♦ Evolution of Switching Architecture to Support Voice Telephony over ATM

Judith R. McGoogan, Joseph E. Merritt, and Yogesh J. Dave

This paper discusses the architectural complexities of extending Lucent's 5ESS®-2000 Digital Switch using the 7R/E™ Packet Driver to add voice telephony over ATM (VTOA) with switched virtual circuits (SVCs). While meeting customers' tight deadlines for introducing this technology, this project addressed many of today's most complex issues, including platform migration, circuit-to-packet switch conversion, and voice/data migration. To provide the media gateway function, the PacketStar™ Access Concentrator (developed at Yurie Systems, now part of Lucent Technologies) was incorporated into Lucent's long-standing, premier switching product, the 5ESS-2000 Switch. Additional forward-looking technology from Lucent provided the connection/signaling gateway functionality.

Introduction

The architecture of Lucent Technologies' 5ESS®-2000 Switch (hereafter referred to as the 5ESS Switch) enables service providers to grow network capacity and support new technologies. Lucent's 7R/E™ Packet Driver was designed to implement our strategy for evolving the 5ESS Switch to enable use of off-the-shelf components along with internally developed components for rapid deployment of new technologies and interfaces as standards are stabilizing. One example of this strategy was a project aimed at the international market that extended the 5ESS Switch to add voice telephony over ATM (VTOA) with switched virtual circuits (SVCs).

This paper will discuss:

- The problem this project addressed;
- The architecture of the solution—including the network view, an overview of the 5ESS Switch with the 7R/E Packet Driver, and descriptions of each of the major new components that have been added;
- The new signaling and routing protocols;
- A high-level example of the corresponding call flow that illustrates the use of traditional integrated services digital network (ISDN) user part (ISUP), a pre-standardized protocol designated ISUP+, and asynchronous transfer mode (ATM) signaling; and
- A brief overview of new approaches used for operations, administration, maintenance, and provisioning (OAM&P) of components added using the 7R/E Packet Driver.

Problem Statement for Initial Release to International Market

In today's market, strong forces are pushing for evolution from circuit-based to packet-based technology.[1] Customers are increasingly installing ATM capabilities in their core networks for data applications, and they want to use these core ATM data networks to transport voice traffic as well. Internationally, many network providers must lease private lines to provide voice services. Using their ATM data networks to route the voice traffic would eliminate the high prices they now pay for leased lines. These customers also hope to reduce their operational costs by routing their voice traffic through ATM. The ATM network ensures that traffic is routed to the appropriate target; hence, the trunk groups from a given local switch only need

Panel 1. Abbreviations, Acronyms, and Terms

10BaseT—IEEE 802.3 100-meter local area network using Ethernet twisted-pair cable
100BaseT—IEEE 802.3 local area network 100-Mb/s Fast Ethernet standard
AAL1—ATM adaptation layer type 1
AAL2—ATM adaptation layer type 2
ACM—address complete message
ACM+—ISUP+ version of ACM
ANM—answer message
ANM+—ISUP+ version of ANM
API—application programming interface
ATM—asynchronous transfer mode
BICC—bearer independent call control
C7—International (CCITT) Signaling System 7
CAS—channel associated signaling
CBR—constant bit rate
CCITT—Comité Consultatif International de Télégraphique et Téléphonique, now part of the International Telecommunication Union
CG—Connection Gateway
CPU—central processing unit
CORBA*—Common Object Request Broker Architecture
DLTU—digital line and trunk unit
DS0—Digital signal level 0; transmission rate of 64 kb/s (1 channel) in time division multiplex hierarchy
E1—European signal rate of 2.048 Mb/s (30 64-kb/s channels)
EC—echo cancellation
EMS—element management system
ESA—end system address
ETSI—European Telecommunications Standards Institute
GUI—graphical user interface
I/O—input/output
IAM—initial address message
IAM+—ISUP+ version of IAM
IEEE—Institute of Electrical and Electronics Engineers
IETF—Internet Engineering Task Force
IISP—interim inter-switch protocol
ILMI—integrated local management interface
ISDN—integrated services digital network
ISUP—ISDN user part
ISUP+—modification of ISUP; a pre-standard version of the BICC signaling protocol that uses TCP/IP over an ATM data network
ITU-T—International Telecommunication Union–Telecommunication Standardization Sector
LAN—local area network
MTP—message transfer part
MTP3—MTP Level 3
NEBS—new equipment building standards
OAM&P—operations, administration, maintenance, and provisioning
OC-3—optical carrier digital signal rate of 155 Mb/s in a SONET system
OC-12—optical carrier digital signal rate of 622 Mb/s in a SONET system
PNNI—private network-network interface
PSTN—public switched telephone network
PSU—packet switch unit
PVC—permanent virtual circuit
QoS—quality of service
REL—release message (ISUP)
REL+—ISUP+ version of REL
RLC—release complete message (ISUP)
RLC+—ISUP+ version of RLC
SAC—synchronous/asynchronous conversion
SCT—signaling correlation tag
SDH—synchronous digital hierarchy
SM-2000—Switching Module 2000 (5ESS® Switch)
SMP—switching module processor (5ESS Switch)
SNMP—simple network management protocol
SONET—synchronous optical network
STM—synchronous transfer module
STM-1—synchronous transport module 1; SDH standard for transmission over OC-3 optical fiber at 155.52 Mb/s
STM-4—synchronous transport module 4; SDH standard for transmission over OC-12 optical fiber at 622.08 Mb/s
SVC—switched virtual circuit
TCP/IP—transmission control protocol/Internet protocol
TDM—time division multiplex/multiplexed/multiplexing
UBR—unspecified bit rate
UNI—user-network interface
VBR—variable bit rate
VCI—virtual channel identifier
VPI—virtual path identifier
VTOA—voice telephony over ATM
WAN—wide area network

to be sized to accommodate aggregated outgoing and incoming traffic. This means the network provider must only manage several "big fat pipes" rather than a complex mesh of many "small pipes."

In designing the architecture for this project, the goals were as follows:

- Protect our customers' investments in 5ESS Switches as the core network evolves to packet-based ATM networks;
- Provide a VTOA solution for the international market as quickly as possible by evolving the existing circuit-switched 5ESS Switch to provide the same services as today's time division multiplexed (TDM) trunks over a core ATM network; and
- Use ATM to provide "smart trunks" that dynamically associate themselves with different switches by looking at the "call-ed" address in the signaling message.

Some of the key concepts of the design were:

- Use Lucent's new Connection Gateway to provide signaling interworking;
- Use the PacketStar™ Access Concentrator media gateway acquired from Yurie Systems for circuit-to-packet conversion;
- Since standards are still evolving, use a pre-standard protocol (ISUP+) to provide signaling interworking between the narrowband voice domain and the ATM domain, and use Lucent's new Sapphire application programming interface (API) for the media gateway control protocol; and
- Use the Common Object Request Broker Architecture (CORBA*) to provide interoperability and to allow rapid changes to the craft interface.

As we extended the 5ESS Switch to support ATM interoffice trunking, it was important to:

- Maintain existing 5ESS Switch voice quality,
- Make no changes to the existing interfaces on the 5ESS Switch, and
- Allow the craft who maintain the 5ESS Switch to access all of its components via a single graphical user interface (GUI).

Architecture Overview

To provide VTOA service, several new elements were added to the 5ESS Switch using the newly developed 7R/E Packet Driver. These additions support deployment of voice ATM trunking over a core ATM data network to interconnect 5ESS Switches. In this section, we first describe the network in which they are deployed. After that, we provide an overview of the 5ESS Switch with the 7R/E Packet Driver. Lastly, we describe each of the major new elements.

Network

Figure 1 depicts a network with four 5ESS Switches, each equipped with a 7R/E Packet Driver. When calls originate from the 5ESS Switch on the left side and terminate on one of the 5ESS Switches on the right side, the originating 5ESS Switch determines the next switch in the call path. It then signals the terminating office via a pre-standard version of the bearer-independent call-control (BICC) signaling protocol called ISUP+, which uses transmission control protocol/Internet protocol (TCP/IP) over an ATM data network.

Overview of 5ESS Switch with 7R/E Packet Driver

The initial release of the 5ESS Switch with the 7R/E Packet Driver adds several new components to provide interworking of narrowband and broadband technologies. The new components are:

- The Connection Gateway (CG), new technology from Lucent that provides signaling and connection control functions;
- The PacketStar AX 1250 or PacketStar AX 2300 (PSAX 1250/2300), technology acquired from Yurie Systems that performs access concentration and synchronous-to-asynchronous conversion (that is, media gateway functions); and
- An optional CBX 500™ Multiservice WAN Switch, technology acquired upon Lucent's merger with Ascend.

Figure 2 shows a logical block diagram of the 5ESS Switch with the 7R/E Packet Driver. The existing digital line and trunk unit (DLTU) provides a narrowband TDM interface that terminates E1 trunks. The incoming E1 trunks contain embedded narrowband

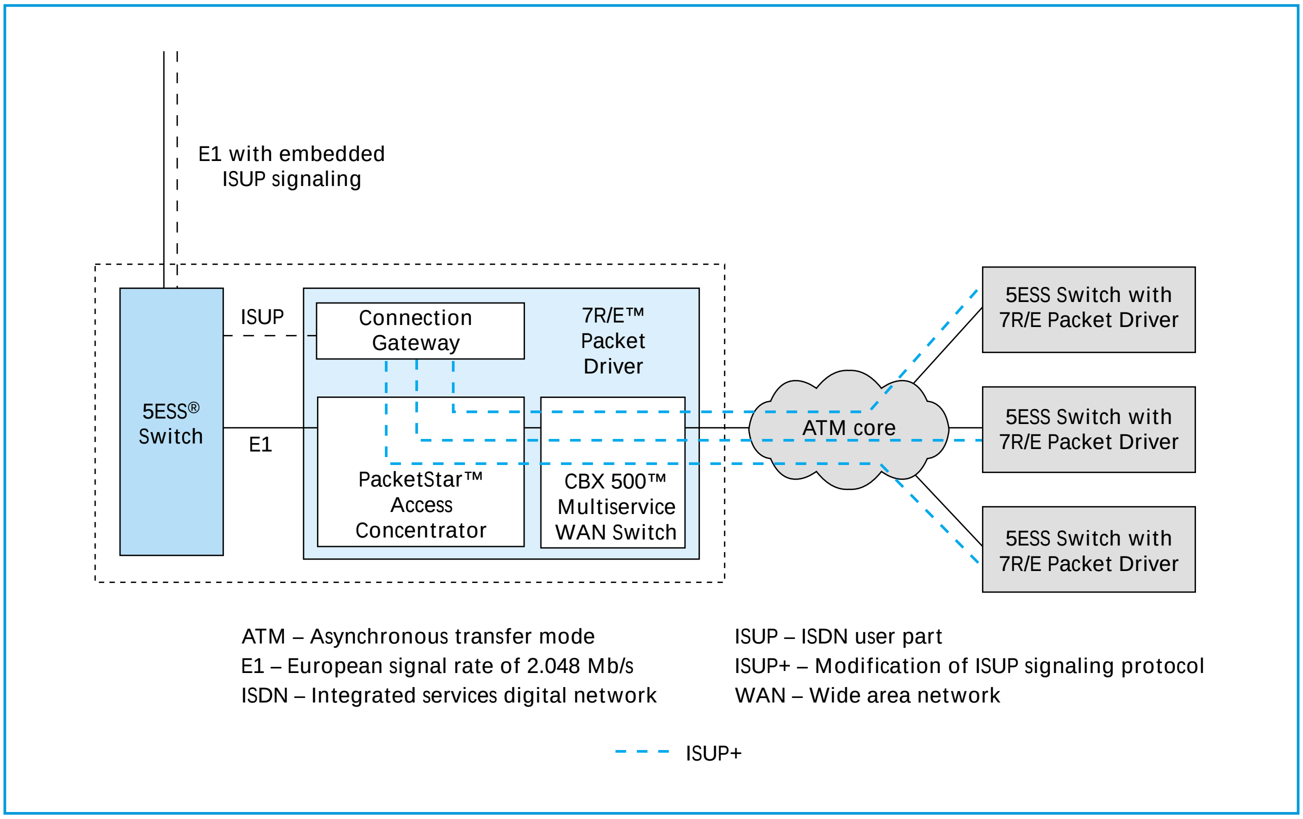


Figure 1.
VTOA network architecture.

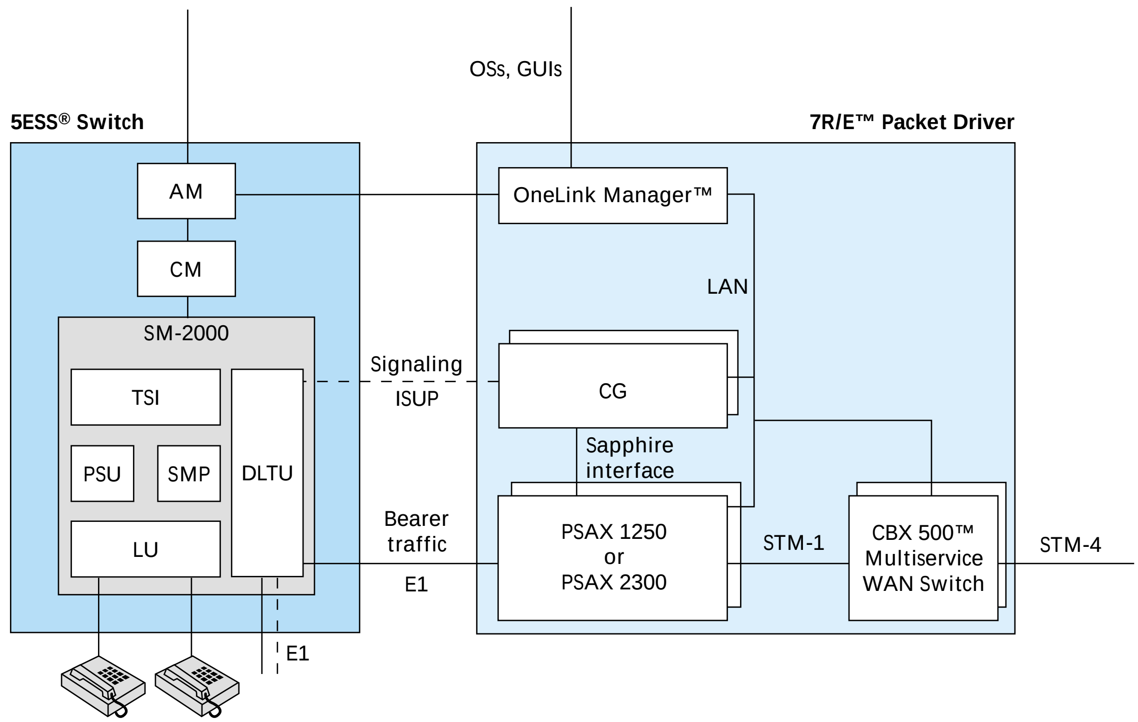
C7 signaling. The signaling and bearer portions are then split, with some E1's carrying only signaling going from the DLTU to the CG and other E1's carrying the bearer traffic going from the DLTU to the PSAX 1250/2300.

The CG keeps information about the connections in the PSAX 1250/2300, provides the ISUP+ signaling, and performs the call control and media control functions. A proprietary Sapphire interface is used to communicate between the CG and the PSAX 1250/2300 over an Ethernet local area network (LAN).

The PSAX 1250/2300 provides voice-channel echo cancellation (EC) and performs synchronous/asynchronous conversion (SAC) of the voice-to-AAL1 ATM cells. The PSAX 1250/2300 terminates TDM E1 traffic on enhanced E1 I/O cards and terminates ATM on STM-1 I/O cards. Each PSAX 1250/2300 is fully duplicated with protection switching. The PSAX 1250/2300 supports STM 1+1 automatic protection switching and line card protection switching on the STM-1 lines. The PSAX 1250/2300 general-purpose I/O card slots can be used for E1, digital-signal-processor, and ATM STM-1 I/O modules.

The optional CBX 500 ATM switch performs the ATM SVC switching, provides concentration of STM-1 to STM-4, and provides the ability to dual home on multiple ATM backbone switches for reliability. The ATM switches are fully duplicated and support STM 1+1 automatic protection switching on all lines.

A duplicated control LAN interconnects all of the elements within the 7R/E Packet Driver. The 7R/E Packet Driver element management system (EMS), the OneLink Manager™, is connected to the same LAN for OAM&P access and control. The CG also uses this LAN to communicate using ISUP+ over TCP/IP with CGs in other nodes. User interfaces are provided via an Ethernet WAN and via protocol X.25[2] from the International Telecommunication Union–Telecommunication Standardization Sector (ITU-T) for the TDM side of the 5ESS Switch.



AM – Administrative module
CG – Connection Gateway
CM – Communications module
DLTU – Digital line and trunk unit
E1 – European signal rate of 2.048 Mb/s
GUI – Graphical user interface
ISDN – Integrated services digital network
ISUP – ISDN user part
LAN – Local area network
LU – Line unit
OS – Operations system
PSU – Packet switch unit
SM-2000 – Switching module 2000
SMP – Switching module processor
STM-1 – Synchronous transport module 1 (155.52 Mb/s)
STM-4 – Synchronous transport module 4 (622.08 Mb/s)
TSI – Time slot interchanger
WAN – Wide area network

Figure 2.
5ESS® Switch with 7R/E™ Packet Driver block diagram.

The ATM STM-1 lines from the PSAX 1250/2300 are connected directly to the ATM data network or, optionally, are switched through the CBX 500 ATM switch. The CBX 500 switch would then connect to the ATM data network. Hence, the ATM interface may be either STM-1 lines from the PSAX 1250/2300 or, optionally, STM-1 or STM-4 lines from the internal ATM switch.

Connection Gateway Overview

The 7R/E CG provides the *connection control* function, where connection control is defined as trunk selection (egress) and trunk signaling control (ingress and egress) as an integrated part of the 7R/E Packet Driver architecture. Here, trunks refer to virtual trunks for both the traditional public switched telephone network (PSTN) and the packet network. To provide the trunk control function, the CG handles C7 signaling in concert with the PSAX 1250/2300 for the narrowband synchronous trunk circuits being carried over the packet network.

In the current implementation of the CG, a duplex processor pair runs in an “active/warm standby” mode, with the C7 protocol stack distributed over both processors. Each processor terminates two E1 lines that carry C7 signaling messages. C7 signaling messages that arrive at the "standby" processor are handled on that processor up to MTP3 and then forwarded to the "active" processor. The active processor does the connection control and media control functions for signaling messages arriving on both processors.

The CG provides the interworking between the C7 signaling protocol and the protocols for making ATM connections necessary to support calls being made by the 7R/E Packet Driver. The CG also provides functions for digit analysis and routing.

Primary functions. Following are the primary functions of the CG:

- C7 signaling
  - Call throttling
  - Call distribution
  - C7 link management
  - C7 interfaces
- Connection management
  - Core network routing through Sapphire protocol
  - Connection control protocol
- Call processing
  - Digit analysis
  - Numbering plan support
  - Routing
- Element management
  - Interface to the EMS
  - Element OAM&P (for example, measurement pegging)

CG interfaces. Following are the interfaces to the CG:

- *Interface to the Switching Module 2000 (SM-2000) on the 5ESS Switch for signaling.*
- *Interface to the PSAX 1250/2300 for media gateway control functions.* The standards for a protocol between a media gateway controller and a media gateway are evolving. For this release, the protocol between the CG as media gateway controller and the PSAX 1250/2300 as media gateway will be Lucent's proprietary Sapphire protocol. In the future, this protocol is likely to evolve to protocol H.248,[3] supported by the ITU-T, and/or Megaco,[4] supported by the Internet Engineering Task Force (IETF).
- *Interface to the element management system.* The interface between the CG and the EMS is simple network management protocol (SNMP) Version 2.0 over TCP/IP.

Figure 3.
The PacketStar™ Access Concentrator 2300 chassis.

PacketStar Access Concentrator—Media Gateway for Circuit-to-Packet Conversion

The PacketStar ATM Access Concentrator provides the media gateway circuit-to-packet conversion capabilities needed in this architecture. Each PSAX 2300 has 2.3 Gb/s of ATM switching capacity. The compact 19-inch chassis, shown in **Figure 3**, features 19 slots. Four of these are reserved for redundant Stratum 3/4 clock modules and central processing unit (CPU) modules. The 15 user slots can be configured with I/O modules and server modules incorporating specialized features.

The PSAX 1250/2300 is a multiservice switch that can be deployed in a range of solutions involving voice, data, and video applications. The bus-based architecture, in conjunction with its Stratum 3/4 modules, provides the system's core ATM technology. The PSAX 1250/2300 is compliant with the 5ESS Switch new equipment building standards (NEBS) and supports live insertion of all modules. Its enhanced traffic management capability supports ten quality-of-service

(QoS) levels (four at constant bit rate [CBR], five at variable bit rate [VBR], and one at unspecified bit rate [UBR]) and allows service providers great flexibility in provisioning ATM services. The PSAX 1250/2300 AQueMan™ adaptive queue management algorithm enables it to dynamically allocate and manage bandwidth across all applications while maintaining ATM Forum[5] standard QoS levels. Each I/O module can be configured to have an adaptive egress cell buffer up to 64 MB or 1 million cells.

Together with the CG, the PSAX 1250/2300 provides point-to-point bearer channel connections. In this role, it provides the SAC and packet encoding (AAL1 for CBR traffic and AAL2 voice compression for VBR traffic) for VTOA applications along with the ATM signaling and routing terminations for all the ATM interfaces.

CBX 500 ATM Switch

An optional CBX 500 ATM switch performs per-call switching of SVCs and concentration up to STM-4 and enables the 7R/E Packet Driver to home on multiple ATM backbone switches. This release of the 5ESS Switch with the 7R/E Packet Driver can be equipped with zero or one CBX 500 switch to provide CBR ATM service for the VTOA SVC application.

Signaling and Routing

Figure 4 shows the protocols that are used in signaling and routing between two 7R/E Packet Drivers.

C7 Signaling

Incoming narrowband signaling is embedded C7 signaling in E1 lines using European Telecommunications Standards Institute (ETSI) Version 1 ISUP (ITU-T Recommendation Q.767[6]). The signaling and bearer portions are then split, with each E1 line carrying only signaling from a given DLTU to the corresponding CG or carrying the bearer traffic from the DLTU to the corresponding PSAX 1250/2300.

Signaling Between the CG and PSAX 1250/2300 Using the Sapphire API

Because standards for media gateway protocols have not yet been finalized, this initial release uses Lucent's Sapphire API to communicate between the CG and the PSAX 1250/2300. The Sapphire API is a proprietary, bidirectional protocol that provides a robust, scalable call-control interface for off-board CGs to access the PSAX 1250/2300 products in order to perform signaling interworking (for example, among ATM, ISDN, C7, and channel associated signaling [CAS]). At the network layer, the Sapphire API uses a TCP/IP connection. In addition to providing extensive configuration, system initialization, alarm management, resource management, and test/diagnostic support, the Sapphire API features various fault-management capabilities (for example, keep-alive messages) to ensure the integrity of the communications link between the PSAX 1250/2300 and the CG.

Signaling Between 7R/E Packet Drivers Using ISUP+

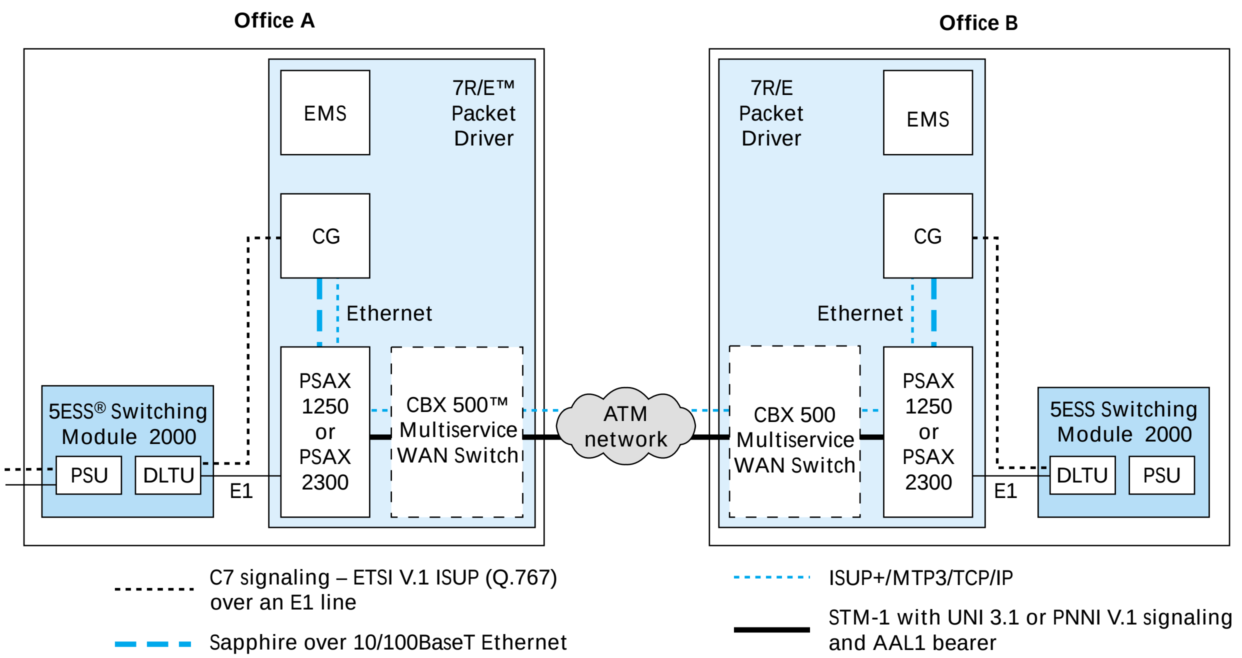
The ISUP+ signaling between two 7R/E Packet Drivers happens through CGs. A standards body is working to define a BICC protocol (based on ISUP) that can be used between CGs. Until that standard is finalized, the CG uses a pre-standard version of BICC. Called ISUP+, this version contains modifications to ISUP that add information related to the ATM bearer (for example, end system address [ESA] and signaling correlation tag [SCT] parameters). ISUP+/MTP3/TCP/IP is used as signaling between 7R/E Packet Drivers. The ISUP+ message is carried over the ATM network through PSAX 1250/2300 units on a dedicated permanent virtual circuit (PVC). The physical path is:

1. Over 10/100BaseT Ethernet from the originating CG to the PSAX 1250/2300;
2. Over an ATM dedicated PVC from the PSAX 1250/2300 to a CBX 500 switch and then to the ATM core and a terminating PSAX 1250/2300; and
3. Over 10/100BaseT Ethernet from the terminating PSAX 1250/2300 to the corresponding CG.

ATM Signaling Protocols on the PSAX 1250/2300

The minimum configuration used in this release consists of ATM Forum user-network interface (UNI) 3.1 user-side signaling to support interim inter-switch protocol (IISP)-type and SVC-type connections to the ATM network, along with integrated local management interface (ILMI) Version 4.0 on the user side. This configuration will support connections to non–customer-managed ATM networks.

Depending upon the customer ATM network configuration, additional reliability and network robust-



10BaseT – IEEE 802.3 100-meter local area network using Ethernet twisted pair cable
100BaseT – IEEE 802.3 local area network 100-Mb/s Fast Ethernet standard
AAL1 – ATM adaptation layer type 1
ATM – Asynchronous transfer mode
C7 – International Signaling System 7
CG – Connection Gateway
DLTU – Digital line and trunk unit
E1 – European signal rate of 2.048 Mb/s
EMS – Element management system
ETSI – European Telecommunications Standards Institute
IEEE – Institute of Electrical and Electronics Engineers
ISDN – Integrated services digital network
ISUP – ISDN user part
ISUP+ – Modification of ISUP signaling protocol
ITU-T – International Telecommunication Union – Telecommunication Standardization Sector
MTP3 – Message transfer part Level 3
PNNI – Private network-network interface
PSU – Packet switch unit
Q.767 – ITU-T Recommendation Q.767
STM-1 – Synchronous transport module 1 (155.52 Mb/s)
TCP/IP – Transmission control protocol/Internet protocol
UNI – User-network interface
WAN – Wide area network

Figure 4.
Protocols used for VTOA.

ness can be achieved by using the signaling protocol defined in the private network-network interface (PNNI) protocol Version 1.0. This can be used to support message flows for establishing point-to-point and point-to-multipoint connections across the ATM network. This protocol is based on the ATM Forum UNI signaling, with mechanisms added to support source routing, crankback, and alternate routing of call setup requests in case of connection setup failure.

Call Flow

Figure 5 provides a high-level picture of the basic call flow[7] between 5ESS switches with 7R/E packet Drivers. This picture denotes the ISUP and ISUP+ signaling with solid lines and the ATM signaling with dashed lines. It does not show the signaling between the CG and access concentrator components.

The call originates on a line in an originating 5ESS Switch, routes to a TDM trunk on an SM-2000, and then uses the originating 7R/E Packet Driver to gain

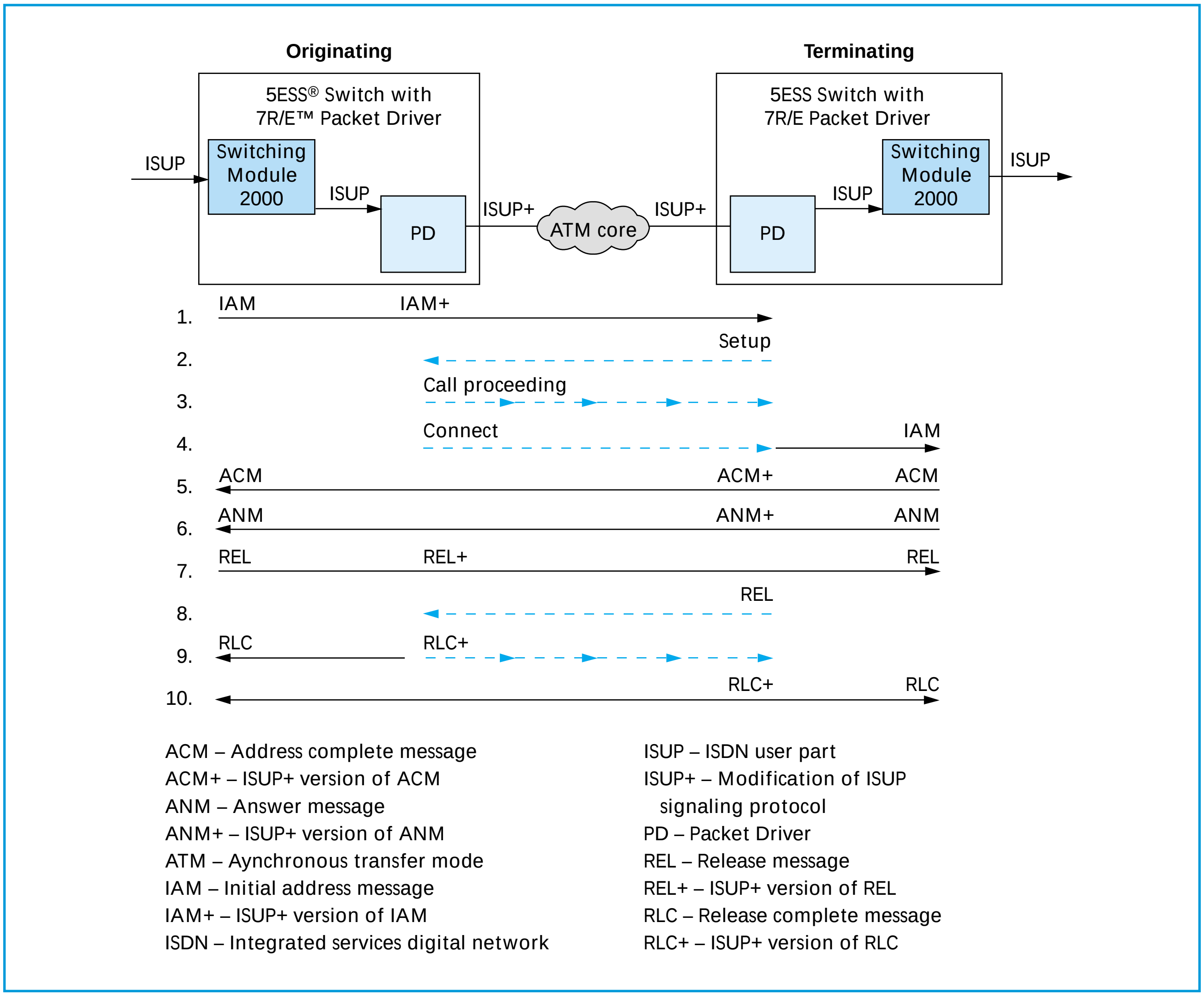


Figure 5.
Basic VTOA call scenario using SVCs.

access to the ATM core network. The call egresses the ATM core network to a terminating 7R/E Packet Driver and proceeds from there via an SM-2000 trunk to a terminating 5ESS Switch.

1. When a call originates in the TDM side of a 5ESS Switch, the switching module processor (SMP) determines the next switch in the call path and routes the call to the 7R/E Packet Driver. The SMP selects a specific DS0 timeslot of an E1 line in the trunk group connected to the 7R/E Packet Driver. Next, the SMP sends an initial address message (IAM) to the 7R/E Packet Driver CG. The CG performs the PSAX 1250/2300 connection control function; that is, it maintains the busy/idle status for all the DS0s in the trunk group. When it receives the IAM, it sets the status of the incoming DS0 associated with the circuit identification code in the message to “busy.” Next, it determines the end office and selects a CG on a terminating 7R/E Packet Driver on a 5ESS Switch with trunks to that end office. It then sends the ISUP+ version of an IAM (IAM+) to the destination CG. The IAM+ message includes an SCT and the ATM address of the originating PSAX 1250/2300 associated with the incoming circuit identification code.

Panel 2: What Is CORBA*?[10]

The Common Object Request Broker Architecture (CORBA), is the Object Management Group's answer to the need for interoperability among the rapidly proliferating number of hardware and software products available today. Simply stated, CORBA allows applications to communicate with one another no matter where they are located or who has designed them. CORBA 1.1 was introduced in 1991 by Object Management Group (OMG) and defined the Interface Definition Language (IDL) and the Application Programming Interfaces (APIs) that enable client/server object interaction within a specific implementation of an Object Request Broker (ORB). CORBA 2.0, adopted in December of 1994, defines true interoperability by specifying how ORBs from different vendors can interoperate.

The ORB is the middleware that establishes the client-server relationships between objects. Using an ORB, a client can transparently invoke a method on a server object, which can be on the same machine or across a network. The ORB intercepts the call and is responsible for finding an object that can implement the request, pass it the parameters, invoke its method, and return the results. The client does not have to be aware of where the object is located, its programming language, its operating system, or any other system aspects that are not part of an object's interface. In so doing, the ORB provides interoperability between applications on different machines in heterogeneous distributed environments and seamlessly interconnects multiple object systems.

In fielding typical client/server applications, developers use their own design or a recognized standard to define the protocol to be used between the devices. Protocol definition depends on the implementation language, network transport and a dozen other factors. ORBs simplify this process. With an ORB, the protocol is defined through the application interfaces via a single implementation language-independent specification, the IDL. And ORBs provide flexibility. They let programmers choose the most appropriate operating system, execution environment and even programming language to use for each component of a system under construction. More importantly, they allow the integration of existing components. In an ORB-based solution, developers simply model the legacy component using the same IDL they use for creating new objects, then write "wrapper" code that translates between the standardized bus and the legacy interfaces.

2. The terminating CG hunts for an idle DS0 line to the SM-2000 in its office and sets its status to "busy." It also selects a terminating PSAX 1250/2300 and tells it to set up an SVC. The terminating PSAX 1250/2300 initiates a UNI SVC setup message back across the ATM data network using the ATM address of the originating PSAX 1250/2300.
3. The originating PSAX 1250/2300 then notifies the CG, which uses the SCT to associate the ISUP and ATM messages.
4. The originating CG tells its PSAX 1250/2300 to return an SVC connect message. When the terminating PSAX 1250/2300 receives this SVC connect message, it notifies the terminating CG of the virtual path identifier/virtual channel identifier (VPI/VCI) assignment, and that CG sends the IAM to the terminating SM-2000. The terminating SM-2000 then sends an IAM signal to the end office.
5. When the far end office returns the address complete message (ACM), the terminating SM-2000 cuts the voice path through and sends the ACM to the terminating CG. The terminating CG sends a cut-through message to the terminating PSAX 1250/2300 and signals the ISUP+ version of an ACM (ACM+) to the originating CG. The originating CG sends a cut-through message to the appropriate PSAX 1250/2300. The originating CG sends an ACM message to the originating SM-2000 via the packet switch unit (PSU). The originating SM-2000 cuts the path through and signals ACM to the end office.
6. When the terminating switch detects an answer, the answer messages (ANMs)—ANM, ANM+, and ANM—follow the same path.

At this point, the call setup is complete, a connection is established, and a talking path is in place. When the caller hangs up, Steps 7–10 show the release (REL, REL+, and REL) and release complete (RLC, RLC+, and RLC) messages used to tear down a call.

OAM&P Environment

The OneLink Manager EMS software integrates the management of the PSAX 1250/2300 access concentrator, the CG, and the CBX 500 switch. All billing responsibility remains in the 5ESS Switch. The GUI on the EMS enables the network operator to conduct fault management, configuration management, performance monitoring, and security management.

The EMS software supports a southbound SNMP interface to network elements and a northbound CORBA[8,9] interface to the GUI. The user interface is through a GUI client/server architecture in which the GUI is the client and the EMS is the server. The client and server communicate over the CORBA bus. (See **Panel 2** for a description of CORBA.)

Conclusion

The robust design of the 5ESS Switch distributed architecture has enabled it to evolve for many years to incorporate newly emerging technology. With the addition of the 7R/E Packet Driver, this capacity to evolve has expanded, allowing incorporation of both off-the-shelf and internally developed components to enable rapid deployment of new technologies. This approach has made it possible to meet customers' tight deadlines for introducing new VTOA capabilities.

Acknowledgments

The VTOA capability is the product of hard work and dedication by many people. We want to specifically acknowledge the other members of the Lucent team that worked on the architecture for this. They include Young-Fu Chang, Chin Chen, Christopher Chrin, Socorro Curiel, Kristin Kocan, Edward Krause, Kalyani Krishnamachari, Dennis Leinbaugh, Wenko Lin, Marc Malonowski, Jeff Martin, Donald McBride, Don Nelson, Kate O'Connor, Kevin Overend, Diane Pawelski, Greg Razka, Eldred Schrofer, Stephen Sentoff, Paul Steed, Gary Swanson, Raymond Sin, Tzuoh-Ying Su, Patricia Taska, Henry Yan, Tongzeng Yang, David Yost, Hsien-Chuen Yu, Charles Witschorik, and Meyer Zola.

*Trademark

CORBA is a registered trademark of the Object Management Group.

References

1. K. F. Kocan, P. A. Riley, and R. J. Zurawski, "Universal Premises Access to Voice Band and ATM Networks Using a Broadband Interworking Gateway," *Bell Labs Tech. J.*, Vol. 3, No. 2, Apr.–June 1998, pp. 93-108.
2. International Telecommunication Union, "Interface between Data Terminal Equipment (DTE) and Data Circuit-Terminating Equipment (DCE) for Terminals Operating in the Packet Mode and Connected to Public Data Networks by Dedicated Circuit," ITU-T Rec. X.25, Ver. 10/1996, <http://www.itu.int>.
3. International Telecommunication Union, "Draft new ITU-T Recommendation H.248 (Rev. COM16-107)," Feb. 2000, <http://www.itu.int>.
4. Media Gateway Control (Megaco) Working Group, "Megaco Protocol," IETF draft-ietf-megaco-protocol-08.txt, Apr. 2000, <http://www.ietf.org/ids.by.wg/megaco.html>.
5. ATM Forum, <http://www.atmforum.com>.
6. International Telecommunication Union, "Application of the ISDN User Part of CCITT Signalling System No. 7 for International ISDN Interconnections," ITU-T Rec. Q.767, Ver. 2/1991, <http://www.itu.int>.
7. W. Stallings, *ISDN and Broadband ISDN*, 2nd ed., Macmillan, New York, 1992.
8. M. Henning and S. Vinoski, *Advanced CORBA® Programming with C++*, Addison-Wesley, Reading, Mass., 1999.
9. R. Orfali, *Client/Server Programming with JAVA™ and CORBA*, 2nd ed., edited by D. Harkey, Wiley, New York, 1998.
10. <http://www.omg.org/corba/whatiscorba.html>.

(Manuscript approved May 2000)

JUDITH R. McGOOGAN is a distinguished member of technical staff in the Broadband Switching Concept Center in Lucent Technologies' Switching Solutions Group in Naperville, Illinois. She received a B.S. in mathematics and an M.S. in computer science from the University of Oklahoma in Norman. Ms. McGoogan has contributed to the 7R/E™ architecture and was the lead architect on the International VTOA SVC project. Her work now focuses on the software architecture for broadband switching products. She is a Lucent representative to the Object Management Group and cur-

rently serves as co-chair of the Realtime Platform Special Interest Group.

JOSEPH E. MERRITT, formerly of Yurie Systems, is director of the Product Line Management Department in Lucent Technologies' Inter-Networking Systems group in Landover, Maryland. He received both a B.S. and an M.S. in mechanical engineering from the Rochester Institute of Technology in New York and an M.B.A. from the University of Maryland in College Park. He is responsible for all business/product planning activities and profitability for the Access Technologies business group and has developed voice and data solutions technology and product plans for the service provider market for Lucent's ATM access concentrator products.

YOGESH J. DAVE is a member of technical staff in the Signaling Platforms Systems Department in Lucent Technologies' Switching Solutions Group in Columbus, Ohio. He received an M.S. in electrical engineering from the Illinois Institute of Technology in Chicago and an M.S. in physics from Gujarat State University in Ahmedabad, India. He has worked on various signaling solutions, including SS7, and on network architecture for 7R/E™ Packet Solutions, including the 7R/E Packet Driver. ◆