ISDN Basic Rate Interface Interoperability with Key and Hybrid Systems

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More than one million AT&T small business customers have invested billions of dollars in MERLIN® II and MERLIN LEGEND® telecommunications equipment, typical small customer premises equipment (CPE) switches. Many of these customers want to be able to use applications such as video conferencing and high-speed data, available only with digital facilities, such as integrated services digital network (ISDN), either through ISDN primary rate interface (PRI) lines or ISDN basic rate interface (BRI) lines. Before the fourth quarter of 1994, the MERLIN LEGEND control unit supported only PRI connectivity. Unfortunately, PRI lines are beyond the price range of many customers because of the large number of channels they require and their associated costs. On the other hand, customers who want ISDN BRI lines must change their service features and replace most of their existing MERLIN II and MERLIN LEGEND equipment. This paper describes a BRI solution—based on a software-emulated terminal (SET) model—for customers who want the capabilities that ISDN offers, as a natural extension of the digital architecture of the MERLIN Communications System. Its system architecture and infrastructure now support basic rate access from MERLIN Communications Systems to a central office (CO). The SET model that resides within the MERLIN LEGEND control unit supports both the ISDN B-channel transport service and access to CO-based supplementary services. The SET appears to the central office as one or two physical terminals, complete with handset, keypad, and feature buttons. Combining the emulated terminals with the internal architecture of the MERLIN LEGEND produces a seamless user interface, regardless of network connectivity. With this design, customers can continue to use their embedded base of equipment, while gaining access to digital transport and advanced services accessible through BRI.

Introduction

ISDN PRI and BRI have been positioned in the U. S. market as state-of-the-art digital gateways that allow access to higher-speed data and advanced applications. PRI facilities, composed of 1 data channel and 23 bearer channels (23B + D), can carry 23 circuit-switched calls simultaneously. Because of the large number of channels they require and their associated costs, PRI facilities are beyond the price range of many customers. BRI facilities, comprising 1 data channel and 2 bearer channels (2B + D), can carry 2 circuit-switched calls simultaneously. The U. S. versions of ISDN BRI are designed to work directly with terminal equipment (TE1), making it difficult for users of existing CPE to

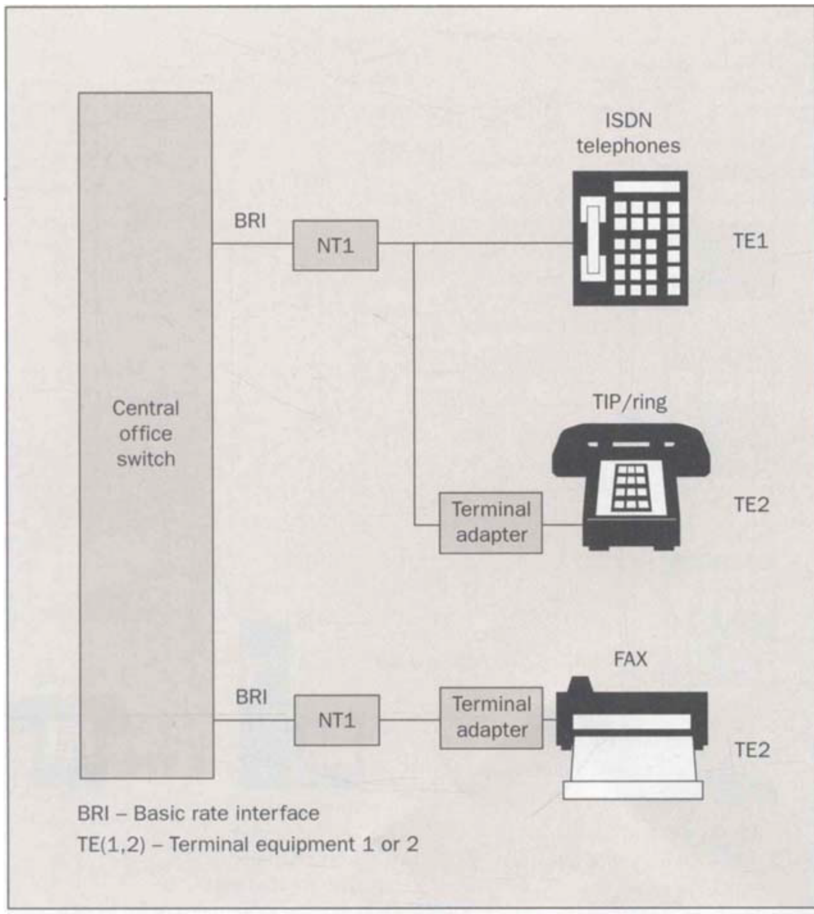

Figure 1. A typical ISDN BRI offering, in which each ISDN telephone is directly connected to the central office by a BRI line.

take advantage of these advanced applications. The incompatibility arises because typical offerings of ISDN BRI in the U. S. consist of CENTREX single-line configurations, in which a BRI line connects each ISDN telephone directly to the central office (see Figure 1). For current users of key and hybrid systems with a large embedded base of tip/ring devices (such as fax machines and modems), system voice terminals, and telephony application packages (such as voice mail), this move would require changing most, if not all, of their equipment.

This paper describes an approach that allows customers to keep their existing terminal and common equipment, while taking advantage of ISDN capabilities, such as high-speed fax (for example, Group 4 [G4]) capabilities, video teleconferencing, and high-speed Internet access. Customers can incrementally and seamlessly add ISDN terminal equipment and applications as needed, making ISDN features much lower in cost than they would be if the current key or hybrid system, also known as *NT2*, were moved from its existing environment to a single-line CENTREX environment.

The SET solves this problem by resolving the mismatch between a terminal-oriented protocol and the network interface of a customer premises switch, presenting telephone users behind the key or hybrid switch with seamless network access. Figure 2 shows the SET implemented on the MERLIN LEGEND® Communications System. The capability to connect to a BRI line—that is, BRI *connectivity*—and its accompanying features have minimal impact on the existing terminal interface and preserve all of the existing terminal equipment and system features.

This design removes many of the roadblocks commonly associated with ISDN. First, it provides customers with incremental digital network connectivity, allowing them to protect their investment in existing CPE, and provides access to advanced ISDN services. Second, because customers retain their current terminal user interfaces, they save on training and the lost productivity associated with changing to new user interfaces. Third, the design supports additional MERLIN LEGEND system functionality, such as bridging, power fail services, and local control of moves and rearrangements at the customer premises.

SET Implementation

The SET model is designed to operate with the 5ESS® Generic 8 (5E8) Custom BRI interface.[1] Its 5E8 terminal Type D model supports circuit-switched voice and data in a point-to-multipoint environment and allows

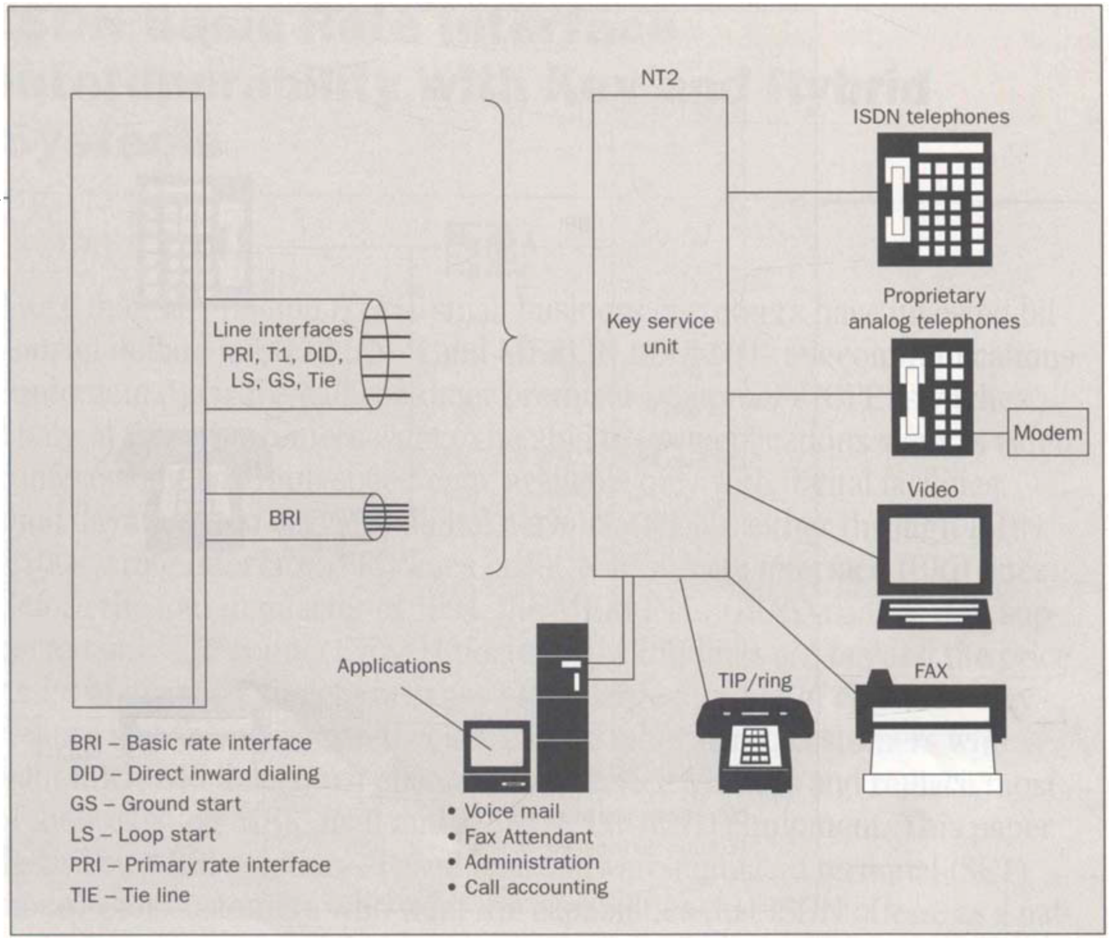

Figure 2. A typical MERLIN LEGEND configuration with the addition of a central office BRI line interface. Similar to other types of central office facilities, each BRI facility can be shared among any of the voice or data terminal endpoints in the system.

access to a selected set of supplementary services, including such features as call transfer and automatic callback.

Overview. The MERLIN LEGEND system has a multiprocessor design in which the main CPU, servicing the common call switching and feature operation functions, works in tandem with a variety of port processors. These port processors handle the different lower-level signaling protocols required by the physical interface of the lines and stations supported by the system. Within this architecture, the BRI connection incorporates a new BRI port processor to process Layers 1 and 2—the Open Systems Interface (OSI) physical and data link layers, respectively—of the signaling and protocol associated with the 5E8 ISDN BRI interface. Each BRI port processor complex, or board, contains eight ports, for a maximum of eight BRI lines. Multiple BRI boards can be installed to support more lines. To complete the package, the software running in the main CPU has been enhanced to support the protocol for Layer 3—the OSI network layer—and to interface with lower-layer functions. The main body of the SET model is implemented in Layer 3, which is described below.

The BRI interface provided by the 5ESS switch is designed to work with ISDN terminal equipment (TE1), such as the AT&T 7500 series of ISDN phones.

Panel 1. Abbreviations, Acronyms, and Terms

bearer channel—a communication pipe that carries user data, for example, voice, digital data, etc.
BRI—basic rate interface
CO—central office
CPE—customer premises equipment
5E8—5ESS switch, Generic 8
ISDN—integrated services digital network
PRI—primary rate interface
SCA—selected call appearance
SET—software-emulated terminal
SPID—service profile identification (ID)
TE1—terminal equipment
TEIs—two equipment identifications (IDs)

(In this context, "ISDN phones" refer to the ISDN telephones manufactured by AT&T, as opposed to the ISDN telephones supported on the station side of the MERLIN LEGEND system.) However, the MERLIN LEGEND control unit is a nonterminating NT2 device, which creates a mismatch in the protocol. To enable the MERLIN LEGEND system to use BRI lines, the system must act as if ISDN phones

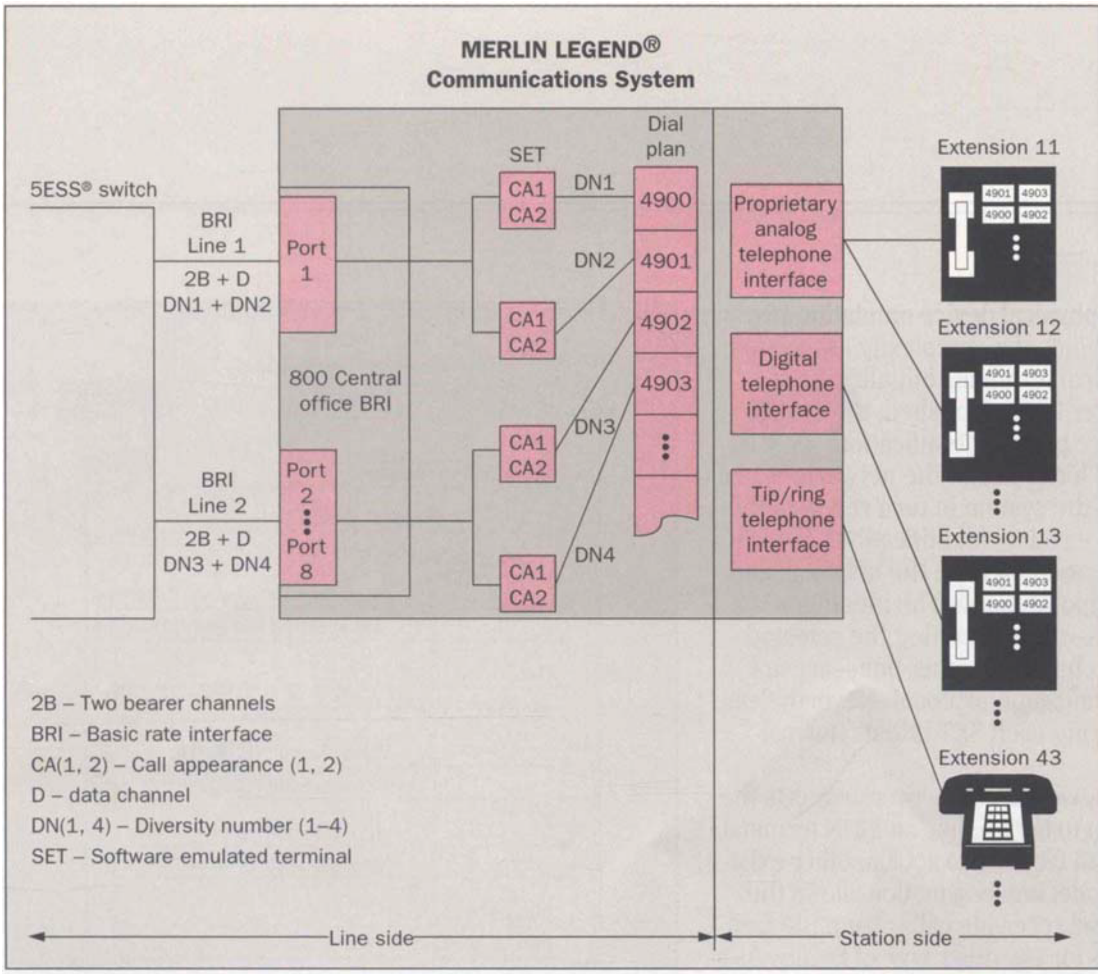

Figure 3. A representation of four SETs. Each BRI directory number (one SET with two logical call appearances) is mapped into an internal facility number, for example, 4900. Each facility can then be administered and subsequently accessed by one or more voice or data terminal endpoints.

are connected to each BRI line port. Switchhook status, dialing, button presses, and other equipment must all match what the 5E8 would expect from an ISDN phone. Furthermore, station users behind the MERLIN LEGEND system expect BRI facilities to work the same way as their existing analog facilities with respect to placing and receiving calls and using system features.

To accomplish this dual role, the MERLIN LEGEND system provides both of the interfaces—emulating an ISDN phone at the 5E8 interface, and acting like an analog facility to station users. The conversion between the two models is handled within the system. By using a SET design based on a model of ISDN terminal equipment with the required functionality, the MERLIN LEGEND Communications System can provide the necessary BRI connectivity.

Figure 3 depicts the configuration of the MERLIN LEGEND Communications System. A BRI line connected to a BRI board can emulate two SETs, each of which is assigned one directory number, for a total of two directory numbers per BRI line. These are sufficient to take advantage of the maximum bandwidth offered by the two bearer (B)-channels per BRI. Mapping occurs between the directory number associated with each SET and a dial plan number within the system that allows the station users to access the BRI facility.

Normally, one call appearance (CA1) per SET would be sufficient for call origination and termination, that is, one active call per directory number. But to support the transfer capability based on the 5E8 protocol specification, a second call appearance, CA2, is added to the emulation model. During the transfer operation, when the *transfer source party*, or the party that is being transferred, is on hold on CA1, CA2 is used to call the transfer destination party. This transfer capability is described in more detail later in this paper.

Terminal Initialization. In the standard configuration, each connected BRI line in the MERLIN LEGEND system emulates two SETs. At the beginning of this emulation model, the system goes through the initialization protocol to "connect" what appears to the 5E8 as two physical terminals. Figure 4 shows the messages exchanged to establish a connection between the MERLIN LEGEND system and the 5E8.

At startup, when Layer 1 is connected to the network, the SET instructs the BRI port processor to obtain two equipment IDs (TEIs) from the 5E8 and to establish the Layer 2 state machine. Because the MERLIN

LEGEND system is one physical device emulating two terminals, this design avoids the complexity associated with true multiple physical terminals initializing over the same line. After Layer 2 is established, the system sends two unique service profile identifications (SPIDs) to identify the emulated terminals to the network. When the SPIDs are validated, the system in turn receives the user identifications and terminal identifications (which identify the emulated terminals) from the network, and the BRI line enters multipoint mode. The messages depicted after this point—such as setting the selected call appearance (SCA) to button number one—are not part of the terminal initialization protocol. Nevertheless, they are necessary to bring each SET into its normal call-handling mode.

Call Processing Overview. The network expects the MERLIN LEGEND system to behave like an ISDN terminal, while users expect the BRI facilities to act like other existing facilities. The SET model implementation allows the procedures for placing and receiving calls over a BRI facility to remain the same as for any other type of facility. As a result, the MERLIN LEGEND station user perceives no difference between a BRI facility and any other analog facility. To realize this perception, the SET internally converts user actions associated with placing calls into valid 5E8 button depressions and switchhook transitions, which make it appear as if the call had originated from an ISDN terminal. Conversely, for an inbound call delivered by the network, the SET translates the ISDN messages locally and presents the BRI call to the user in the same manner as any other type of call.

Within the software, the MERLIN LEGEND system manages two loosely coupled ISDN *call state machines*—one for the SET model and one for the key model. Call control state machines are finite state machines that define the states and transitions used to establish and disconnect a call. The *key* model, the state machine behind the SET, handles the generic call processing functions in a switching system, such as calling from one station to another or calling from a station to an external party over an analog line. The SET model manages a call state machine for the BRI lines with the network that handles the Q.931 messages, as defined by the protocol. (Q.931 is an international standard that defines finite state machines and the transition-controlling messages that control them.) The two state machines work together to provide end-to-end call connectivity. A Q.931 message received from the network by the SET gets translated into an internal stimulus, which is forwarded to the key model; the reverse is also true. As a result, call state transitions occur in both models.

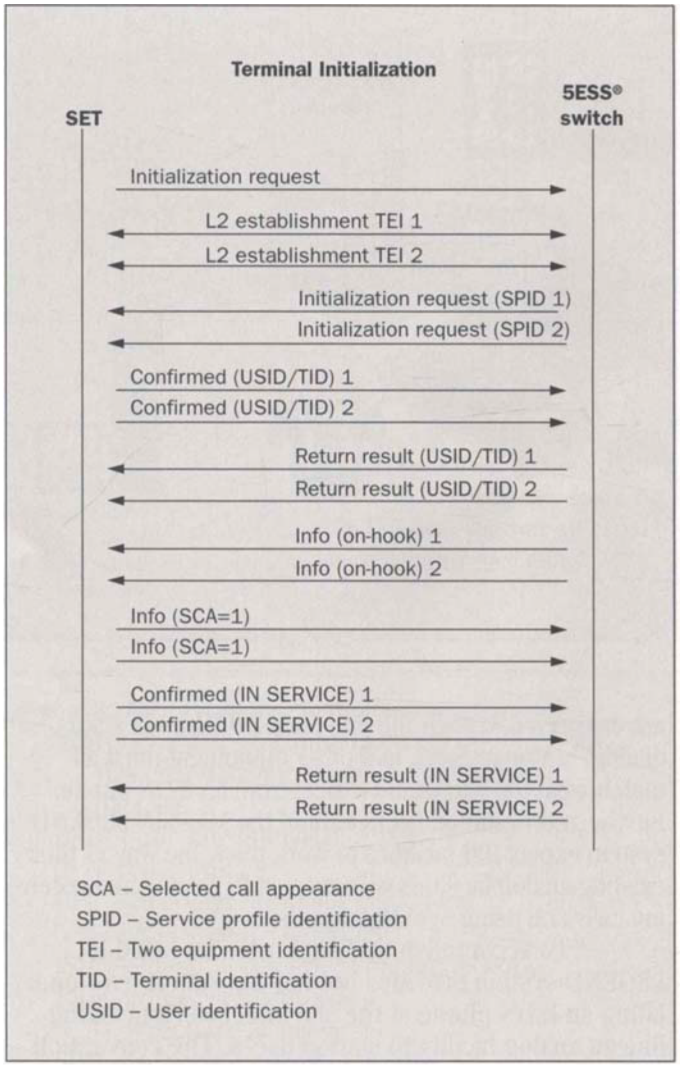

Figure 4. The establishment messages exchanged between the MERLIN LEGEND Communications System and the 5E8, known as terminal initialization.

The sections that follow focus on call establishment within the context of the SET model. They describe the call handling and user interface of the MERLIN

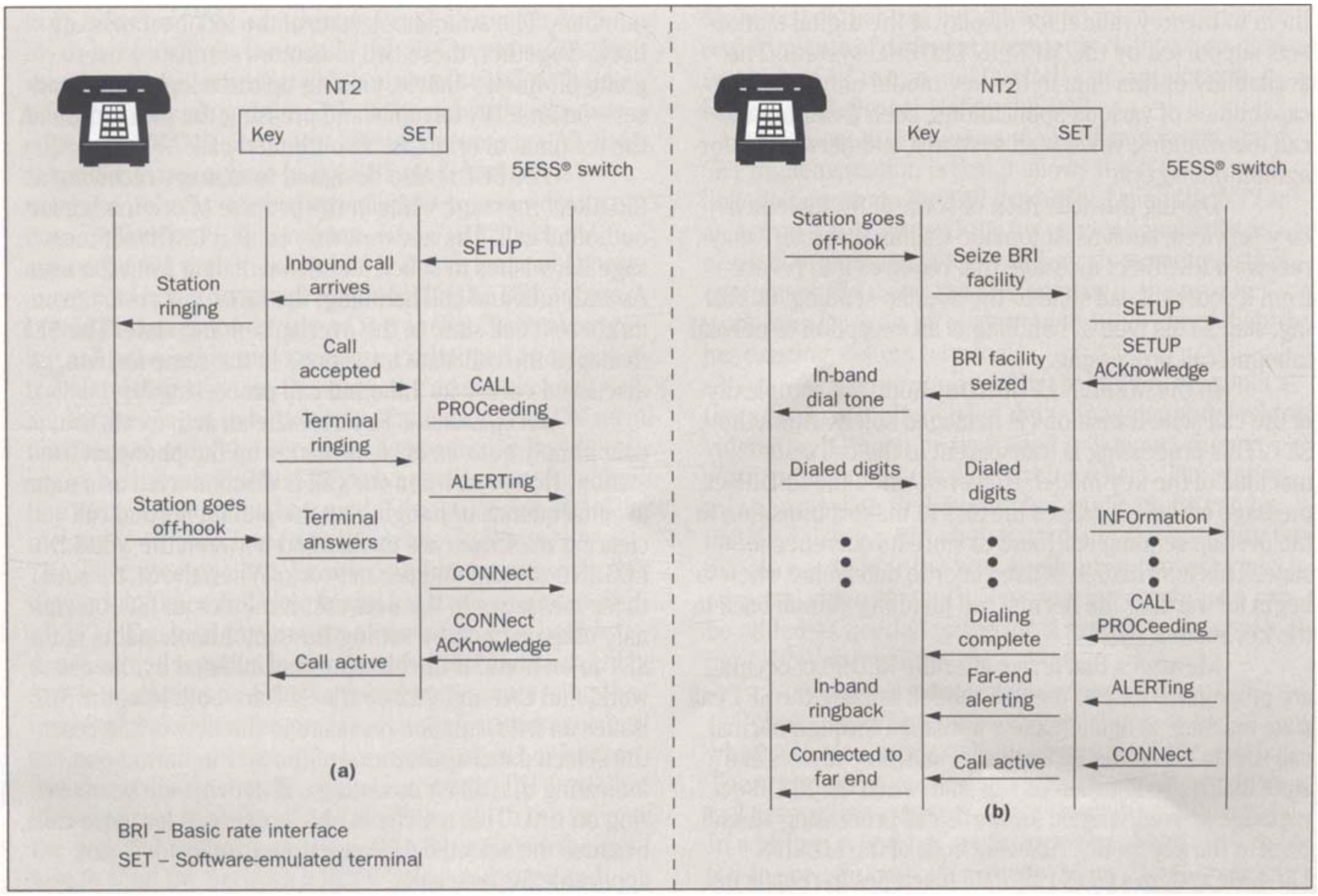

Figure 5. The messages exchanged between the MERLIN LEGEND Communications System and the network to establish (a) an inbound call and (b) an outbound call.

LEGEND system and discuss how the system software manages its dual role as a facility and an ISDN terminal.

Inbound call processing. Figure 5a depicts the Q.931 messages exchanged between the MERLIN LEGEND system and the network for an inbound call. When the SET receives an inbound call from the network, it processes the Q.931 messages received and responds accordingly. In addition, the SET model propagates the bearer capability and lower-layer compatibility (both required for call establishment), the calling party number, and called party number to the key model. It also manages call state transitions, for example, when a REDIRect message is received.

The SET checks only for the presence of the bearer capability information element in the SETUP message, but does not verify any of its contents. After the key model and the SET determine that the call can be accepted, the SET forwards the contents of both the bearer capability and lower-layer compatibility information elements to the key model, which in turn sends the information to the ISDN station(s) for validation and compatibility checking. If the information elements are accepted, the station processes the call and the key model instructs the SET to issue normal call processing messages to the network. Otherwise, the key model informs the SET to reject the call, and the SET responds to the network accordingly.

The SET extracts the calling party and called party numbers from the SETUP message and forwards them to the key model for display at the digital station sets supported by the MERLIN LEGEND system. The availability of this data in the key model enhances the capabilities of various applications, such as automatic call distributors, voice mail systems, and personal information managers.

During the activation of some 5E8 supplementary services, such as Automatic Callback, the SET may receive a REDIRect message that requires it to revert from its current call state to the overlap sending, or *dialing*, state. This type of handling is an exception to normal inbound call processing.

In the MERLIN LEGEND system, the complexity of the call state transitions is managed solely within the SET. This processing is transparent to the call state machine of the key model. However, when the REDIRect message arrives, it causes the SET to make a transition to the overlap sending state and to store its current call state. This information is used later to determine when to begin forwarding the normal call handling stimuli back to the key model.

Messages that arrive after the REDIRect occurs are propagated only to the SET model, causing the SET call state machine to again make a transition through normal call states. When the SET call state machine arrives at a state that is greater than its call state when the REDIRect message arrived, it again forwards call processing stimuli back to the key model. Allowing both of the MERLIN LEGEND system's ISDN call state machines to remain out of synchronization actually saves on real-time performance because there is no need to perform station transitions or updates. The key model may remain in a transitory call state for a temporary period of time, but it will be resynchronized with the SET when the SET's call state is greater than the key call state when the REDIRect arrives.

Outbound call processing. Figure 5b depicts the Q.931 messages exchanged between the MERLIN LEGEND system and the network for an outbound call. When the key model issues a stimulus to the SET that a user is initiating a BRI call, the SET transforms this action into 5E8 switchhook states and button depressions as if this call were originating from an ISDN terminal. The SET model requires that all calls, except the destination party of a central office-based transfer, originate from CA1. Therefore, the origination call appearance value is set to button one because the network maps call appearances to button numbers. The switchhook state of the SET becomes off-hook. Together, these two indicators simulate a user going off-hook—that is, picking up the telephone's handset—on an ISDN terminal and pressing the first button on the terminal to originate an outbound call.

The SET is also designed to manage receiving a REDIRect message while in the process of originating an outbound call. The network may issue a REDIRect message if it wishes to solicit additional dialing from the user. As with inbound call handling, the SET must revert from its current call state to the overlap sending state. The SET manages the call state transitions in the same fashion, as discussed earlier in "Inbound call processing."

Call termination. To terminate an active call, the user simply goes *on-hook*, or hangs up the phone, at the station. However, when the call is disconnected as a natural consequence of hanging up the phone, normal call clearing messages are exchanged between the MERLIN LEGEND system and the network. When the SET issues these messages to the network, it mimics an ISDN terminal going on-hook by setting the switchhook status of the SET to on-hook. If the clearing was initiated by the network, and CA1 and CA2 on the SET are both idle, the SET issues an INFOrmation message to the network to reset the selected call appearance of the SET to button one, indicating that all forthcoming call activity will be occurring on CA1. This activity is only processed for voice calls, because the selected call appearance indicator is not applicable for data calls.

Central office-based transfer. The MERLIN LEGEND system supports the implicit transfer feature provided by the network, referred to as *CO Transfer* throughout the rest of this paper. To access the CO Transfer feature, the user depresses the Transfer button on the MERLIN LEGEND system while on an active BRI call on CA1. Next, the user depresses a preprogrammed BRI Access button, which sends a TRANSfer message to the network. When the TRANSfer message is acknowledged, the user can dial the destination party. When that party answers, the user can complete the transfer, at which time the MERLIN LEGEND system sends a second TRANSfer message to the network.

Once the user has initiated a transfer, the call is considered on hold for TRANSfer in the key model. When the BRI Access button is depressed, the key model communicates a request to the SET to access the CO Transfer feature. This mechanism was adopted by the system to equate to an ISDN terminal user depressing the Transfer button on his or her terminal. As a result, the SET issues a TRANSfer message to the network, which places the call on hold at both the network and the SET. If the network acknowledges the TRANSfer request, the SET accesses CA2, the second call appearance in the SET model, which is reserved only for originating calls to a transfer destination. Unlike the ISDN terminals (TE1s), CA2 does not appear on the user's station set. It is a virtual call appearance that is only accessed by the SET if the BRI Access button is depressed during a CO transfer. Normal outgoing call processing messages are exchanged to access the transfer destination. In this case, the origination call appearance is set to button two, simulating an ISDN terminal user selecting the second call appearance button on his or her terminal. The SET converts the transfer completion stimulus from the key model into a second TRANSfer message, which is issued to the network. When the TRANSfer message is acknowledged by the network, the network initiates call clearing on both call appearances.

The user may return to the source on hold by depressing the status button associated with the call. The SET is emulating an ISDN terminal user reaccessing the transfer-held source by pressing the call appearance button associated with the transfer source on his or her terminal. The SET converts this action into an INFOrmation message that instructs the network to return the value of the selected call appearance to CA1. This allows the system to send the network a RECONNect message and retrieve the call from hold on CA1.

Benefits

Having the SET integrated into the switching fabric of the existing MERLIN LEGEND system is a definite advantage. It enables all switch functions (such as maintenance, station arrangement, and assorted applications) to treat the BRI as simply another component of the CPE in the MERLIN LEGEND system. By attaching the SET to the NT2 internal fabric, the NT2 becomes a natural interworking point for existing behind-NT2 terminals. This protects the customer investment in existing equipment and supports the user interface at all system terminals, thereby eliminating the need for retraining end users.

ISDN network implementations that assume a "terminal" model may have restrictions on their BRI configurations that limit B-channel access. The SET model discussed earlier can be adjusted to meet the separate requirements of different user-network interface models (such as 5E8 Custom and the Bell Communication Research [Bellcore] National ISDN).

Facilitating Migration. A significant result of the SET implementation is that it allows the NT2/network links to migrate to the BRI gradually. Using the NT2 as an agent, it substitutes BRIs for conventional lines as needed, interworking ISDN BRI services with existing equipment. By using the SET approach, the user network interface can be converted to BRI without disturbing existing system terminals.

As users require BRI capabilities, for applications such as higher-speed data, imaging, and desktop video, the NT2 can be upgraded to support the network connections (as discussed earlier). The station mix appropriate to the intended applications can be installed using a BRI station card and the specialty terminals needed for the new application (for example, a personal video system). New specialty terminals can be added as needed to the local system without affecting ISDN connectivity.

Preserving Existing Applications. Existing CPE switches support numerous applications, many of which are also supported locally by the CPE switch. These include voice mail and fax attendant systems, call accounting systems, and automatic call directors. In addition, a body of applications has been custom fitted to specific customer needs. Many, if not most, of the existing application platforms do not depend on ISDN for transport; they communicate with the NT2 using a local protocol. These applications can provide services to the users even as their terminals and network connections are upgraded.

New Services Available on an Incremental Basis. The single point of upgrade can also support new network-based services. In a setting where user terminals are directly attached to the network, any new network protocol or supplementary service procedures will need to be installed individually in the terminal base. If an NT2 acting as agent is upgraded, its system terminals will have access to the new services without having to upgrade user endpoints individually. New services can be added incrementally, reducing the upgrade costs and making new supplementary services available to all users simultaneously.

Simplified Provisioning. One drawback to this type of ISDN deployment has been the difficulty in administering individual terminals. With the rich supplementary service mix and numerous channel configuration options, literally hundreds of parameters must be administered to initialize a BRI line. One advantage of the SET approach is that all BRIs to the NT2 can use a common service profile. The NT2s can support customized user interfaces, and feature button and Call Appearance arrangements, without requiring changes in the central office. The use of common service profiles should minimize provisioning errors on ISDN BRI lines.

Conclusion

Implementing the user-network interface as a SET is beneficial to both CPE owners and to network service providers. The small NT2 helps to deploy the ISDN. The established base of NT2s in the U. S.—as embodied in the key model system controllers—is significant, and a substantial base of key-behind-CENTREX lines have already been deployed. These owner–users have little desire to make large-scale changes to their equipment, but are generally interested in taking advantage of upgrades and new services that will benefit their business. Active support of the NT2 will accelerate the deployment of the ISDN.

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Reference

1. *5ESS Switch Custom ISDN Basic Rate Interface Specification*, AT&T 235-900-343, December 1991.

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