THE ROLE OF ISDN IN AT&T INFORMATION SYSTEMS ARCHITECTURE

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AT&T Information Systems Architecture defines a framework for compatibility among AT&T products as well as with key products of other vendors. A key direction of Information Systems Architecture is the use of standard, open interfaces and protocols. Standards now being defined for the Integrated Services Digital Network (ISDN) play an important role in the architecture. Support of ISDN will provide customers with uniform access to integrated voice and data capabilities which are provided through digital transmission and common channel signaling. Support of ISDN within Information Systems Architecture promises to provide customers with compatibility and high functionality. The AT&T Information Systems PBX product family already supports many capabilities that provide ISDN functionality. These capabilities make incorporation of ISDN in Information Systems Architecture and full support of ISDN a direct step in product evolution.

A systems architecture defines a structure for describing communications connectivity between users of information and sources of information. The architecture identifies the services to be provided and categorizes or structures them in an orderly way. It then describes the rules, procedures, and formats to provide the services and achieve communication among products. (For the purposes of this article, connectivity is defined as physical and/or logical linkages for purposes of communication.)

Customers benefit from a vendor architecture through compatibility and evolution. An architecture can assure that individual products work well together, so that a customer can construct complex integrated systems. As the customer's needs change, an architecture can help ensure that new equipment can be added incrementally without

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requiring removal and replacement of the installed base. An architecture also provides the customer with a blueprint for the vendor's direction, in the sense of scope (types of products encompassed) and principles (objectives).

Architecture is also of value to developers. Many products need to work with other products. Without an agreed-upon set of protocols and interfaces, several versions of a product providing similar functions might be necessary just to work with other products. A good example can be found in the telephone network. If each new central office switch or each new loop technology defined its own telephone interface, then many different versions of telephones would be needed. The telephone network also demonstrates how architecture supports smooth evolution. By having a clear view of the role of elements in telephone networks and the protocols and interfaces between elements, new technology (for example, transmission systems) can be introduced without adverse impact on equipment already in place, such as switches. And the evolution has occurred without disruption of service for end users.

Information Systems Architecture is an overall architectural plan for compatibility. The Integrated Services Digital Network (ISDN) provides an answer to many of the lower-layer equipment incompatibility problems in the integrated voice and data environment. Therefore both Information Systems Architecture and ISDN are important to customers preparing to procure new systems.

Information Systems Architecture

One major objective of Information Systems Architecture is to provide the basis for an integrated, synergistic AT&T product family. The integration of voice and data, the integration of premises capabilities with network services, and integrated system management are major aspects. Another important element is the integration of key products and services from other vendors, so that AT&T products will work well with a base of other vendor

equipment in a complex system. International and domestic protocol standards play an important role in achieving this compatibility in the future. Finally, evolution plays an important role in guiding the architecture, so that new directions take into account the installed base of equipment.

Scope. The scope of the products encompassed by Information Systems Architecture is shown in Figure 1. Spread throughout the customer building are workstations of various types such as telephones, terminals, modems, and image devices. Premises distribution takes the information from throughout the building (or buildings, in a campus arrangement) and brings it to centralized locations where switches might be found. This distribution must be capable of supporting needs ranging from low-bit-rate telemetry to video.

Switches can be circuit switches, such as the *Merlin*™ system, AT&T System 75, AT&T System 85, and the *5ESS*™ switch; or they can be packet switches, such as the Information Systems Network (ISN). The switching function may also be distributed, as in the case of the department-sized Starlan network. Computers of various types, either general-purpose or those with intimate linkages to switches to provide integrated services, are included as well. The premises products work with networks of various types, such as public and private circuit- and packet-switched networks, and vendor-proprietary private computer networks. Another unifying element across all these product types is the software or applications providing services to users. Such services include those that need to communicate as an inherent part of the application, such as messaging services and file transfer, as well as the management capability to administer and maintain the overall system. Information Systems Architecture does not specify the individual products themselves. Rather, it addresses what those products must do to achieve communications compatibility.

Structure. Information Systems Architecture makes use of the layering concepts and service categories present

Figure 1. Scope of
Information Systems
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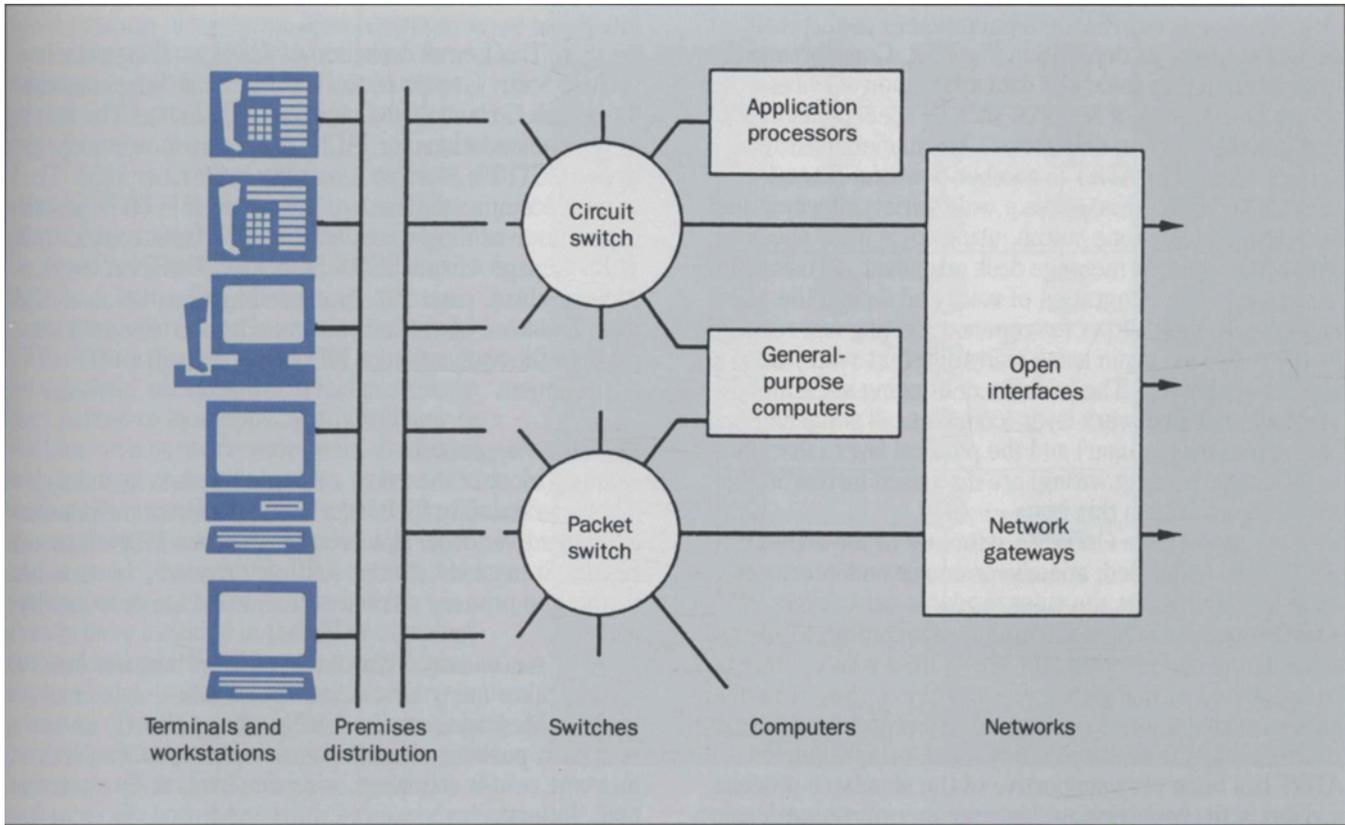
in the International Organization for Standardization (ISO) reference model of open system interconnection (OSI). This model is described further in "ISDN Architecture," by R. T. Roca, page 4. Information Systems Architecture is based on this model because the language and concepts already exist and are well known in the industry, and because it will facilitate the introduction of international standard protocols. Information Systems Architecture has supplemented the OSI reference model to cover areas not included (Figure 2). Providing a common premises distribution plan is a major customer concern, since rewiring of

buildings is typically a very costly process. Therefore consistent media for premises distribution are included. System management capabilities to send and receive the information necessary to manage a network of products, as well as to manage the protocol layers (e.g., select parameters) are also fundamental to compatible communications.

The OSI model is primarily computer-oriented. ISDN introduces the concept of the integration of voice and data. Information Systems Architecture integrates voice into the model by recognizing that there are differences in protocol needs for voice and data, but there are

also advantages to bringing them together conceptually at particular layers as depicted in Figure 2. Conceptualizing the integration of voice and data application services allows for planning of services such as speech-annotated text and dialing from directories. The unified messaging service offered by AT&T is another powerful example. Users may leave messages in a wide variety of ways, such as pushing a telephone button, using voice mail, speaking with a secretary or message desk attendant, or using electronic mail. The integration of voice and data in the architecture then allows for common alerting and retrieval by the recipient, again using many different voice, data, and image devices. The benefits of bringing voice and data together at the network layer (common call setup and numbering plan for the user) and the physical layer (sharing facilities and building wiring) are discussed further in this and other articles in this issue.

Role of ISDN. Once the structure of the architectural model is decided, specific protocols and interfaces must be identified as the rules products must follow to achieve compatibility. International standard protocols are arrived at in open forums and hence are a solution that can be supported by many companies. They represent an alternative for customers to being tied to a proprietary protocol controlled by the business interests of a single vendor. AT&T has been very supportive of the standards process and has actively participated in a number of committees. The international standard protocols at all layers of the model play a key role in determining the future direction of Information Systems Architecture.

The ISDN standards in particular represent a major step in reaching agreement on the integration of voice and data in the lower layers of the model. The small set of standard interfaces being defined for ISDN will provide lower-layer compatibility between a wide variety of vendor products. The support of the ISDN interfaces and protocols is therefore an important part of the Information Systems Architecture lower-layer protocol plan.

Integrated Services Digital Network

The formal definition of ISDN is taking place in various Study Groups of the International Telephone and Telegraph Consultative Committee (CCITT).[1] The first set of recommendations for ISDN, the I series, was adopted by the CCITT's Plenary Assembly in October 1984. The I series recommendations are summarized in other papers in this issue of the *Journal* (see "ISDN Architecture" by R. T. Roca, page 4, and "ISDN Standards Evolution" by H. Aldermeshian, page 19). Any true implementation of ISDN must be based on these recommendations. Figure 3 summarizes the application of ISDN interfaces in a PBX environment.

Customer Perspective

Most of the effort expended to date in defining and understanding ISDN has been by service providers and equipment vendors. However, in order for ISDN to be successful, it must satisfy the customer's needs. In customer terms, the primary attributes of interest are functionality and cost.

Functionality. Information used by business customers takes many forms that involve voice, data, and control. Messages may be left by talking directly to the recipient, pushing a button on a telephone, talking with a message center attendant, via voice mail, or by electronic mail. Intimate marriages of voice and data occur in such applications as speech annotation of text and dialing from a directory. The marriage of personal computer and telephone as a workstation offers opportunities for custom screening of calls, automatically bringing up files related to the call, and many others. The functionality which will be provided by ISDN is limited only by the imagination of customers and service providers.

In the near term, ISDN functionality is based on digital connectivity, enhanced services, and integration. Customers will have far greater data throughput than is available in existing analog arrangements, without the

added expense of modems. This high-speed connectivity will significantly enhance the data exchange required for applications such as graphics, computer-aided design, and document interchange.

The near-term enhanced services provided by ISDN will be very similar to those provided by many PBX manufacturers in existing products. These services include standard business features like call waiting, transfer, conference, and hold. One real promise of ISDN is that, through the use of common channel signaling, services which had previously been limited to local applications will now be available on a network-wide basis. In theory, with common channel signaling, enhanced services can be provided by the network, a standalone enhanced services provider, the local exchange company, or the PBX vendor. One example of an enhanced service which has already been included in the ISDN signaling protocol and which will have a fundamental impact on day-to-day telecommunications is the provision of calling party identification. Calling party ID will help us decide whether to answer incoming calls and will minimize instances of nuisance calls and computer fraud via telephone.

ISDN also promises the benefits associated with voice and data integration. In the ISDN model, a single interface provides access to both voice and data communication. The voice and data connections are controlled by a single signaling channel. This integration can provide enhanced capabilities such as phone management, directory services, and integrated messaging. The integration provided by ISDN also simplifies building operations. The single voice/data interface simplifies building wiring by using two twisted pairs (two additional pairs are optional for power) to provide all voice and data needs. The single

Figure 2. Open system interconnection model with Information Systems Architecture additions.
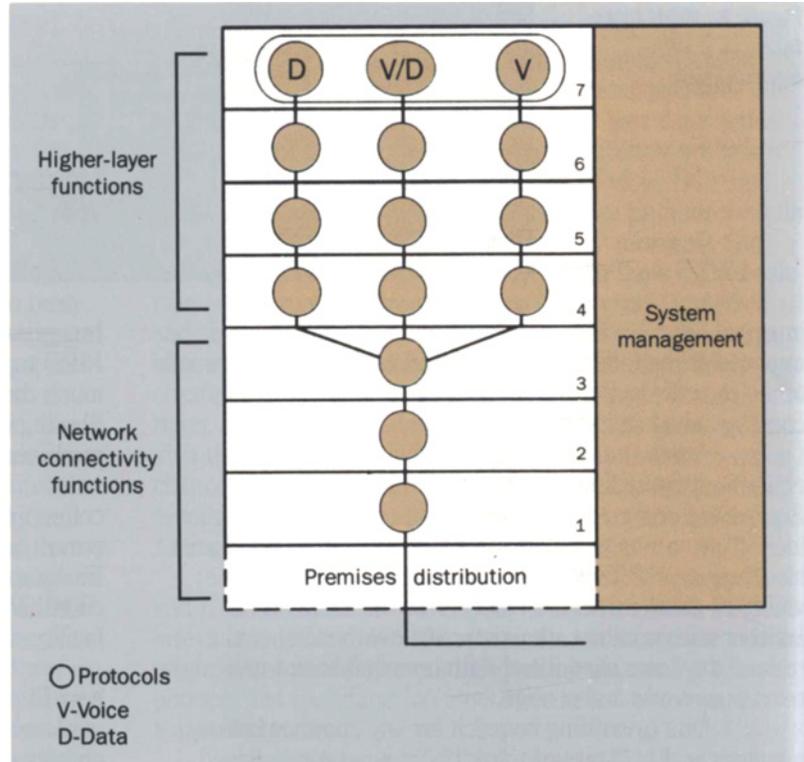
voice/data interface eliminates the need for coaxial cable and separate wiring runs as well as separate data lines and modems. It also reduces the physical space required for equipment and cuts down on the maze of wire that is all too often located under a knowledge worker's desk.

Cost. In addition to providing increased functionality, ISDN must reduce customers' overall cost of doing business in order to be successful. ISDN promises to improve cost from several perspectives.

The first and most obvious cost improvement comes from the support of standard interfaces. If a majority of switch and terminal vendors support the standard

Figure 3. ISDN Interfaces in a PBX environment.
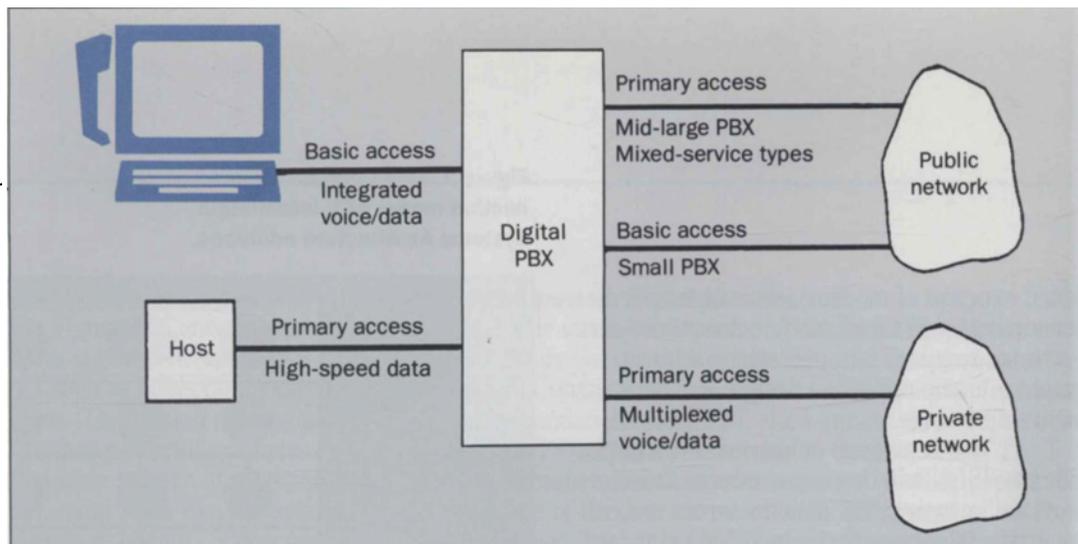
interface, the production volumes of VLSI required to implement the interfaces will be substantial. The large volumes should result in reduced costs for devices and a corresponding reduction in equipment costs.

Another aspect of standard interfaces is that equipment from different vendors will be compatible. Equipment compatibility means that a customer is not locked into a single vendor's solution. Standard interfaces also support the ISDN goal of terminal portability. The ability to move terminals freely from one location to another with minimal administrative overhead should reduce the costs associated with terminal inventories and rearrangements and change.

One overriding concern for any communications manager is that "state of the art" equipment purchased today will become obsolete in the near future. No one can completely predict the evolution of telecommunications equipment and services. However, it can be safely assumed that ISDN and its associated standards will form the framework for advances in voice and data communication. Thus, support of ISDN capabilities today should ensure compatibility with future equipment. Over the long term, this upward compatibility should reduce overall customer cost.

The ability to provide all voice and data communication over two twisted pairs should greatly reduce building wiring costs. These cost reductions will come primarily from the elimination of separate distribution plans for voice and data, such as twisted-pair wiring plus coax.

Integrated access will also allow the local switch (e.g., PBX) to provide switched access for data applications in much the same way as voice connectivity is provided today. Sharing of network facilities among voice and data similarly promises to be a source of savings.

Common interfaces and services and the use of common channel signaling between switching nodes will permit an integrated approach to system management. Integrated system management will result in more efficient billing arrangements, testing and maintenance, facility allocation, and terminal management, for example.

A real, but even more difficult to quantify, cost benefit of ISDN is improvement in the efficiency of the work force. High-speed data access, phone management and directory services, improved messaging, and cross-network feature transparency should all make the knowledge worker more efficient and reduce the customer's overall cost of doing business.

ISDN Functionality on AT&T PBXs

This section reviews existing services and capabilities on AT&T Information Systems PBXs which provide the customer with ISDN-like capabilities. Where appropriate, the existing capabilities are compared to the interfaces defined in the I series of recommendations. Support of ISDN functionality on existing products significantly enhances AT&T Information Systems understanding of how to provide the ISDN concept and eases the growing pains associated with evolution to full ISDN. A summary of

AT&T System 75 and AT&T System 85 ISDN and ISDN-like interfaces is shown in Figure 4.

Digital Communications Protocol. The digital communications protocol (DCP) defines a digital interface for the direct termination of digital telephones and workstations on AT&T System 75 and AT&T System 85. DCP is very similar to the ISDN basic interface in that it contains two 64-kb/s information channels which are controlled by a separate signaling channel. A comprehensive signaling channel message set has been defined for DCP. The message set allows a broad range of voice and data features to be provided to the end user, in addition to providing a complete terminal maintenance capability.

DCP differs from the basic-rate interface in the details of the physical interface, in the signaling channel rate (8 vs. 16 kb/s), and in the signaling channel protocol. These differences exist simply because DCP was defined in 1979-80, a full four years before the initial ISDN recommendations were published. However, because of its 2B + D capability and comprehensive feature complement, DCP end users today enjoy a service which is essentially equivalent to that envisioned for the ISDN user of the future.

DCP's functionality and similarity to the basic-rate interface have provided AT&T with a significant advantage in its evolution to ISDN. This advantage is most obvious when defining the feature complement and the associated signaling protocol for ISDN terminal interfaces. All AT&T implementations of the basic-rate interface will have functionality based on the DCP model.

The existing ISDN call control procedures (Q.931) define little more than the procedures for controlling basic circuit-switched calls. The procedures for terminal maintenance and basic business features such as conference, transfer, hold, and multiline operation have not been defined. Any "ISDN" interface which provides these features in the near term will have to go beyond the currently defined standard. Signaling procedures for supplementary services over an ISDN interface are currently being defined by several vendors. The more prudent of these vendors are basing their work on a direct extension of the existing Q.931 protocol. AT&T Information Systems is working to extend Q.931 to include all the capabilities currently defined for DCP in addition to any new capabilities that have emerged in the ISDN standardization process.

From a communications point of view, DCP and ISDN end points are fully compatible. Due to differences in the physical interface and signaling, DCP terminals and port circuits are not plug-compatible with their ISDN basic-rate counterparts. However, since the physical interface and signaling terminate locally, in the switch, differences between DCP and the ISDN basic-rate interface do not create compatibility problems for end-to-end communications. For end-to-end ISDN compatibility the keys are 64-kb/s transmission and voice/data integration with common channel signaling. Since DCP has these capabilities, DCP terminals can readily coexist in an environment which is seeing increasing application of ISDN endpoints.

ISDN basic-rate interfaces on AT&T System 75 and AT&T System 85 will be fully compatible with DCP interfaces. DCP and ISDN terminals can be accommodated on the same switch just as DCP terminals, analog telephones, and multifunction electronic sets are compatibly supported today.

Data Transport. AT&T Information Systems, in System 75 and System 85, has defined four modes for data transport in the 64-kb/s information channel. Mode 0 defines a clear 64-kb/s channel. In this case, the data transport protocol is defined by the end user. Mode 1 defines a 56-kb/s data transport format where the least significant bit of each frame is used for control. Mode 1 was defined for compatibility with AT&T's Digital Data Service. DCP Mode 2 defines a rate-adaption scheme for the transport of synchronous and asynchronous data at rates up to 19.2 kb/s. Mode 2 data modules are used to adapt terminals with EIA RS232 or V.24 interfaces for transmission over 64-kb/s channels. In addition to providing rate adaption with an HDLC-based approach, Mode 2 also includes a handshaking sequence to establish the var-

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ious data transmission options at call initiation and regular transmission of the status of the interface control leads.

Mode 3 provides reliable transmission of multiple data streams over the same physical channel. Mode 3 is based on the concept of layer 2 multiplexing. The multiplexing is accomplished using LAPD, the ISDN standard for carrying signaling and packet data on the D channel. Mode 3 also incorporates the data transfer phase of X.25 at layer 3. In order to permit integrated voice/data services and provide a single approach to call control, signaling for data call establishment is via the D channel.

LAPD and the X.25 data phase were chosen for Mode 3 for several reasons. First, they are existing standards which provide all the functionality desired in a packet-mode protocol. Second, LAPD's layer 2 multiplexing permits cost-effective implementations and allows multiple layer 3 protocols to be used over the same interface. This multiplexing also allows the statistical use of bandwidths on a physical channel which is shared by more than one terminal device. Third, implementation of LAPD

is an inherent part of any ISDN interface, and devices that perform the LAPD function will be readily available. Fourth, through the use of the X.25 data phase at layer 3, straightforward interworking with existing X.25-based public data networks and compatibility with both packet assembler-disassembler (PAD) and OSI environments are provided.

Mode 3 can be used to allow a data endpoint (e.g., a personal computer) to establish multiple logical connections to a host over a single physical channel. Mode 3 can also be used to allow multiple terminals to share physical host access. This capability is attractive for local applications to allow access to multiple hosts and to save on physical port costs and building wiring. Mode 3's multiplexing is also attractive in remote applications when transmission costs are reduced.

Data transport Modes 0, 1, 2, and 3 are currently supported on both the DCP and DMI interfaces (see next page). Because the modes are tied to the 64-kb/s information channels and not the specifics of the interface
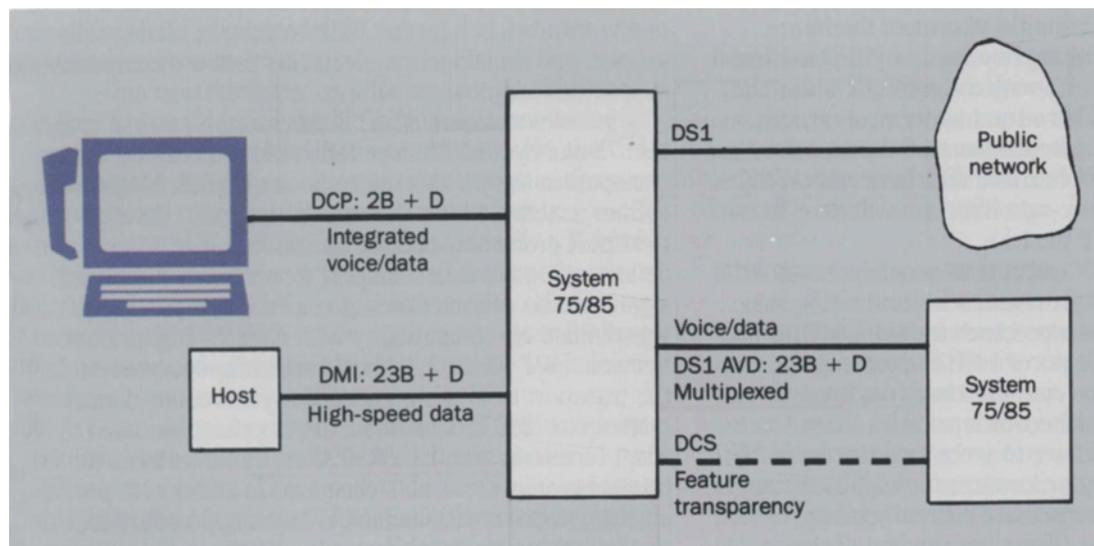

Figure 4. Existing ISDN capabilities on System 75 and System 85.

definition, they will transport data just as effectively as over ISDN B channels. AT&T Information Systems ISDN interfaces will support the same set of data transport modes and they will be fully compatible with existing DCP and DMI endpoints.

The ISDN data transport is defined in Recommendations X.30 and X.31. X.30 uses a two-step approach to rate-adapt synchronous data for 64-kb/s transmission. Transport of asynchronous data is not addressed. The X.30 scheme also permits up to eight synchronous data streams to be multiplexed in the same 64-kb/s channel. Mode 2's support of asynchronous data terminals makes it more attractive than the ISDN rate-adaption scheme for practical applications. In addition, Mode 2's HDLC-based approach is well positioned for evolution to statistically multiplexed data transport, and the availability of HDLC devices should lead to a less complex implementation than X.30.

X.31 defines the use of X.25 terminal equipment in ISDN. X.31 is a nonintegrated approach in that the signaling for data call establishment is transferred within the data channel rather than in the common signaling channel. Mode 3's use of the common signaling channel for data call establishment provides much greater opportunity to take advantage of the integrated voice/data capabilities promised by ISDN. In addition, Mode 3's use of LAPD for layer 2 multiplexing provides implementation flexibility which permits more cost-effective switching arrangements than existing X.25 implementations. For these reasons, AT&T is pursuing the standardization of Mode 3 for ISDN packet data transport.

Mode 3 has been represented in both domestic and international standards organizations as the LAPD-based packet mode. It has been proposed as an integrated ISDN endpoint protocol which could operate at any interface rate (e.g., 64 kb/s, 1536 kb/s, 1920 kb/s). Discussions regarding standardization of the LAPD-based packet mode are still under way.

DS1 Alternate Voice/Data. The DS1 alternate voice/data (AVD) interface on AT&T System 75 and AT&T System 85 is similar to the ISDN primary-rate interface. DS1 AVD uses the standard DS1 electrical interface which has been adopted for the primary-rate interface in North America and Japan. In addition, DS1 AVD provides twenty-three 64-kb/s channels for information transport and a single 64-kb/s common signaling channel. The present implementation of DS1 AVD differs from the primary-rate interface in that a bit-oriented signaling technique is used in channel 24 rather than the Q.931 functional signaling protocol. The use of common channel signaling and support of twenty-three 64-kb/s channels for voice or data are significant in the evolution to ISDN. Eventual adoption of the full primary-rate interface will only require changes in the signaling channel. The physical interface and the 64-kb/s data transmission algorithms are not affected.

Distributed Communications System. DCS is a networking feature provided on AT&T's enhanced *Dimension* PBXs, System 75 and System 85. DCS is used to provide feature transparency between diverse geographic locations. Use of DCS makes multiple customer locations appear like a single location from a communications point of view. DCS is provided by establishing data links which carry the feature transparency messages between locations. DCS is a precursor of ISDN in that it provides the kind of functionality which will be available when primary rate facilities with common channel signaling exist between the nodes in a private network. However, as discussed previously, messages and procedures required for support of enhanced features are not presently defined for ISDN. Thus, DCS provides a capability which is not available from a present implementation of the ISDN interface. AT&T Information Systems will use the experience gained from providing DCS networks to participate in defining extensions to Q.931 which can provide cross-network feature transparency.

Digital Multiplexed Interface. The digital multiplexed interface[2] combines the 23B + D capability of the DS1 AVD interface and AT&T Information Systems' four data transport modes to provide a multiplexed interface for data

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transport between a PBX and a host computer. DMI is a licensed interface of AT&T Information Systems, and there are currently more than 90 data communications-oriented vendors that are DMI licensees. Initial implementations of DMI will use signaling as described for the DS1 AVD interface. In this case, DMI is compatible with ISDN in its use of the physical primary rate interface and the support of twenty-three 64-kb/s channels for data transmission.

A message-oriented signaling protocol which is a fully compatible subset of CCITT Recommendations Q.921 and Q.931 has also been defined for the DMI D channel. Implementation of message-oriented signaling on DMI is a significant step in the evolution to ISDN. The call control procedures defined for DMI will also be applicable for interfaces to terminals and to public and private networks. The message-oriented signaling interface will be available on System 75 and System 85 approximately one year after initial availability of DMI. After implementation of message-oriented signaling, DMI will be AT&T Information Systems' first complete ISDN interface.

Evolution to ISDN

The preceding sections have summarized existing capabilities of AT&T System 75 and AT&T System 85 and described how these capabilities have positioned these products for a smooth evolution to ISDN. The following sections describe additional steps which must be taken in order to reach full ISDN compatibility.

Basic-Rate Interface. Support of the basic interface requires new port circuits and new software to support the ISDN signaling procedures. A complementary ISDN terminal family will be developed. For these activities to make sense, devices to aid in the physical interface implementation are required, and the signaling channel protocol must be expanded to support advanced business terminal features. Addressing the device need, AT&T Technologies, Advanced Micro Devices, and Intel Corporation, among others, have announced their plans to provide a family of ISDN devices, with focus on the basic rate. From the func-

tionality point of view, expansion of the signaling protocols to incorporate enhanced features has been made a top priority by both domestic and international standards bodies. AT&T Information Systems will continue to be an active participant in their standardization process. However, the complications associated with defining a functional protocol for enhanced features are such that it is unlikely that there will be formal CCITT recommendations in this area before 1988.

Public Network Interfaces. Primary-rate facilities with signaling as defined by Q.921/931 comprise the ISDN network interface. Interfaces of this type have already been announced by AT&T Communications and AT&T Network Systems (see companion papers). These interfaces are equivalent to the DMI message-oriented signaling interface and use the appropriate signaling messages to support the services provided by AT&T Information Systems. Implementation of DMI will include a large part of the development effort required to support these ISDN network interfaces. Thus both System 75 and System 85 are positioned to take advantage of ISDN interfaces as they become broadly available. Since DCP provides functionality at least equivalent to the ISDN basic interface, the services provided by the network ISDN interface will be available to both DCP and ISDN terminal users.

Private Network Interfaces. Private network ISDN interfaces are also based on the use of primary-rate facilities and Q.921/931 signaling. Implementation of DMI with message-oriented signaling once again establishes a solid base on which the private network interface capability can be built. Because the nodes in a private network will often be other AT&T PBXs, the functionality provided by this interface will initially be greater than the functionality provided by the public network interface. As a starting point, the Distributed Communications System capabilities previously described can be incorporated in the private network interface. Enhancements to these capabilities using as yet undefined Q.931 messages will be included as it becomes clear that these services are of value to the customer.

Summary

AT&T Information Systems Architecture provides the framework through which AT&T Information Systems can provide integration of AT&T products as well as promote compatibility with other vendors' products. A key aspect of Information Systems Architecture is support of the standard interfaces and capabilities being defined for ISDN. Support of ISDN will provide customers with standard access to enhanced capabilities which are based on integrated voice and data, digital connectivity, and common channel signaling.

The formal definition of ISDN is still under way. Near-term implementations of ISDN are limited by the extent to which the CCITT recommendations for ISDN have been completed. AT&T is actively participating in various standards forums to define meaningful ISDN interfaces and capabilities. In the interim, the AT&T Information Systems PBX product family already supports many of the capabilities which are envisioned for ISDN. Present customers are thus provided with ISDN functionality, and AT&T is committed to making the evolution to full ISDN compatibility a straightforward process.

References

1. CCITT Study Group XVIII I Series Recommendations, October 1984.
2. Digital Multiplexed Interface Specification, Issue 3.0, April 1985.