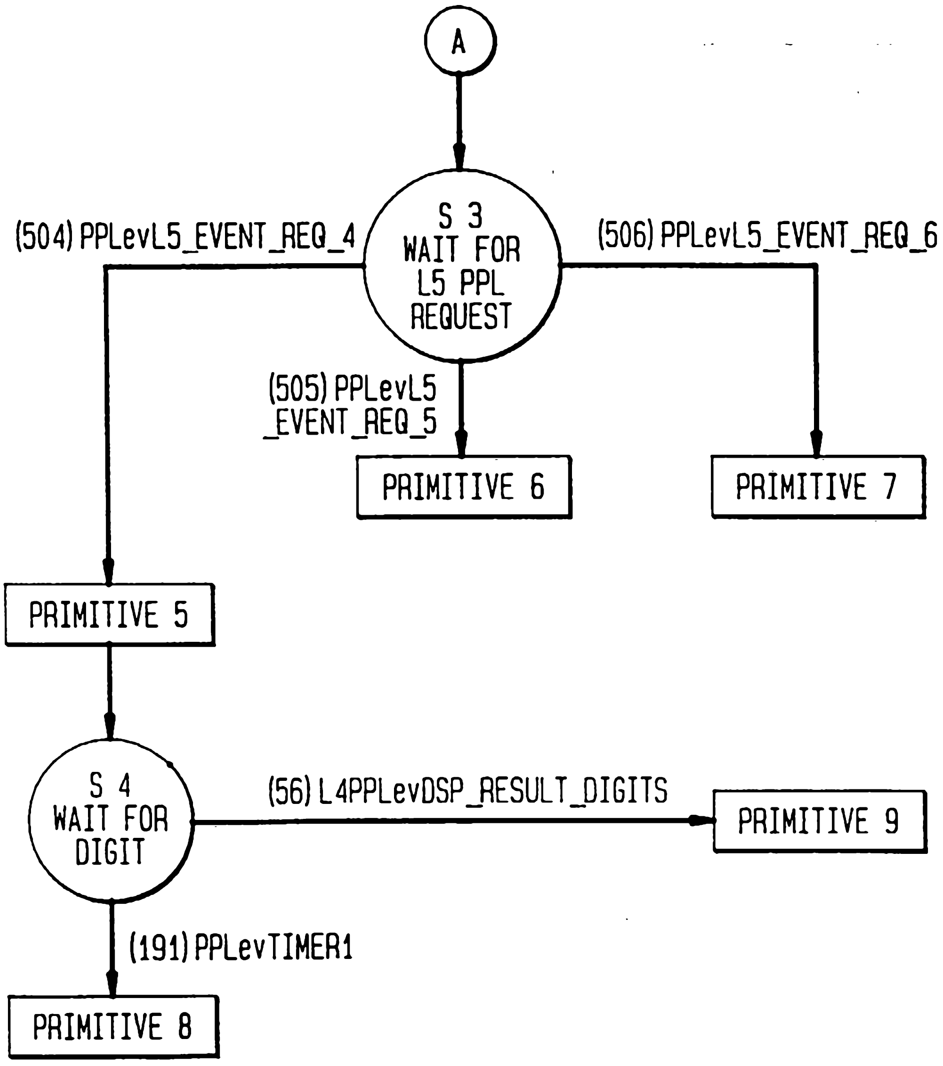

A
S 3
WAIT FOR
L5 PPL
REQUEST
(504) PPLevL5_EVENT_REQ_4
(505) PPLevL5
_EVENT_REQ_5
(506) PPLevL5_EVENT_REQ_6
PRIMITIVE 6
PRIMITIVE 7
PRIMITIVE 5
S 4
WAIT FOR
DIGIT
(56) L4PPLevDSP_RESULT_DIGITS
PRIMITIVE 9
(191) PPLevTIMER1
PRIMITIVE 8

FIG. 7F

780

PRIMITIVE ID	1ST ATOMIC FUNCTION	2ND ATOMIC FUNCTION	3RD ATOMIC FUNCTION	4TH ATOMIC FUNCTION	5TH ATOMIC FUNCTION
PRIMITIVE #1	af035 (0x01, 0x00)				
PRIMITIVE #2	af060 (0x16, 0x00)	af062 (0x00, 0x00)	af140 (0x00, 0x00)	af212 (0x01, 0x00)	af050 (0x01, 0x10)
PRIMITIVE #3	af035 (0x04, 0x00)				
PRIMITIVE #4	af047 (0x01, 0x00)	af053 (0x01, 0x00)	af036 (0x02, 0x01)	af147 (0x00, 0x00)	
PRIMITIVE #5	af060 (0x16, 0x00)	af140 (0x00, 0x00)	af212 (0x03, 0x00)	af050 (0x01, 0x10)	
PRIMITIVE #6	af060 (0x16, 0x00)				
PRIMITIVE #7	af060 (0x16, 0x00)				
PRIMITIVE #8	af035 (0x04, 0x00)				
PRIMITIVE #9	af047 (0x01, 0x00)	af053 (0x01, 0x00)	af036 (0x03, 0x0)		

FIG. 7G

790

STATE NO.	EVENT	EVENT ID	PRIMITIVE ID	NEXT STATE	STATE TYPE
STATE 0	L4PPLevL3_SETUP_INDICATION	ev050	PRIMITIVE 1	STATE 1	NORMAL
STATE 1	L4PPLevL5_EVENT_REQ_1	ev501	PRIMITIVE 2	STATE 2	NORMAL
STATE 2	PPLevTIMER1 L4PPLevDSP_RESULT_DIGITS	ev191 ev066	PRIMITIVE 3 PRIMITIVE 4	STATE ? STATE 3	UNKNOWN NORMAL
STATE 3	L4PPLevL5_EVENT_REQ_4 L4PPLevL5_EVENT_REQ_5 L4PPLevL5_EVENT_REQ_6	ev504 ev505 ev506	PRIMITIVE 5 PRIMITIVE 6 PRIMITIVE 7	STATE 4 STATE ? STATE ?	NORMAL UNKNOWN UNKNOWN
STATE 4	PPLevTIMER1 L4PPLevDSP_RESULT_DIGITS	ev191 ev066	PRIMITIVE 8 PRIMITIVE 9	STATE ? STATE ?	UNKNOWN UNKNOWN

FIG. 8A

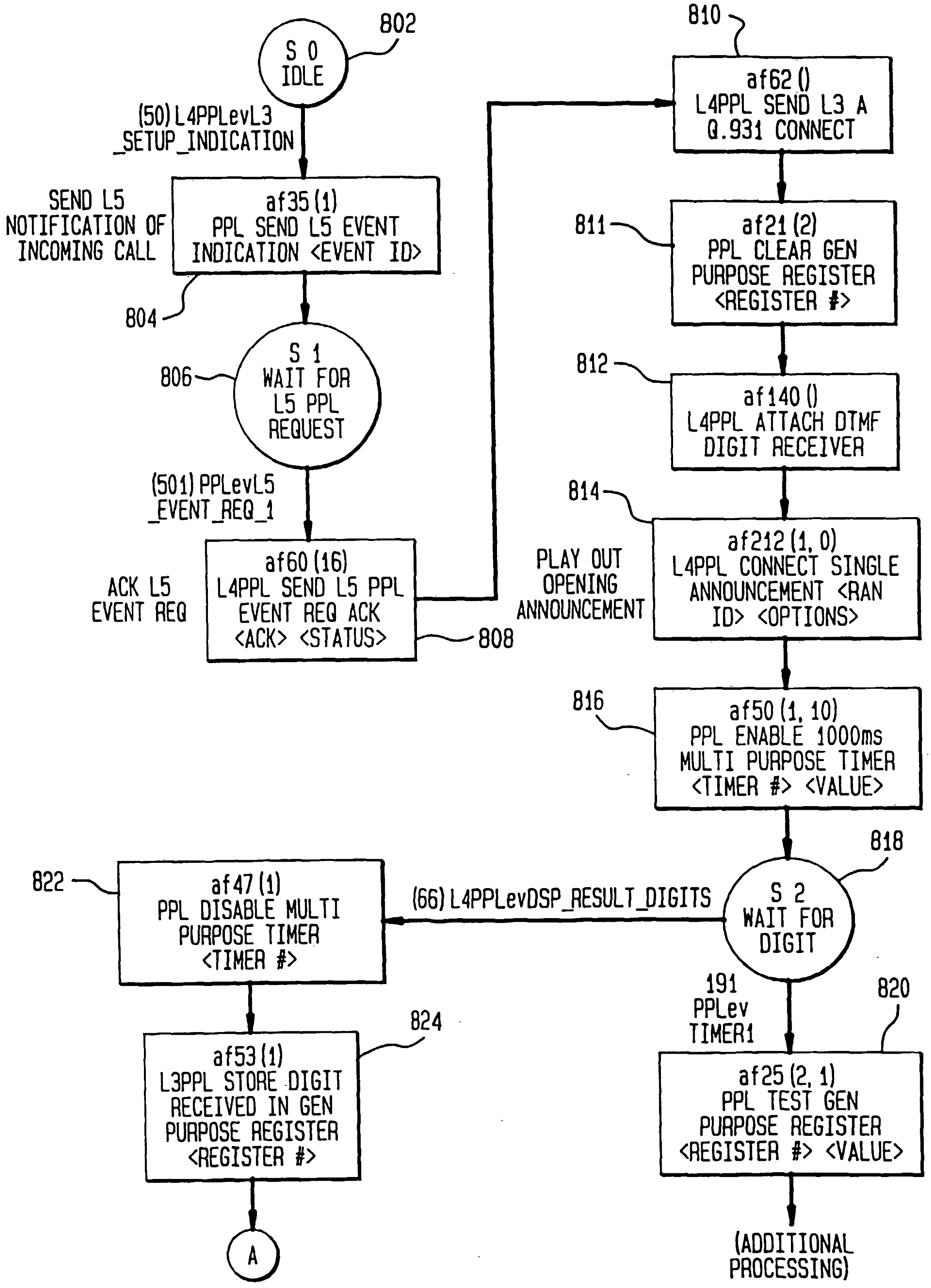

802
S 0
IDLE
(50) L4PPLevL3
_SETUP_INDICATION
SEND L5
NOTIFICATION OF
INCOMING CALL
af35 (1)
PPL SEND L5 EVENT
INDICATION <EVENT ID>
804
806
S 1
WAIT FOR
L5 PPL
REQUEST
(501) PPLevL5
_EVENT_REQ_1
ACK L5
EVENT REQ
af60 (16)
L4PPL SEND L5 PPL
EVENT REQ ACK
<ACK> <STATUS>
808
810
af62 ()
L4PPL SEND L3 A
Q.931 CONNECT
811
af21 (2)
PPL CLEAR GEN
PURPOSE REGISTER
<REGISTER #>
812
af140 ()
L4PPL ATTACH DTMF
DIGIT RECEIVER
814
PLAY OUT
OPENING
ANNOUNCEMENT
af212 (1, 0)
L4PPL CONNECT SINGLE
ANNOUNCEMENT <RAN
ID> <OPTIONS>
816
af50 (1, 10)
PPL ENABLE 1000ms
MULTI PURPOSE TIMER
<TIMER #> <VALUE>
818
S 2
WAIT FOR
DIGIT
(66) L4PPLevDSP_RESULT_DIGITS
822
af47 (1)
PPL DISABLE MULTI
PURPOSE TIMER
<TIMER #>
824
af53 (1)
L3PPL STORE DIGIT
RECEIVED IN GEN
PURPOSE REGISTER
<REGISTER #>
A
191
PPLev
TIMER1
820
af25 (2, 1)
PPL TEST GEN
PURPOSE REGISTER
<REGISTER #> <VALUE>
(ADDITIONAL
PROCESSING)

FIG. 8B

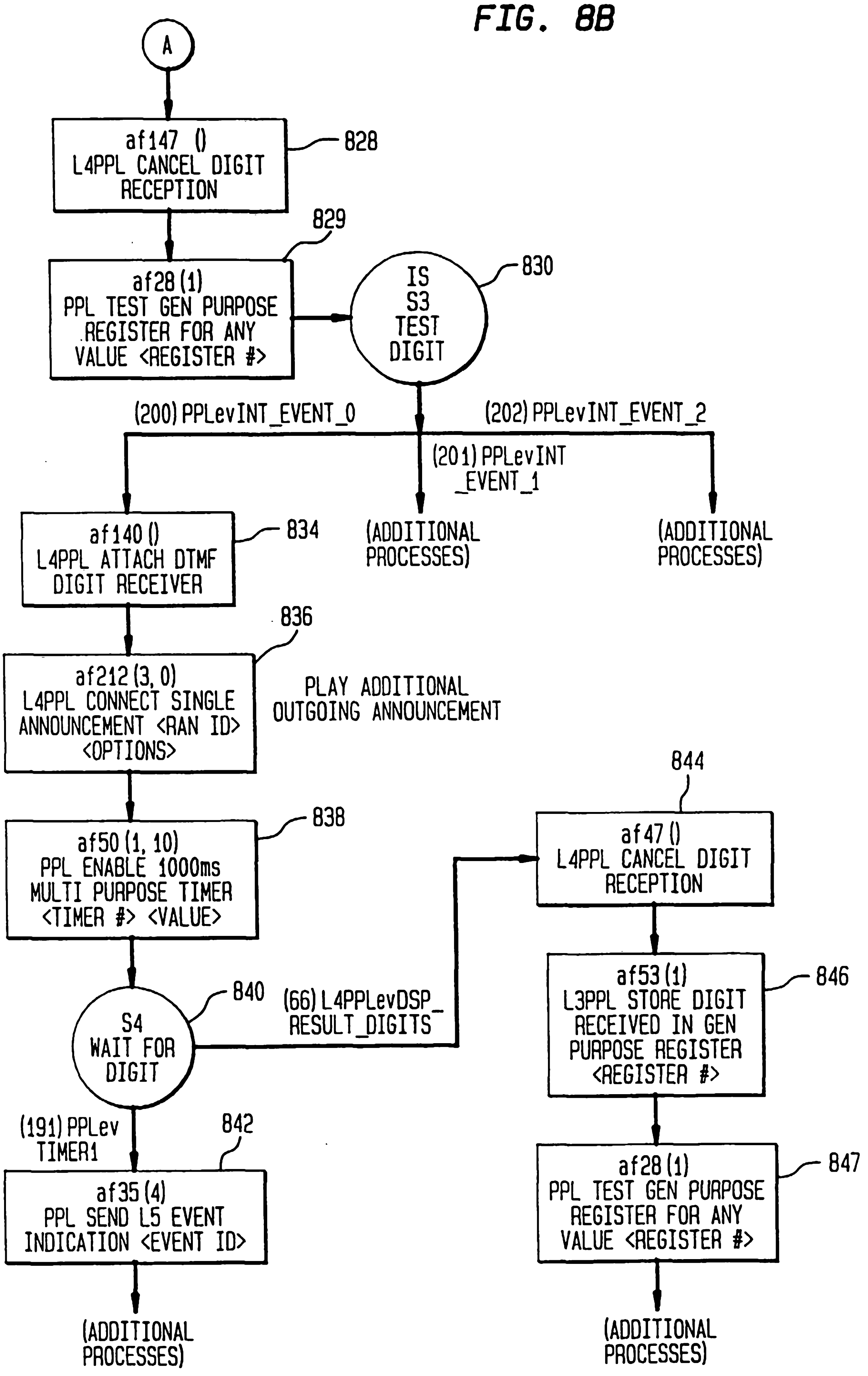

A
af147 ()
L4PPL CANCEL DIGIT RECEPTION
828
829
af28 (1)
PPL TEST GEN PURPOSE REGISTER FOR ANY VALUE <REGISTER #>
IS S3 TEST DIGIT
830
(200) PPLevINT_EVENT_0
(201) PPLevINT _EVENT_1
(202) PPLevINT_EVENT_2
af140 ()
L4PPL ATTACH DTMF DIGIT RECEIVER
834
(ADDITIONAL PROCESSES)
(ADDITIONAL PROCESSES)
836
af212 (3, 0)
L4PPL CONNECT SINGLE ANNOUNCEMENT <RAN ID> <OPTIONS>
PLAY ADDITIONAL OUTGOING ANNOUNCEMENT
844
838
af50 (1, 10)
PPL ENABLE 1000ms MULTI PURPOSE TIMER <TIMER #> <VALUE>
af47 ()
L4PPL CANCEL DIGIT RECEPTION
840
(66) L4PPLevDSP_ RESULT_DIGITS
S4 WAIT FOR DIGIT
af53 (1)
L3PPL STORE DIGIT RECEIVED IN GEN PURPOSE REGISTER <REGISTER #>
846
(191) PPLev TIMER1
842
af35 (4)
PPL SEND L5 EVENT INDICATION <EVENT ID>
af28 (1)
PPL TEST GEN PURPOSE REGISTER FOR ANY VALUE <REGISTER #>
847
(ADDITIONAL PROCESSES)
(ADDITIONAL PROCESSES)

FIG. 8C

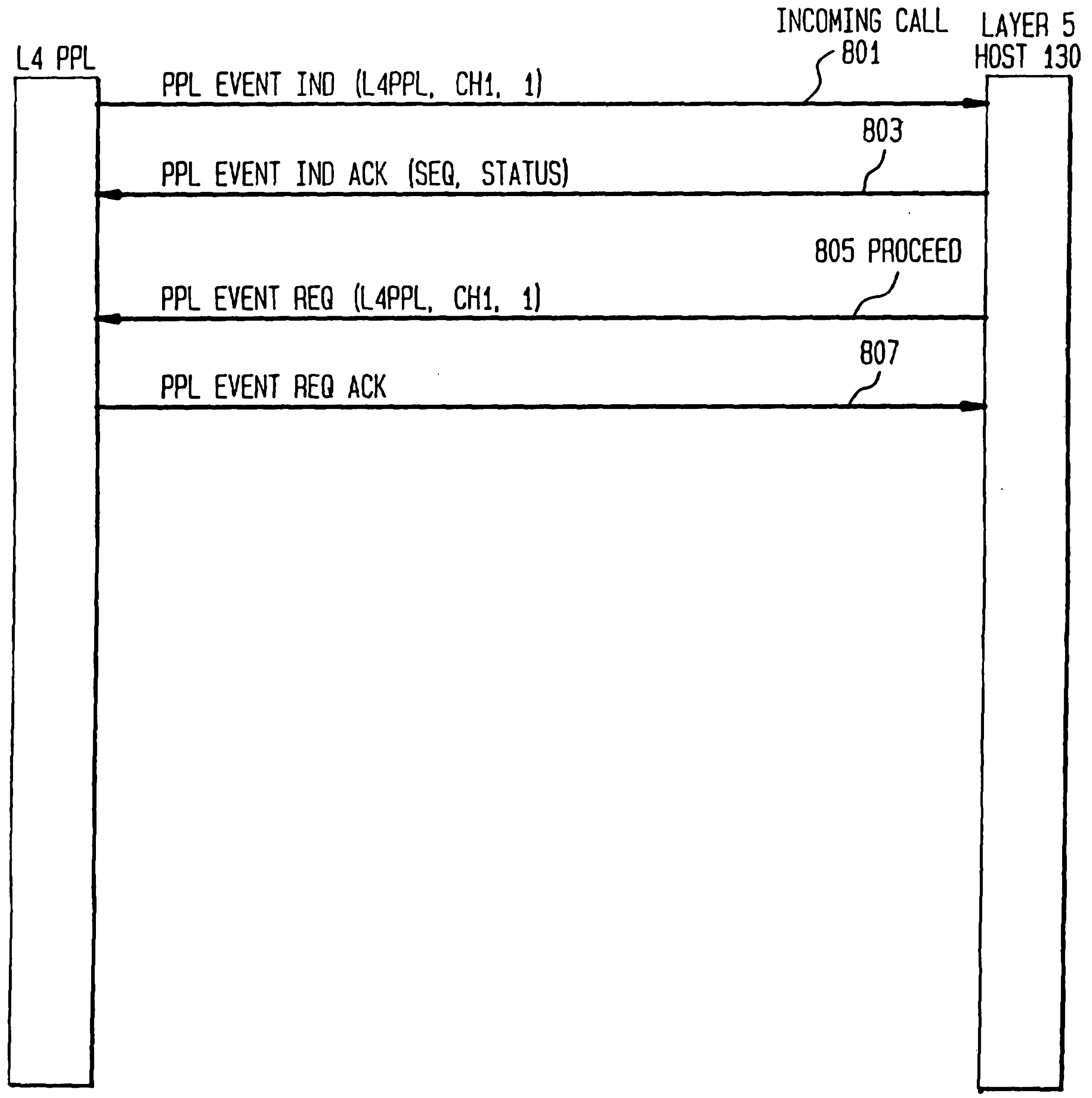

L4 PPL
LAYER 5
HOST 130
INCOMING CALL
801
PPL EVENT IND (L4PPL, CH1, 1)
803
PPL EVENT IND ACK (SEQ, STATUS)
805 PROCEED
PPL EVENT REQ (L4PPL, CH1, 1)
807
PPL EVENT REQ ACK

FIG. 8D

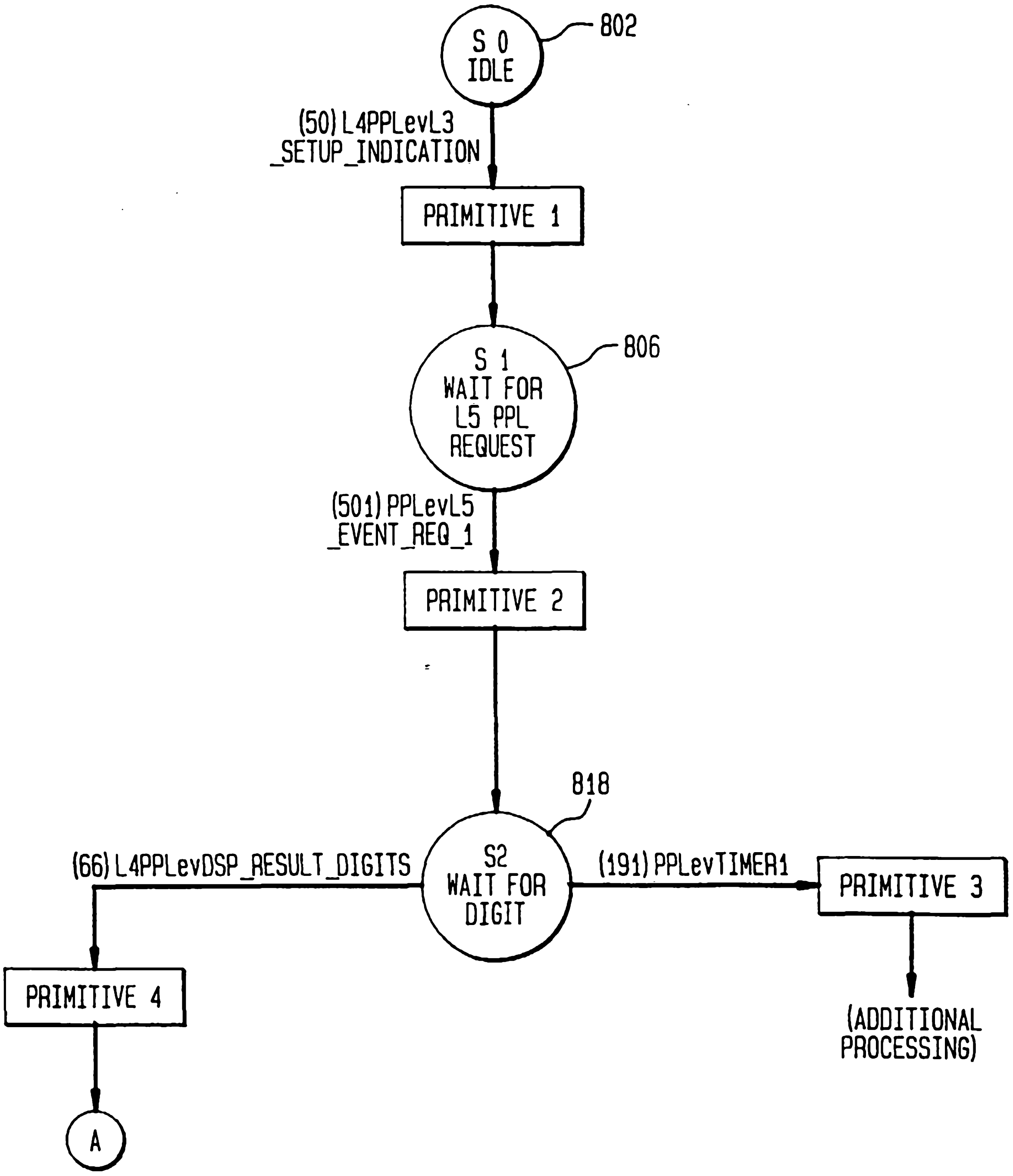

S 0
IDLE
802
(50) L4PPLevL3 _SETUP_INDICATION
PRIMITIVE 1
S 1
WAIT FOR L5 PPL REQUEST
806
(501) PPLevL5 _EVENT_REQ_1
PRIMITIVE 2
818
S2
WAIT FOR DIGIT
(66) L4PPLevDSP_RESULT_DIGITS
(191) PPLevTIMER1
PRIMITIVE 3
(ADDITIONAL PROCESSING)
PRIMITIVE 4
A

FIG. 8E

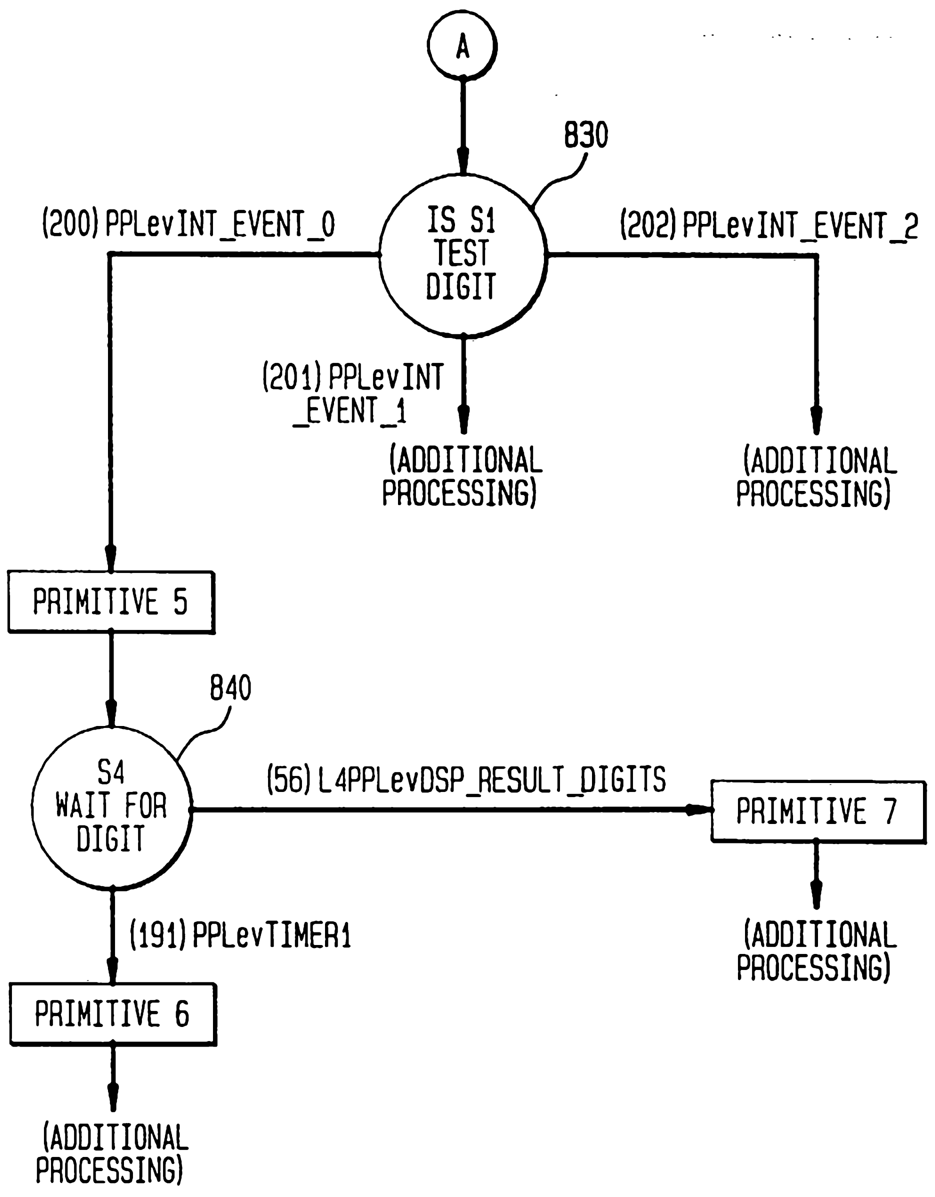

A
830
IS S1 TEST DIGIT
(200) PPLevINT_EVENT_0
(202) PPLevINT_EVENT_2
(201) PPLevINT _EVENT_1
(ADDITIONAL PROCESSING)
(ADDITIONAL PROCESSING)
PRIMITIVE 5
840
S4 WAIT FOR DIGIT
(56) L4PPLevDSP_RESULT_DIGITS
PRIMITIVE 7
(ADDITIONAL PROCESSING)
(191) PPLevTIMER1
PRIMITIVE 6
(ADDITIONAL PROCESSING)

FIG.8F

880

PRIMITIVE ID	1ST ATOMIC FUNCTION	2ND ATOMIC FUNCTION	3RD ATOMIC FUNCTION	4TH ATOMIC FUNCTION	5TH ATOMIC FUNCTION
PRIMITIVE #1	af035 (0x01, 0x00)				
PRIMITIVE #2	af060 (0x16, 0x00)	af062 (0x00, 0x00)	af140 (0x00, 0x00)	af212 (0x01, 0x00)	af050 (0x01, 0x10)
PRIMITIVE #3	af025 (0x02, 0x01)				
PRIMITIVE #4	af047 (0x01, 0x00)	af053 (0x01, 0x00)	af147 (0x60, 0x00)	af026 (0x01, 0x00)	
PRIMITIVE #5	af140 (0x00, 0x00)	af212 (0x03, 0x00)	af050 (0x01, 0x10)		
PRIMITIVE #6	af035 (0x04, 0x00)				
PRIMITIVE #7	af147 (0x01, 0x00)	af053 (0x01, 0x00)	af028 (0x01, 0x00)		

FIG. 8G

890

STATE NO.	EVENT	EVENT ID	PRIMITIVE ID	NEXT STATE	STATE TYPE
STATE 0	L4PPLevL3_SETUP_INDICATION	ev050	PRIMITIVE 1	STATE 1	NORMAL
STATE 1	L4PPLevL5_EVENT_REQ_1	ev501	PRIMITIVE 2	STATE 2	NORMAL
STATE 2	PPLevTIMER1	ev191	PRIMITIVE 3	STATE ?	UNKNOWN
	L4PPLevDSP_RESULT_DIGITS	ev066	PRIMITIVE 4	STATE 3	INTERNAL
STATE 3	PPLevINT_EVENT_0	ev200	PRIMITIVE 5	STATE 4	NORMAL
	PPLevINT_EVENT_1	ev201	PRIMITIVE ?	STATE ?	UNKNOWN
	PPLevINT_EVENT_2	ev202	PRIMITIVE ?	STATE ?	UNKNOWN
STATE 4	PPLevTIMER1	ev191	PRIMITIVE 6	STATE ?	UNKNOWN
	L4PPLevDSP_RESULT_DIGITS	ev066	PRIMITIVE 7	STATE ?	UNKNOWN

FIG. 9

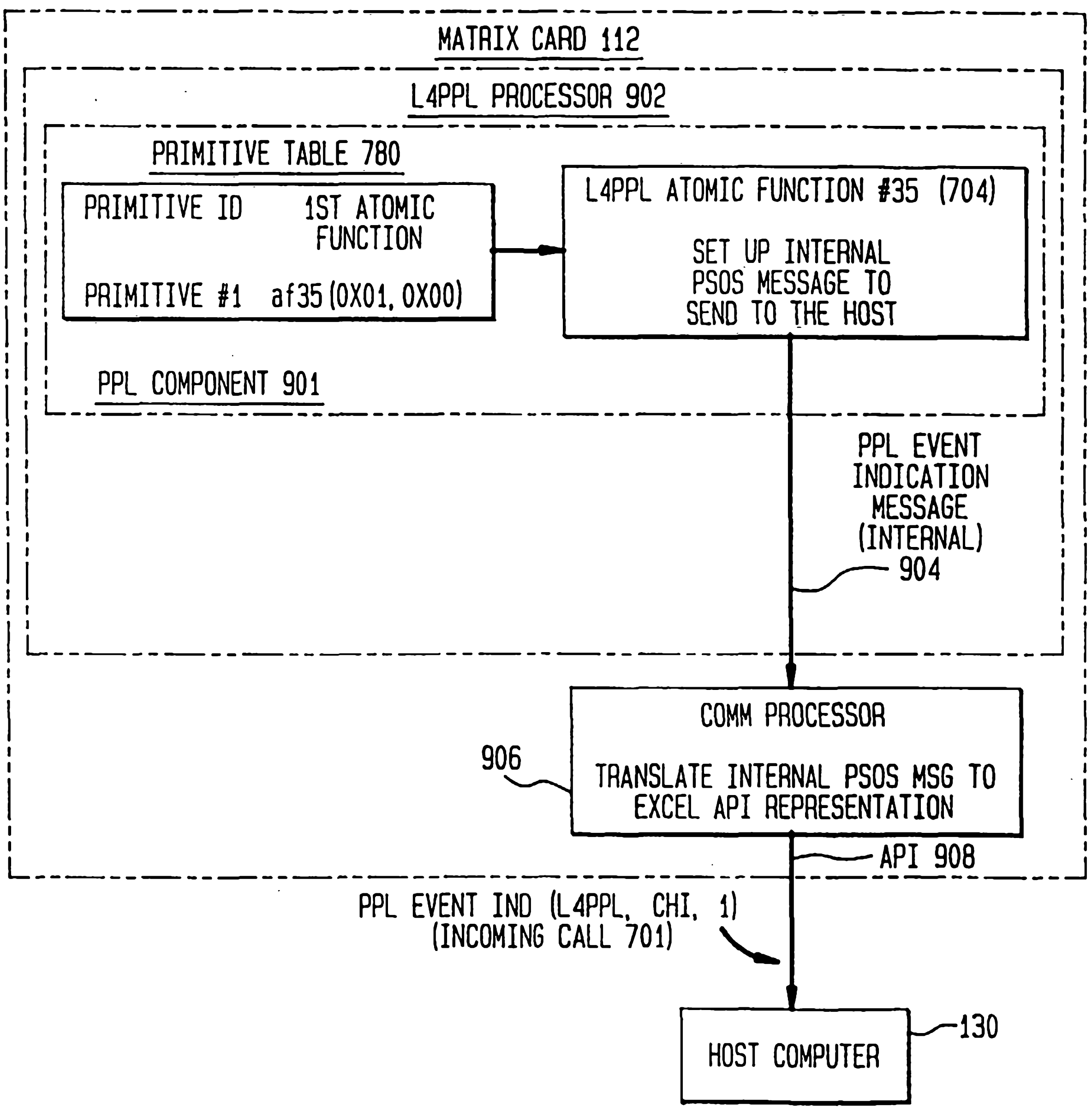

MATRIX CARD 112
L4PPL PROCESSOR 902
PRIMITIVE TABLE 780
PRIMITIVE ID
1ST ATOMIC FUNCTION
PRIMITIVE #1
af35 (0X01, 0X00)
L4PPL ATOMIC FUNCTION #35 (704)
SET UP INTERNAL PSOS MESSAGE TO SEND TO THE HOST
PPL COMPONENT 901
PPL EVENT INDICATION MESSAGE (INTERNAL)
904
COMM PROCESSOR
TRANSLATE INTERNAL PSOS MSG TO EXCEL API REPRESENTATION
906
API 908
PPL EVENT IND (L4PPL, CHI, 1) (INCOMING CALL 701)
HOST COMPUTER
130

FIG. 10

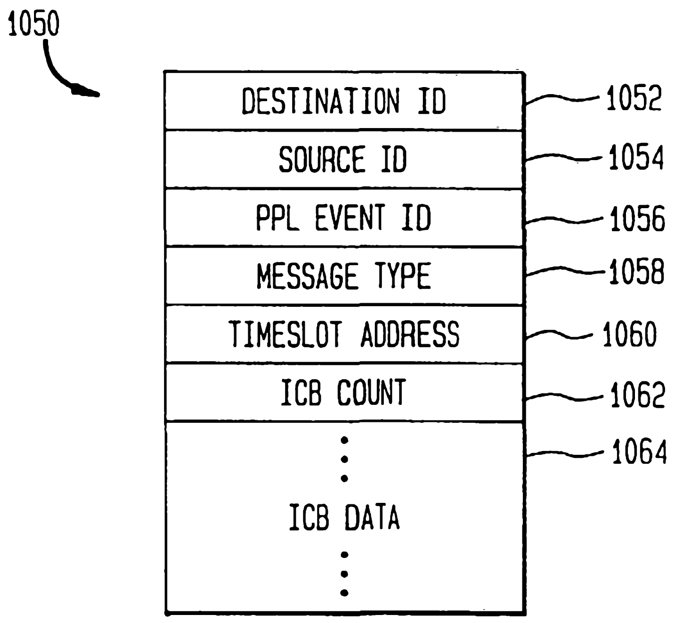
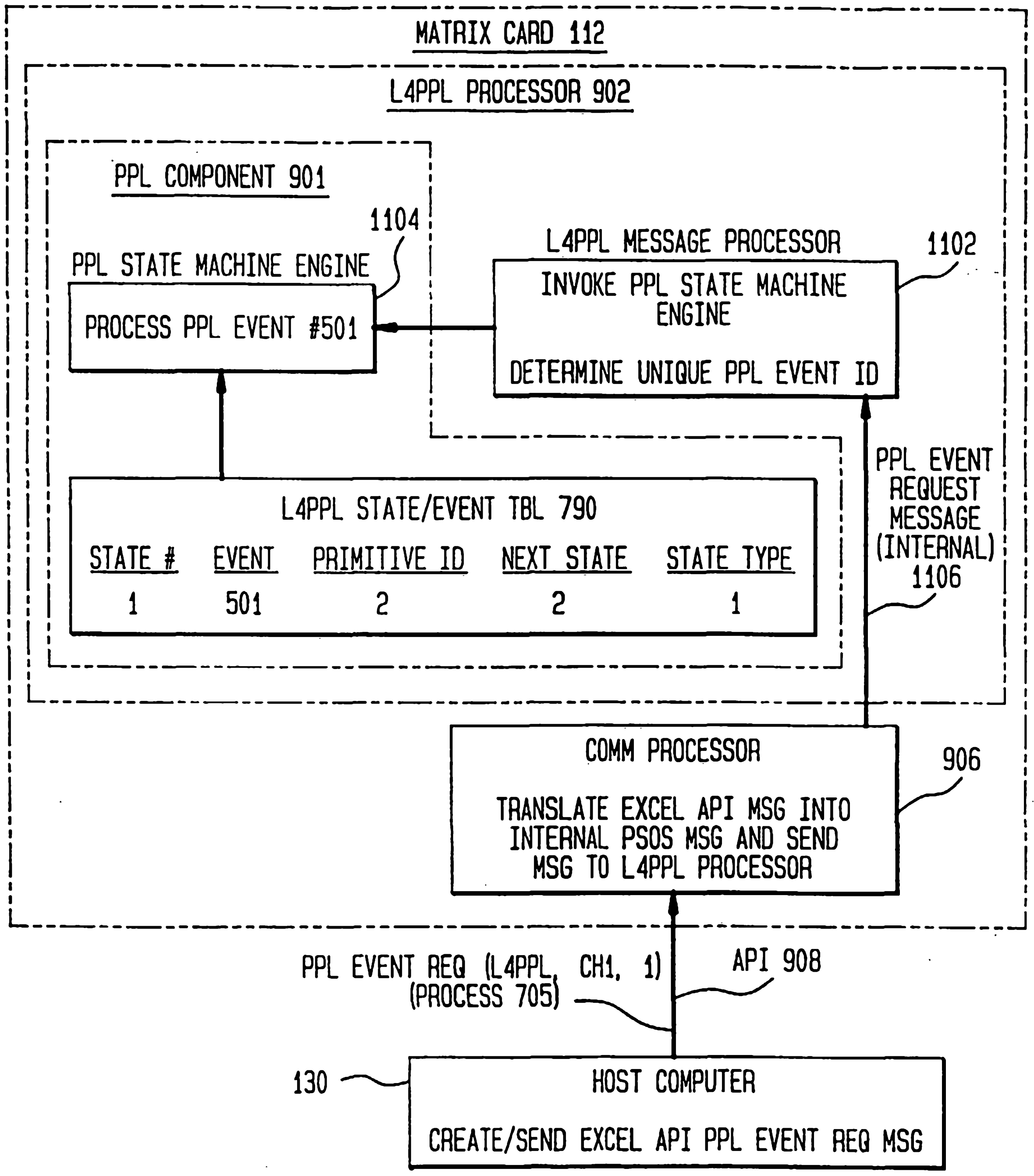

1050
DESTINATION ID
1052
SOURCE ID
1054
PPL EVENT ID
1056
MESSAGE TYPE
1058
TIMESLOT ADDRESS
1060
ICB COUNT
1062
ICB DATA
1064

FIG. 11


MATRIX CARD 112
L4PPL PROCESSOR 902
PPL COMPONENT 901
1104
PPL STATE MACHINE ENGINE
PROCESS PPL EVENT #501
L4PPL MESSAGE PROCESSOR
1102
INVOKE PPL STATE MACHINE ENGINE
DETERMINE UNIQUE PPL EVENT ID
L4PPL STATE/EVENT TBL 790
STATE # EVENT PRIMITIVE ID NEXT STATE STATE TYPE
1 501 2 2 1
PPL EVENT REQUEST MESSAGE (INTERNAL) 1106
COMM PROCESSOR
TRANSLATE EXCEL API MSG INTO INTERNAL PSOS MSG AND SEND MSG TO L4PPL PROCESSOR
906
PPL EVENT REQ (L4PPL, CH1, 1) (PROCESS 705)
API 908
130
HOST COMPUTER
CREATE/SEND EXCEL API PPL EVENT REQ MSG