# AT&T DATA NETWORKING ARCHITECTURE

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This paper presents an overview of AT&T's data networking architecture, called the *integrated data architecture* (IDA). IDA specifies a flexible networking scheme, compatible with the Integrated Services Digital Network (ISDN), that addresses the needs of users into the 1990s. The architecture specifies functional capabilities and interfaces that provide a total, end-to-end networking solution that is applicable to premises-based and wide-area networks, or combinations of both. In this paper, we describe the major trends that shaped IDA, the functional entities and interfaces that form IDA, and examples of IDA-compatible networks.

### Background

The goal of AT&T's integrated data architecture (IDA) is to establish a ubiquitous, ISDN-based, high-performance networking capability for the 1990s. In designing IDA, we have responded to a number of trends in the communications arena. First, and most important, are trends in user requirements. Data processing has become more distributed, which has led to new requirements for the performance, reliability, and flexibility of data networks. For example, local-area network (LAN) connections provide higher throughput and lower delay than traditional asynchronous and synchronous terminal-to-host sessions. (Panel 1 is a list of terms and acronyms in this paper.) LAN users want the same degree of performance when they are not directly attached to a LAN (e.g., downloading a file from a remote computer) as they have when on a LAN. This implies seamless interfaces between LANs and wide-area networks (WANs), as well as higher performance requirements for WANs.

Beyond trends in data processing, there is an increasing tendency to use a common facility network for wide-area voice and data traffic. While such concentration provides significant savings, it leads to stricter requirements for the availability of the network. If the network goes down, an organization may not be able to carry out its primary business. Thus, end users want more control of networks as well as greater reliability.

**Panel 1. Terms and Acronyms in This Paper**

| | | | |
|---|---|---|---|
| BLAN | backbone LAN | LLC | logical link control |
| BRI | basic rate interface | LLC 1 | logical link control, Type 1 |
| CAD | computer-aided design | MAC | medium access control |
| CAM | computer-aided manufacture | MAN | metropolitan-area network |
| CC | cluster controller | NetBIOS | network basic input system |
| CLNP | connectionless network protocol | NIPM | nonchannelized ISDN packet mode |
| CLNS | connectionless network service | NLR | network layer router |
| CONS | connection-oriented network service | OSI | Open Systems Interconnection |
| DDS | digital data service | PC | personal computer |
| DMI | digital multiplexed interface | PHY | physical layer |
| DSU | data service unit | PLP | packet layer protocol |
| DTP | data transfer protocol | PRI | primary rate interface |
| FEP | front-end processor | SNDCF | subnetwork dependent convergence function |
| IDA | integrated data architecture | STDM | statistical time-division multiplexer |
| IEEE | Institute of Electrical and Electronics Engineers | TA | terminal adapter |
| | | TC 4 | transport protocol Class 4 |
| IS | intermediate system | TCP/IP | transmission control protocol/internet protocol |
| ISDN | Integrated Services Digital Network | | |
| ISO | International Organization for Standardization | TDM | time-division multiplexer |
| | | TLR | transport layer relay |
| IWU | interworking unit | UTLI | the UNIX® system's transport library interface |
| LAN | local-area network | | |
| LAPD | link access procedure for the D channel | vi | visual editor for UNIX system |
| LDLAN | local distribution LAN | WAN | wide-area network |

Within the communications industry, a number of trends affect the design of data networks. A key factor has been the increased speeds available to users. New media, most notably fiber optics, are being used within premises and for wide-area networks.

Networks are increasingly affected by the establishment of industry-wide standards. Customers want vendor equipment that functions via standard, nonproprietary interfaces. For example, to succeed in the LAN marketplace, vendors must comply with the Institute of Electrical and Electronics Engineers (IEEE) standards. Within the wide-area communications arena, the most notable standards evolution is the migration of the public switched network to ISDN. ISDN meets customers' needs for integrated transport and provides new service opportunities through a common, out-of-band signaling channel.

### Architecture Model and Functions

In designing IDA, we developed a functional model of data networking that would support multiple applications of the architecture. For example, IDA is designed to apply within a premises network, as well as within a wide-area network, or in a combination of both. This led us to the definition of *networking functions* joined via *interfaces*. Implementers may choose to combine multiple networking functions into a single component as long as the specified

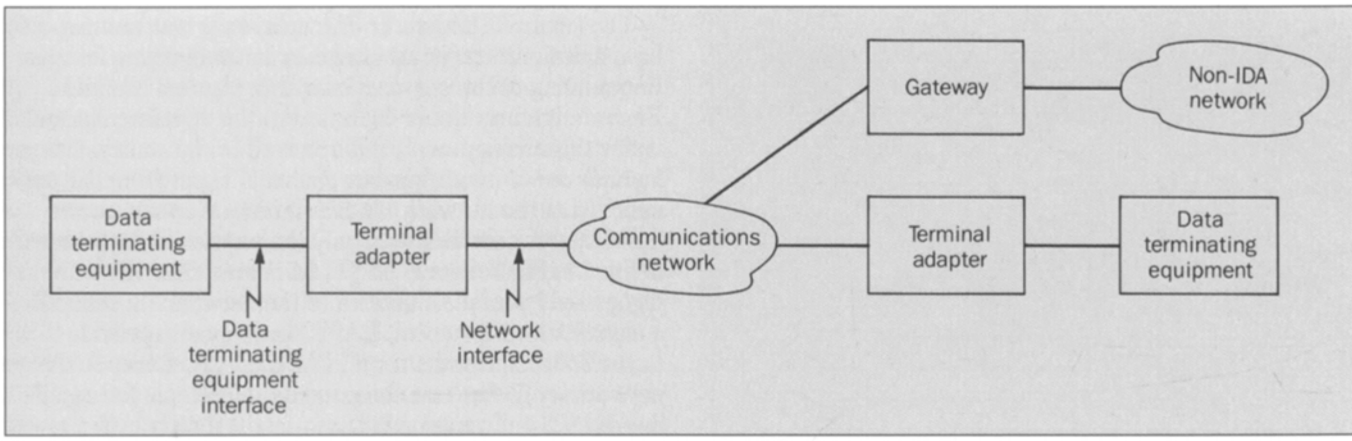



**Figure 1. IDA functional model.**

interfaces are maintained between separate components. Figure 1 shows the IDA functional model. The four basic networking functions are:

- *Data terminating equipment* (DTE), which provides end user (or application) data processing and communicates with other networking components via a data equipment interface. A PC, for example, has a serial interface for communicating with a modem.
- The *terminal adapter* (TA), which converts the data equipment interface into the interface supported by the communications network to which it is attached. This involves mapping the set of protocols defined on the data equipment interface to the network interface. This terminal adaption function can be implemented within the data terminating equipment.
- The *communications network*, which moves data among the data terminating equipment. Functions of the communications network include routing, addressing, administration, security, backup, and network management.
- The *gateway*, which interconnects IDA networks with other networks that do not adhere to the IDA network interface. Gateways are specific to the non-IDA network and perform functions such as billing resolution, address mapping, and protocol format changes. (Gateways can also be used to interconnect two IDA-compatible networks. Here, the gateway function is somewhat simpler because of the similar protocol architecture of the two networks.)



**IDA Interface Specifications.** The network interface builds on the concepts set forth in ISDN (e.g., common, out-of-band signaling channel) but extends the ISDN network interface in a number of ways. The IDA network interface is defined over a broader set of physical interfaces than the basic and primary rate interfaces (BRI and PRI) of ISDN. It also provides packet-mode bearer services in a more flexible manner than in the current ISDN standards.

The physical layer of the IDA network interface (Layer 1) may carry a single channel or multiple, multiplexed channels. [The term "layers" here and below refers to the series of layers defined by the International Organization for Standardization (ISO) Open Systems Interconnection (OSI) Basic Reference Model.[1] The model separates communications services into seven layers and defines the interfaces between layers.] These are *physical* channels that would, typically, correspond to time slots in a time-division multiplexing (TDM) scheme. An example of a

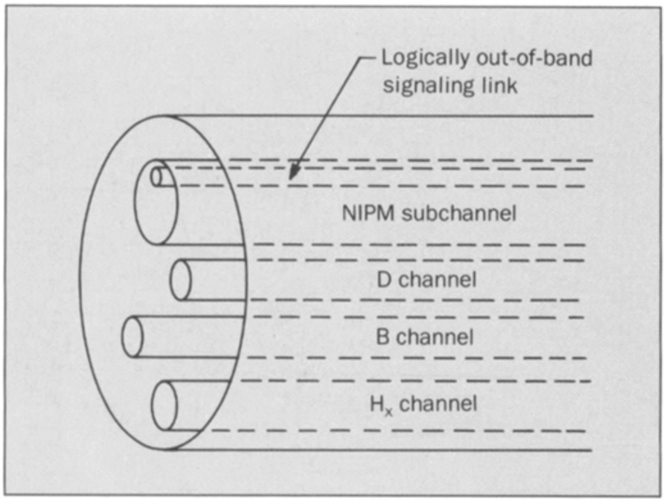



**Figure 2. Physical structure of the IDA network interface.**



single-channel physical interface would be a digital data service (DDS) or analog private-line circuit; an example of a multiple-channel physical interface would be a digital multiplexed interface (DMI), or an ISDN BRI or ISDN PRI physical interface.

The physical structure of the IDA network interface is shown in Figure 2. Each channel may be a TDM or an STDM (statistical time-division multiplexing) channel. STDM channels carry virtual circuits or *logical* channels.

Where multiple TDM channels exist, one channel is designated to carry the signaling information that controls the total interface. Such a channel is referred to as a *physically out-of-band* signaling channel because there is a time slot dedicated to it. For ISDN BRI or PRI, this would be the D channel. The protocol suite supported on the signaling channel is the link access procedure for the D channel (LAPD) at the data link layer and the CCITT Q.931 protocol at the network layer. Channels other than the signaling channel are referred to as *bearer* channels and may be of varying sizes. Examples are the B and H channels of ISDN.

For STDM bearer channels, each channel may also have a designated virtual circuit to carry signaling information relating to the services over that physical channel. Because no time slot is dedicated to the signaling channel under this arrangement, it is referred to, by contrast, as a *logically out-of-band* signaling channel. Thus, from the perspective of the network, an IDA interface either carries TDM bearer channels with only the physical layer protocol defined to the network, or STDM bearer channels with higher layer protocols defined to the network. In particular, a data link layer protocol, LAPD, is defined to provide Layer 2 virtual circuits for STDM channels. Layer 3 (the network layer) has two components: a protocol for signaling—Q.931, as explained above—and a data transfer protocol.

The Layer 2 protocol (the link layer protocol) is also handled differently by the network, depending on whether the virtual circuit is carrying user data or signaling information. For signaling information, the Layer 2 protocol is terminated at the network interface and the signaling protocol, Q.931, is processed by the network. However, for user data streams, the Layer 2 protocol is not terminated at the network interface or at intermediate tandem nodes in the network; rather, only address translation and error detection functions are performed. This scheme, called *ISDN frame relay,*[2] provides for high throughput of user data streams. In the ISDN frame-relay service, error correction occurs on an end-to-end basis between the terminal adapters, if desired. (See Figure 1.)

Another way to view frame relay is that the Layer 2 protocol state machine and the Layer 3 data transfer protocol are end-to-end and are not "seen" by the network. This permits the support of a variety of data transfer protocols, depending on the application. It is ISDN frame relay that provides the performance necessary to support the applications outlined below.

The protocol architecture of the IDA network interface is shown in Figure 3. Note that the data transfer protocol may or may not exist. For example, if the D channel is dedicated to signaling, then the data transfer component of that particular STDM channel becomes null.

A single channel interface devoted to the transport of STDM virtual circuits is of particular interest. An example would be a T1 link in which the full 1.536-megabit-per-second (Mb/s) bandwidth was used to provide a specific service, such as high-speed data or image transfer. When such an interface uses the ISDN frame-relay protocols, it is described as a *nonchannelized ISDN packet mode* (NIPM) interface. It should be emphasized that NIPM does not depend on the ISDN physical interface. NIPM consists of the use of a single physical channel on a variety of interfaces, LAPD as the data link layer protocol, Q.931 as the signaling protocol, and one of a variety of network layer data-transfer protocols, depending on the application.

**Application Requirements.** This section reviews the major categories of end user applications and the requirements that they place on IDA. The applications covered are:

- Terminal to host
- File transfer
- Database enquiry
- Transaction oriented.

**Terminal to host.** This application requires interaction between a terminal and a host. Terminals can range from simple to very sophisticated, as in computer-aided design and/or computer-aided manufacture (CAD/CAM) applications. Correspondingly, three types of terminal-to-host interactions may be defined:

- *Character mode*: relates to screen-oriented applications where single-character echoplex traffic is generated from the terminal in the process of creating a file. (Echoplex is a method of checking the accuracy of transmitted data by returning the received data to the sending end for comparison with the original.) A typical example would be a UNIX® system `vi` (visual editor) session during word processing. Quick response time, translating to fast, round-trip network transit time or very low latency [about 100 milliseconds (ms)] is required. On the other hand, the average bandwidth needed is low.
- *Block mode*: a screen (i.e., a block) is sent at a time. Thus, longer frames [e.g., a screen with up to 24 × 80 bytes] are transferred from the terminal to the host, resulting in a greater, but still modest, bandwidth requirement. Jobs are run in the foreground, and, usually, the user's think time is the constraint. Thus, the latency requirement, while low, is not as stringent as for character mode.
- *Bit mode*: involves computer graphics (e.g., on a Tektronix 4014 terminal) and relies on a host for processing; a single screen refresh requires 180 kilobits per second (kb/s). This application could simultaneously demand high bandwidth and very low latency.

**File transfer.** File transfer is the transfer of bulk data under nonstringent latency requirements. Because of the bulk, the necessary bandwidth tends to be very high.

- *PC file transfer*. Requirements are determined by the transfer requirements of a PC and typically run from 1.2 kb/s to 64 kb/s.
- *Host (file server) file transfer*. Because of the bulk of information transferred, this method results in significantly greater bandwidth. On the other hand, because it

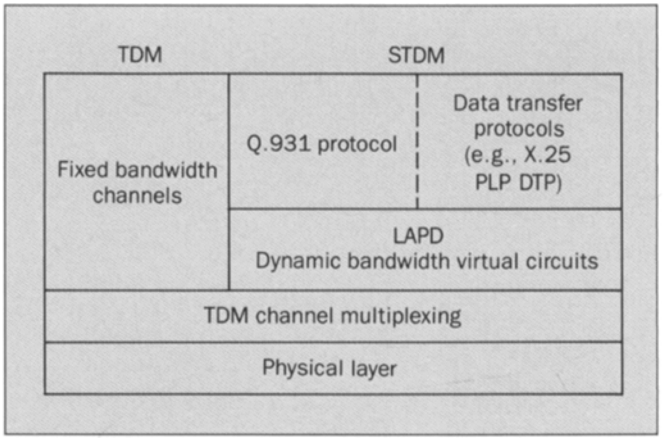
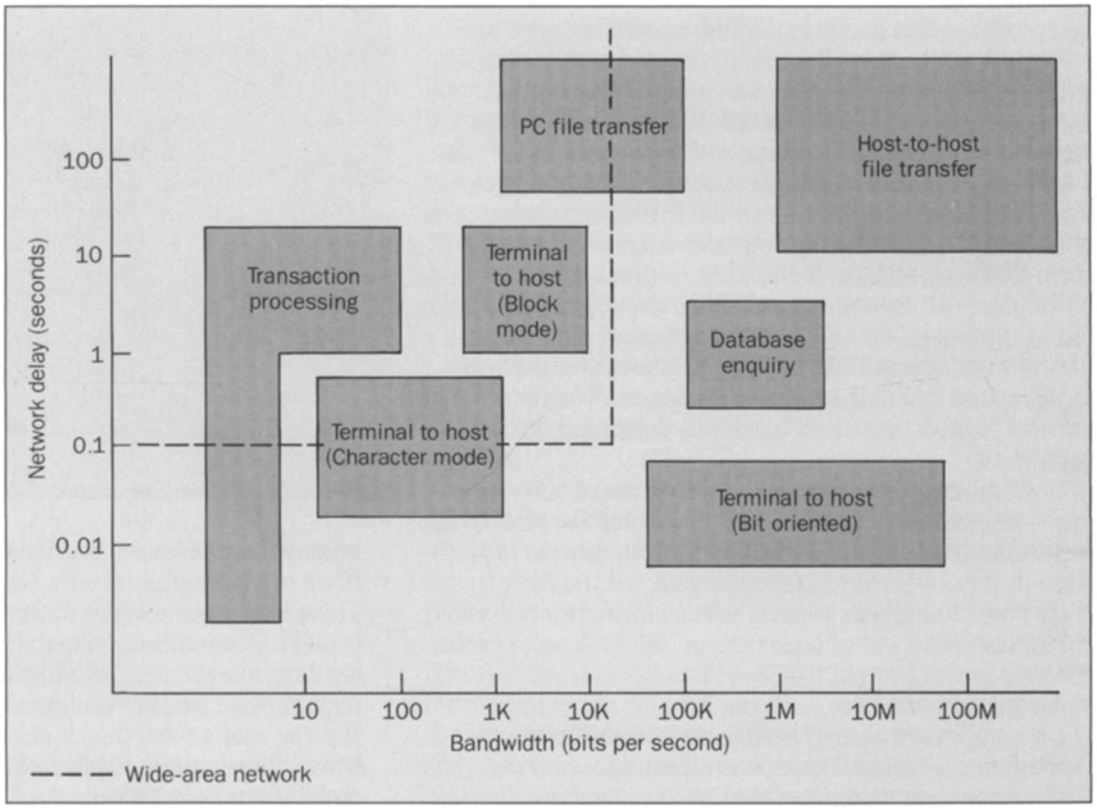



**Figure 3. IDA networking protocol architecture.**

**Figure 4. Latency and bandwidth requirements for user applications.**






could be a background process, it is very tolerant of latency.

**Database enquiry.** Database enquiry involves the inspection, modification, replacement, or erasure of a file's contents. The file could be either local or remote. A series of enquiries and responses takes place before the transfer of database records. Latency requirements are comparable to those of block-mode terminal-to-host, but the bandwidth required is greater.

**Transaction oriented.** This involves transferring a limited amount of information upon which some decision is made, and then returning a limited amount of information to the originator. The bandwidth requirement is low, but there are a wide range of latency requirements. For applications such as telemetry, the latency is low (i.e., milliseconds); whereas, for applications such as credit verification, it is on the order of several seconds.

Figure 4 shows typical latency and bandwidth requirements for a number of different user applications. Today's wide-area networks generally offer performance capabilities in the range shown by the dashed line in this figure. LANs generally offer service for applications requiring greater bandwidth or lower latency. The objective of IDA is to extend the wide-area networking

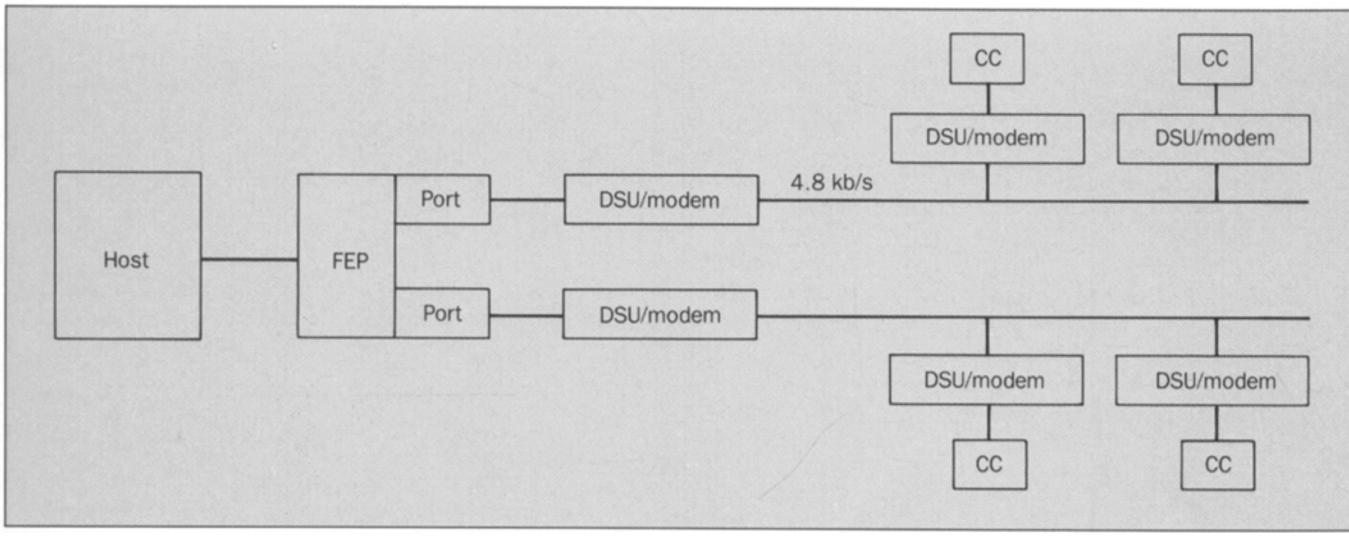



**Figure 5. Synchronous multidrop network.**

capability minimally to a latency below 100 ms and a bandwidth of 1.5 Mb/s. In this way, IDA extends the range of LAN/WAN networking capability.

### Examples of IDA Networks

In this application example, we show how an IDA network can be used to provide a transport service that meets the requirements of today's synchronous multidrop networks.

**Virtual Private Line.** Figure 5 shows a typical multidrop network. An ISDN frame-relay network can be used to serve this market. The packet network is inserted in one of two places: either between the cluster controllers (CCs) and the front-end processors (FEPs), or between the terminals and the CCs. In the former case, the TAs are used to transform the native-mode synchronous protocol into a LAPD format, whereupon the frames are sent through the frame-relay network. The TAs can also perform a number of additional functions, such as selectively transmitting polls only to the CC for which they are intended, thus saving traffic on the backbone network.

Delay performance can be improved by pipelining native-mode synchronous protocols into multiple LAPD frames for transmittal through the network. Finally, options exist for responding to polls at the TAs themselves, rather than sending the polls through the network.

Where the ISDN frame-relay network is interposed between the terminal and the CC, the network supports the coaxial cable interaction typically found between these two devices. This is a useful application in instances where the CC supports a small number of terminals. In this case, the CC can be placed in the data center, rather than at the end user site, and it can support a number of such small sites. With advanced packet technology, this solution allows the performance expected by users across the coaxial cable interface to a CC.

**LAN/WAN Networking.** LANs are used to support high data rates in a limited geographical area and, thus, have low delay and error rates. They provide high-speed communication among PCs and workstations and facilitate

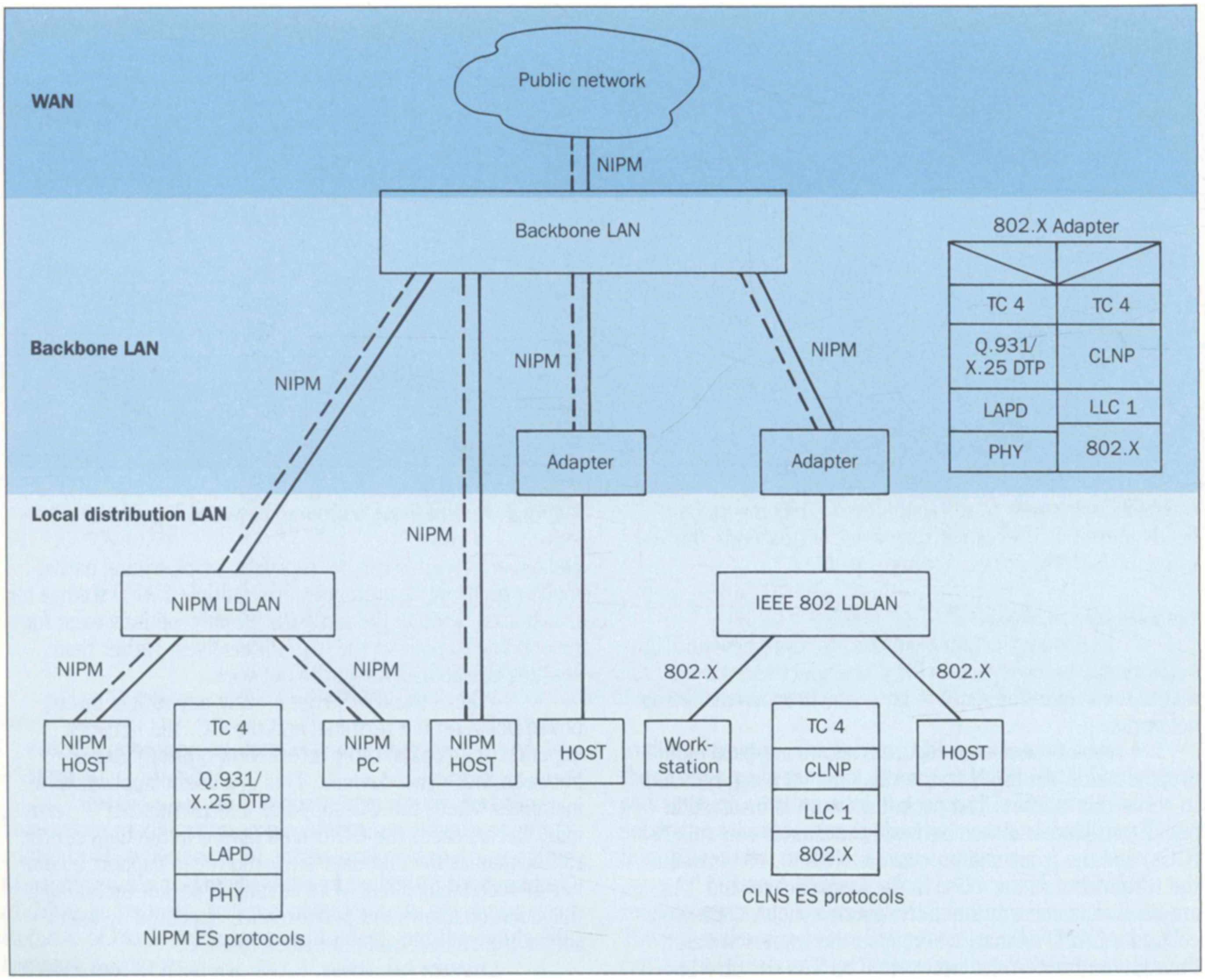



**Figure 6. LAN/WAN networking configuration. The local distribution LAN (LDLAN) supports connectionless protocols, while the backbone LAN and the public network (the WAN) support connection-oriented ISDN/frame-relay protocols.**

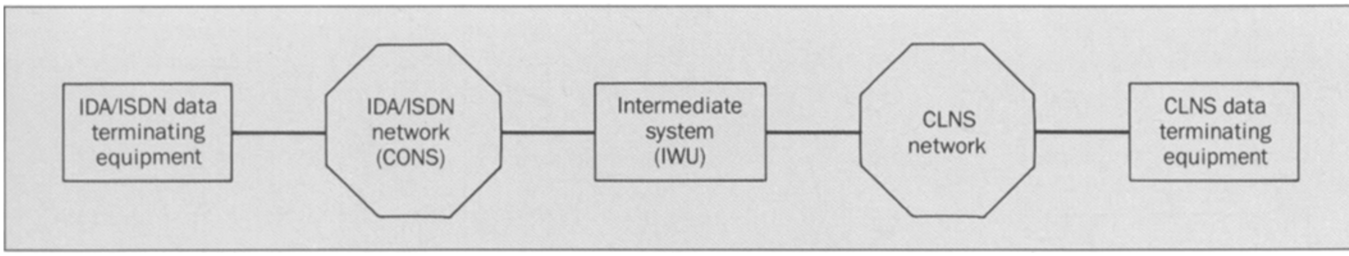



**Figure 7. Interworking between an IDA/ISDN wide-area network and a CLNS local-area network. (CONS = connection-oriented network service; CLNS = connectionless network service.)**

sharing expensive resources such as high-speed printers, disks, and file servers. In addition, they provide interfaces for the existing base of synchronous and asynchronous terminals. Typically, most of the traffic (more than 80 percent) stays within the LAN.

For the most part, LANs are based on shared-medium networking using IEEE 802 standards[3-6] at the lower two layers (the physical layer and the link layer) of the OSI Basic Reference Model.[1] Given the strong dependence on the medium, the data link layer is partitioned into *medium access control* (MAC) and *logical link control* (LLC) sublayers, with the MAC tightly coupled to the particular medium. A variety of MACs have been defined. The most mature of the IEEE 802 MAC standards are IEEE 802.3 (*carrier sense multiple access with collision detection*),[3] IEEE 802.4 (*token bus*),[4] and IEEE 802.5 (*token ring*).[5] All the above MACs use IEEE 802.2 (*logical link control*).[6] Most of the existing LANs use LLC Type 1.

At the higher layers, a variety of connectionless network layer protocols are used, in conjunction with a connection-oriented transport-layer protocol. The most popular of these is the transmission control protocol/internet protocol (TCP/IP) combination,[7,8] which has become the de facto standard. However, many vendors plan to migrate to the ISO-defined protocols: transport protocol Class 4 (TC 4) and connectionless network protocol (CLNP),[9] which in some sense may be viewed as the enhanced and rationalized version of TCP/IP.

The application software, typically, is written to the transport layer interface. Examples include the NetBIOS interface and the UNIX system's transport library interface (UTLI).

The objective of LAN/WAN networking under IDA is *transparent networking* for user applications. This implies LAN networking that is synergistic with WAN networking, through the provision of capabilities that extend the range of applications from LAN-based to LAN/WAN-based networks. Whether the LAN is on the customer's premises or in the central office, as in the CO-LAN service being offered by the regional Bell operating companies, LAN/WAN networking services should be consistently transparent.

ISDN frame-relay networking using the nonchannelized ISDN packet mode interface extends the capability of ISDN to the LAN environment. The nonchannelized ISDN packet mode interface also facilitates the integration of packetized voice and data in a manner consistent with cost-effective, high-performance data networking.

LAN/WAN networking under IDA is also consistent with the direction of the data networking industry and industry standards.

The two major components of IDA LAN/WAN networking are the configuration and the networking scheme. The configuration describes the connectivity of the pieces that make up the end-to-end network, delineating the various interfaces. The networking scheme describes how

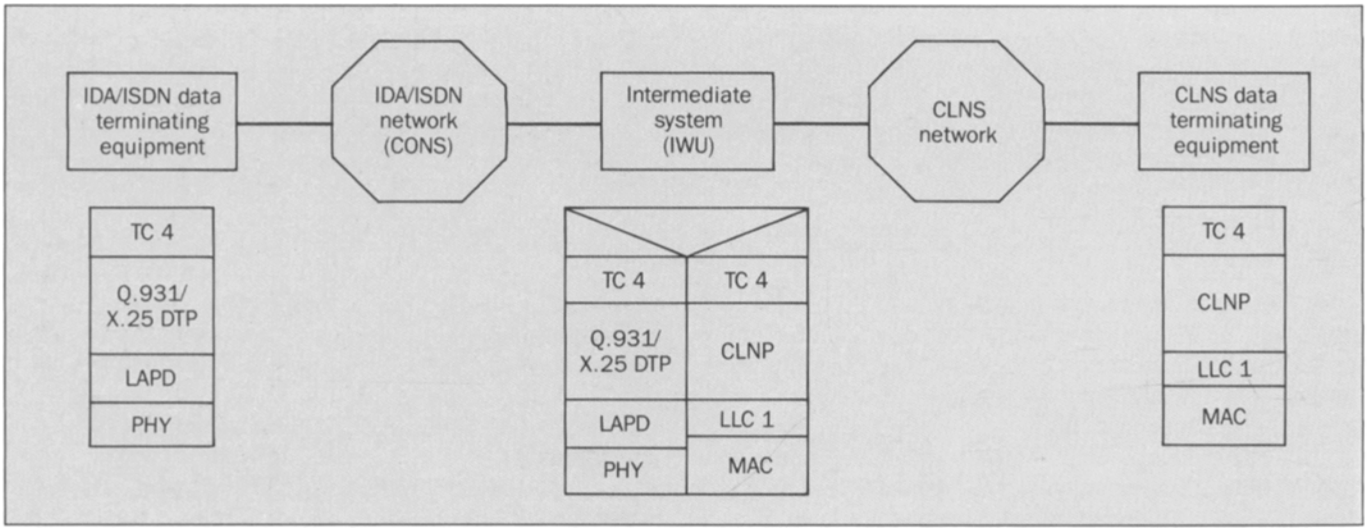





**Figure 8. Protocols for interworking between an IDA/ISDN wide-area network and a CLNS local-area network.**

end-to-end networking is achieved. The IDA LAN/WAN networking configuration is shown in Figure 6. A functional hierarchy exists to support a variety of interfaces. The *local distribution* LAN (LDLAN) is oriented toward local networking, such as departmental networking, and performs the function of adapting to the variety of interfaces that are likely to be found in such an environment. Where the LDLAN uses an interface other than nonchannelized ISDN packet mode, an *interworking unit* (IWU), the TA, is needed to convert from the native-mode interface to NIPM.

The *backbone* LAN (BLAN) is optimized for wide-area networking. The network interface to the backbone LAN, as well as to wide-area networks, is the NIPM.

The left side of Figure 6 shows a potential direction where NIPM is supported down to the PC. There, the local distribution LAN supports NIPM as its network interface.

The right side of Figure 6 shows how the support of IEEE 802 LANs is effected. The IWU—also referred to as an *intermediate system* (IS)—does the conversion between NIPM (ISDN/frame relay) and the IEEE 802 protocols. The noteworthy point is that the LDLAN supports connectionless protocols while the BLAN and the public network, which constitute the wide-area network, support the connection-oriented ISDN/frame-relay protocols. Clearly, to provide the performance needed for transparent networking, it is important to have efficient IWUs.

With respect to end-to-end networking, the following major issues arise:

- What protocol stacks are to be supported in the DTEs (end systems) and ISs?
- What is the addressing scheme?
- What is the routing scheme?

The combination of the DTE stack and the IS stack should provide networking that satisfies the objective: optimal end-to-end ISDN/frame-relay networking on the IDA/ISDN network and efficient interworking with connectionless network service (CLNS) networks. The

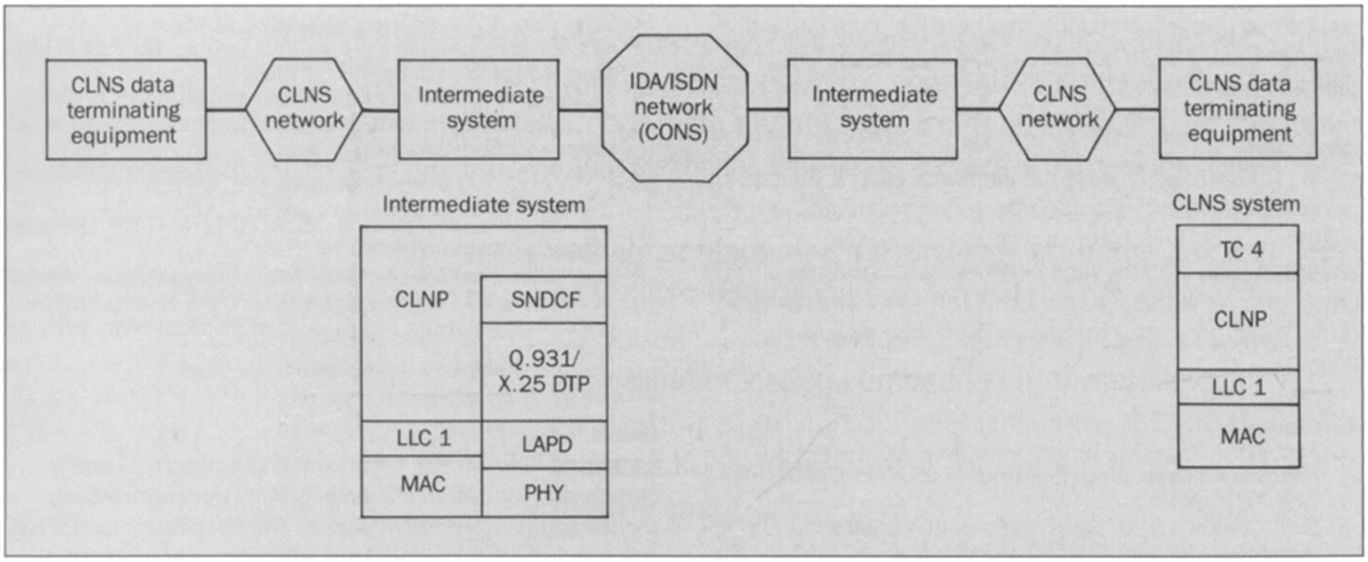





**Figure 9. CLNS networks interworking across the IDA network. (SNDCF = subnetwork dependent convergence function.)**

interworking between the ISDN/frame-relay WAN and the LAN is shown in Figure 7. The protocols supported in the DTEs and ISs are shown in Figure 8.

These consist of the combination of TC 4 and ISDN frame relay. The IS is a TC 4-to-TC 4 transport layer relay (TLR). When all DTEs support TC 4, interoperability is ensured among DTEs for all major U.S. vendors. The transport interface can then be standardized for application software. As indicated earlier, for UNIX system DTEs, the interface is the UNIX system's transport library interface (UTLI) and for MS-DOS® machines, it is NetBIOS. (MS-DOS is a trademark of Microsoft Corporation.) This allows other vendors and value-added resellers to supply DTEs and applications that can easily use the network services.

Figure 8 also shows the intermediate system for CLNS networks. The intermediate system functions as a transport layer relay, using the same transport class, for LAN DTE and IDA/ISDN DTE interworking. It has TC 4, the NIPM stack, and the CLNS stack. The intermediate system for CLNS networks also functions as a network layer router (NLR) for LAN DTE interworking across the IDA/ISDN network. (See Figure 9.) It uses the NIPM stack and the CLNS stack.

Functionally, the IS attempts to operate as a network layer router, if possible, and escalates to operate as a TLR, when necessary. For those instances of communication when the IS operates as an NLR, the DTEs do not behave any differently than when the IS is not being traversed at all. This means that from a purely operational standpoint, the two communicating DTEs perform exactly the same sequence of steps as they normally would, regardless of whether they are communicating directly (i.e., residing on the same subnetwork) or communicating through an IS (i.e., residing on different subnetworks interconnected by one or more ISs). Only by inspecting the source and destination addresses, perhaps, could it be possible for the DTEs to determine that they reside on different subnetworks.

## Conclusion

This paper covers the elements of AT&T's data networking architecture. It outlines the capabilities provided by the architecture, as well as relating the architecture to existing data networking applications. Other articles in this issue of the *AT&T Technical Journal* provide additional information on the topics discussed herein.

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Biographies (continued)

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