

AT&T NETWORK ARCHITECTURE EVOLUTION

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The network of the future will use technologies and architectures that meet the telecommunications needs of our customers. These customer needs are embodied in three AT&T corporate goals: maintain and strengthen the core businesses, expand the focus on data networking, and establish a major position in international markets. To address these goals, AT&T will provide a network that is lowest in cost and rich in features and functionality. Key elements in the network evolution are an aggressive plan for digitalization, implementation of distributed network intelligence, and deployment of advanced technologies. These key elements allow AT&T to expand its existing services and introduce new services including: data capabilities oriented toward customer network management; modernized private networks such as EPSCS; domestic services offered globally; ISDN; and enhanced services. The plans for the AT&T network extend to the year 2000 and beyond to ensure AT&T's leadership position.

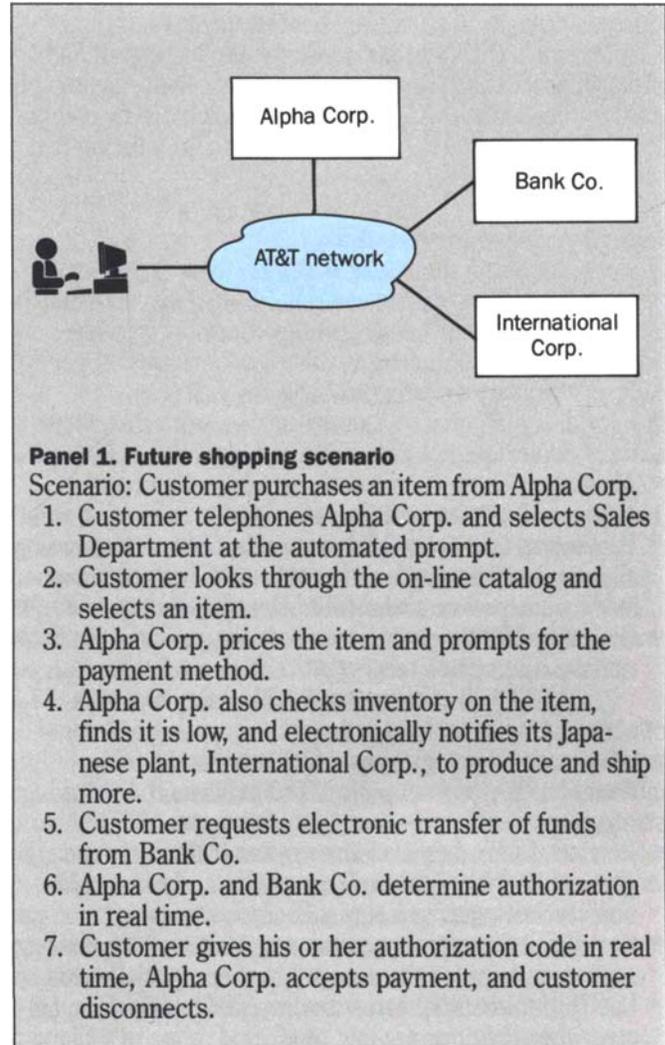
Perspective

Our society is moving toward an information-intensive culture built around the exchange of information. Telecommunications technology is evolving rapidly, with computing capabilities becoming widely distributed in the home, office, and factory. Information is being exchanged between humans, between humans and machines, and between machines. This information exchange is a necessity between a wide range of locations, including the home, businesses, and factories, both domestically and internationally. These factors have initiated the formation of an information movement and management (IM&M) industry.

IM&M customers have a diverse spectrum of needs. Large business customers are looking for the most technologically advanced telecommunications network available. Key requirements include a feature-rich network that provides rapid deployment of these features, along with high quality and flexibility. Robust interfaces between the network and customer premises equipment (CPE), smaller locations, and international locations are critical. Although smaller business and residential customers also want an increasing set of features that provide high-quality solutions to meet their needs, their financial decision criteria are different from large businesses. (In this issue, Bulfer describes the trial of AT&T's Pay-per-View Service,¹ an advanced service.)

Customers also need services that provide information storage and processing in the marketplace. Soon, the capability will exist to perform advanced information processing transactions, such as the shopping scenario in Panel 1. This will create a need for AT&T's customers—business, industry, or consumer—to have information management that encompasses the generation, collection, storage, processing, and transfer of information that originates from a variety of media (voice, data, and image).

As indicated above, AT&T's customers have a rapidly evolving, ever increasing need for IM&M capabilities. The competitive and regulatory context in which AT&T must respond to these customer needs is also evolving. Historically, AT&T has been the clear technological and service leader in the telecommunications field. Since divestiture, competition has grown rapidly. AT&T faces strong competitive challenges from several interexchange carriers who continue to invest heavily to upgrade their networks. These competitive challenges will make it increasingly important for AT&T's network to provide advanced features and high functionality end-to-end solutions quickly and effectively, in response to customer needs for voice, data, and image handling. One step that we are taking to allow rapid implementation of new service concepts is the ASQIC (Advanced Services Quick Implementation Capability) program that Braunstein, Burton,



and McNabb describe² in this issue.

Regulatory requirements have constrained AT&T's ability to meet the full range of customer needs, particularly in the area of protocol processing and enhanced services. However, the regulatory environment has

changed dramatically with the Federal Communications Commission's (FCC) ruling on Computer Inquiry III and protocol processing. Although regulatory requirements still exist in these areas, AT&T will be allowed more flexibility to provide enhanced services and protocol processing that meet customer needs.

Network Architecture Objectives

To design the future AT&T network architecture, we have developed objectives (Panel 2) that incorporate anticipated customer needs and the effects of growing competition and continuing regulatory constraints. Specifically, our primary architectural objectives are:

- Provide a high-quality, feature-rich network that allows rapid deployment of new features.
- Maintain a low-unit-cost core network with diverse access and service options.
- Develop an end-to-end data capability to meet increasing customer expectations and enable AT&T to remain a leading competitor in the IM&M marketplace.
- Globalize AT&T services to satisfy the needs of multinational customers.

AT&T will continue to provide a flexible, cost-effective network to link customers' computing and communications technologies and efficiently handle their information. For this network, AT&T will use the following strategies:

- Rely on standards that define common protocols and physical interfaces to allow computing and communications technologies to interact easily.
- Provide all the capacity customers desire, while allowing customers to tailor the network to their special needs.
- Use fault tolerant systems that recover rapidly from failures when they occur.
- Make full use of new technology to provide new applications to customers.

Key Architectural Strategies

To ensure that AT&T's network continues to meet evolving customer needs and achieves its architecture

Panel 2. AT&T Objectives

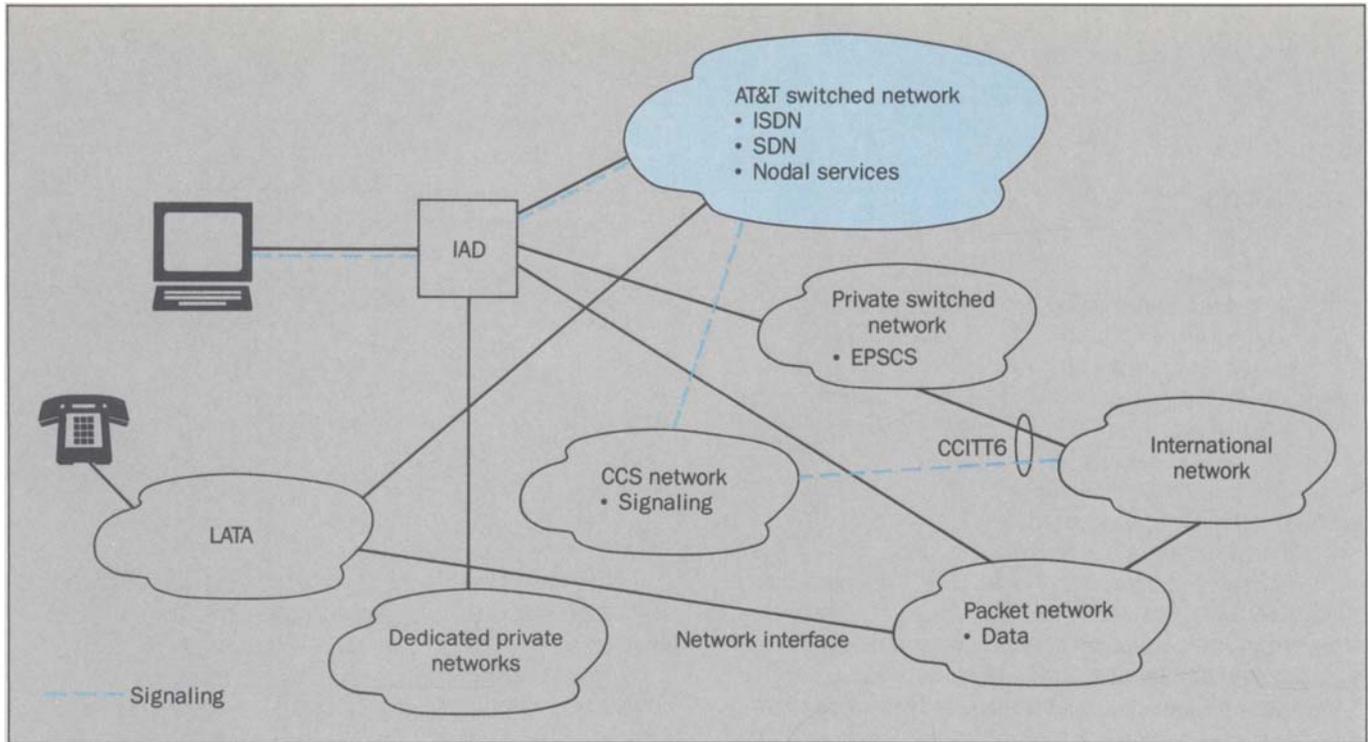
- High-quality, feature-rich network
- Low-unit-cost core network
- Development of an end-to-end data capability
- Globlization of the AT&T network

objectives, we have defined a target architecture for the 1995 time frame that comprises the following key elements.

Evolution of the AT&T switching, signaling, and transmission network elements must continue. AT&T is deploying digital facilities, CCS7 (a version of common channel signaling, CCS), and common software and hardware in this signaling and transport network. This evolution will allow integration of services and capabilities across the network that will provide a cohesive set of services with the flexibility and functionality that AT&T's customers require. This continuing evolution supports the objectives of maintaining a low-unit-cost core network and developing a feature-rich network.

A nationwide, followed by an international, Integrated Services Digital Network (ISDN) will be deployed. The new network capabilities that are inherent in the ISDN architecture support the maintenance of a low-cost core network, evolution of a feature-rich network, and globalization of services. ISDN will be designed to support evolving customer needs for more sophisticated services. In addition, it will provide an integrated network-access capability to support integration of services in the network. The timely introduction of ISDN, at both a domestic and international level, will help AT&T maintain technological leadership.

AT&T's data networking capability will be extended to include a more comprehensive set of end-to-end data features and functions. This will support AT&T's objective of being an end-to-end service provider and a leading competitor in the IM&M industry.



The existing international network architecture will be expanded to facilitate introducing advanced services to meet the needs of multinational customers. The current international deployment of digital facilities and advanced signaling will have a strong effect on this architecture. This strategy supports the objective of globalization of AT&T's network services.

Architectural Evolution

Today, AT&T's network architecture consists of several independent, service-oriented networks. As the architecture evolves through 1995, these networks will be integrated, on both a capabilities and services level. Figure 1 shows AT&T's current architecture, while Figure 2 shows the architecture planned for 1995. The subsections that follow describe this evolution for the 1987 to 1995 time frame. Later sections describe the network's technical direction beyond 1995.

Facility Evolution. AT&T plans to provide more digital connectivity and capability.

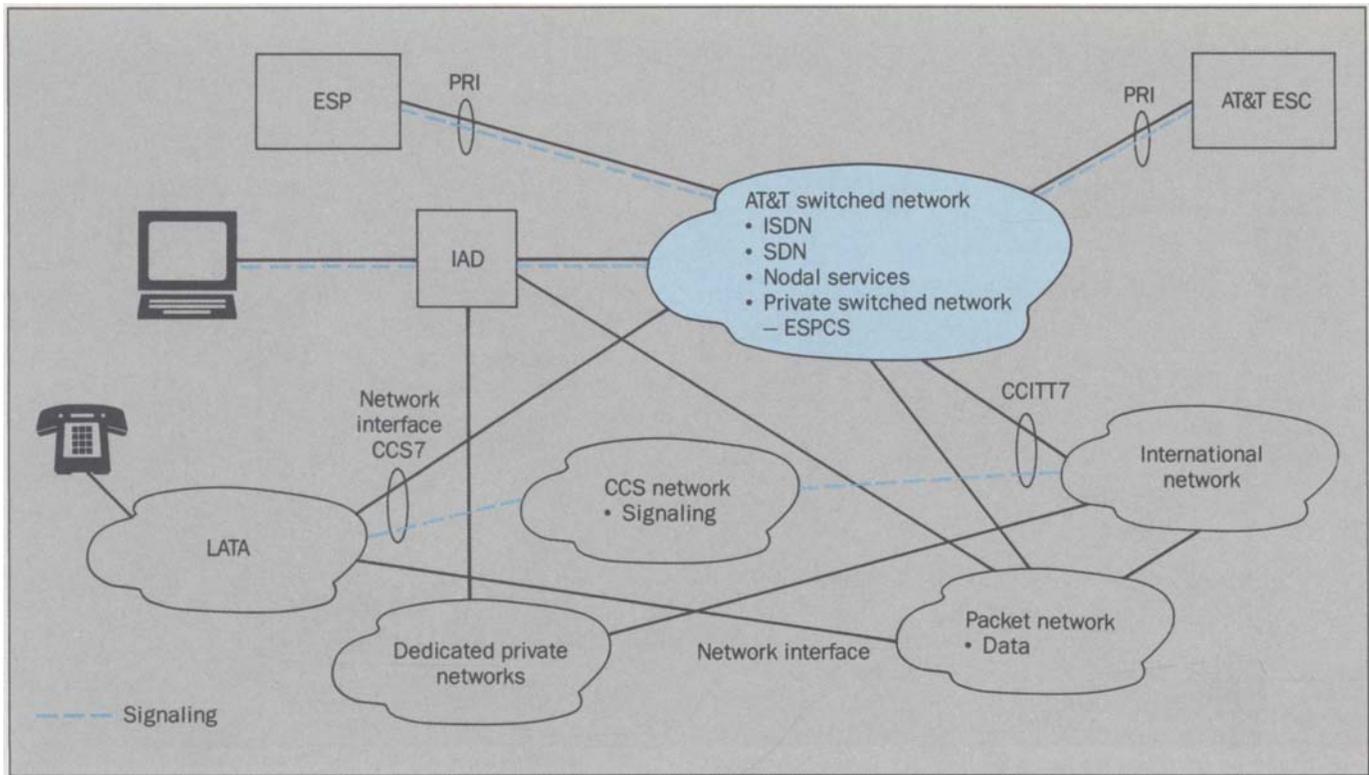
AT&T has embarked on an aggressive digital deployment strategy that is rapidly increasing the percentage of digital circuit miles in its facility network. Eventually, most of AT&T's facility network will be digital.

Figure 1. Current (1987) AT&T network. CCITT6 = a provision of standards set by International Telegraph and Telephone Consultative Committee; CCS = common channel signaling; EPSCS = Enhanced Private Switched Communications Service; IAD = integrated access distributor; ISDN = Integrated services digital network; LATA = local access transport area; SDN = software defined network.

The purpose of this aggressive plan is to reduce cost and increase functionality, design a network that will provide ISDN data capabilities, and give increasing support to customer control and vertical services. AT&T intends to provide as much intelligence, flexibility, and functionality in the network as possible. (Rogalski discusses the facility network plans in his paper on lightwave transmission systems.³)

Access. AT&T will provide a full-featured ISDN capability to serve both large and small customer locations.

ISDN—as a network capability and as an integrated-access alternative to transport voice, data, or image traffic—will be offered using out-of-band signaling. Evolution of the signaling network will enable AT&T to introduce ISDN capabilities⁴ in phases starting in 1987



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Figure 2. 1995 AT&T network. CCS = common channel signaling; CPE = customer premises equipment; EPSCS = Enhanced Private Switched Communications Service; ESC = enhanced services complex; ESP = enhanced services provider; IAD = integrated access distributor; LATA = local access transport area.

using a primary rate interface (PRI), with 23 or more B channels and one D channel (Figure 3).

Among the supported ISDN features will be:

- Identification of the originating station
- Call-by-call switched service selection
- Switched digital capability at 64 kb/s
- User-to-user information.

Interworking with the local exchange carrier's 2B + D basic rate interface (BRI) and primary rate interface (PRI) offerings is being planned.

Since divestiture, the management of access has been a major new activity for AT&T. A systems architecture has been developed to provide an efficient way to manage access costs, and is described in Obuchowski's paper on access charge and revenue architecture.⁵

SPC Network. AT&T will use several techniques in

the evolution of its stored program controlled (SPC) network.

Advanced technologies. AT&T will extend the capability of its switched network through the strategic use of advanced technologies.

In the ASN, we will continue to use the 4ESS™ switching system as the high-functionality switch for domestic and international switching center (ISC) functions throughout the early 1990s. To provide a more flexible, lower cost ASN, we are considering the use of wideband-packet technology to provide integrated transport and switching in a common packet form for a variety of voice, data, and image applications. Wideband-packet technology may eventually serve as an integration vehicle for the ASN and AT&T-provided, dedicated private-line subnetworks. The goal of such integration is increased effectiveness through universal provisioning and maintenance procedures, regardless of the services involved.

A new, high-functionality switching system that uses electronic and, possibly, photonic technologies is under study for the mid-1990s. (In this issue, Hinton discusses applications of the photonic technology.⁶) Besides the usual narrowband circuit capability, the advanced

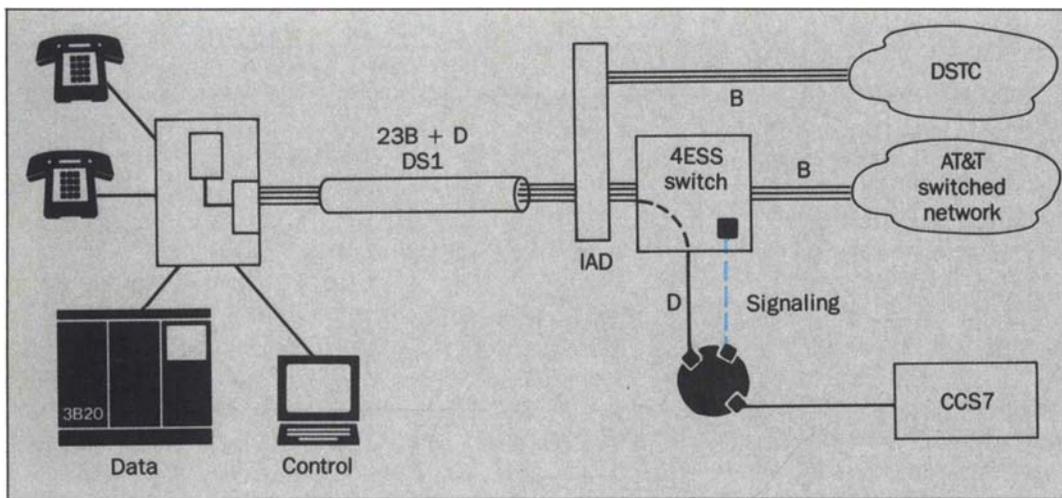


Figure 3. AT&T ISDN primary rate interface has 23 B channels and 1 D channel; the DS1 rate is 1.544 Mb/s. CCS7 = common channel signaling, version 7; DSTC = digital serving test center; IAD = integrated access distributor; ISDN = integrated services digital network.

switching technology could support wideband circuit and packet switching. Application of this switch in the network could provide voice, data, and image transfer, as well as facility restoration and rearrangements.

Enhanced CCS network. AT&T will enhance the common channel signaling network to provide the basis for distributed network intelligence and new service features.

In the AT&T network, common channel signaling is evolving from CCS6 to CCS7, a message-oriented protocol that is a variant of CCITT7. (This is a provision of the International Telegraph and Telephone Consultative Committee.) AT&T plans to introduce CCS7 this year. Introduction of the No. 2 Signal Transfer Point (2STP); increased capacity of high-speed, 56-kb/s digital signaling links; and out-of-band signaling using CCS7 all combine to facilitate a rich set of new services.

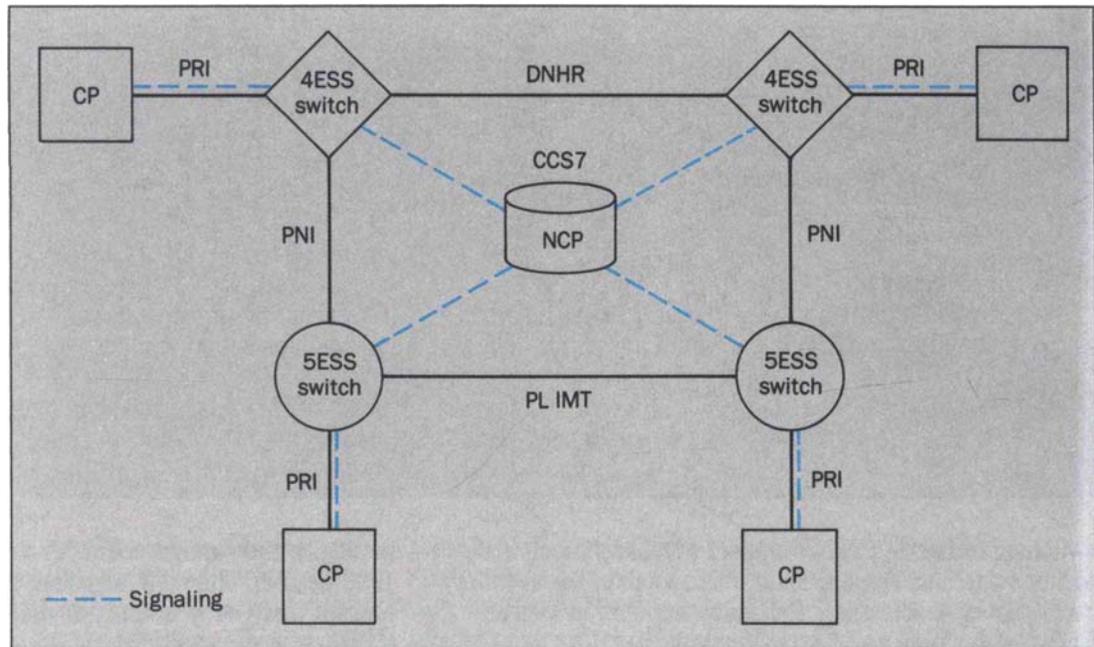
This more robust, digital signaling network is the foundation for new services with sophisticated features that require message-oriented signaling protocols to transport special customer messages. In addition to improvements to the internal AT&T signaling network, network interconnection links with local exchange carrier

networks and foreign countries are also planned for the 1990 period. This new signaling architecture, which Lawser and Oxley discuss in their paper about the CCS7 network,⁷ will also facilitate distributed processing.

Distributed intelligence. AT&T will use distributed intelligence to provide sophisticated features and functionality.

Over the planning period, the trend toward distributing service-control logic (which is the feature set required to support service capabilities) will continue. By introducing advanced technology and deploying common software and hardware in various network elements, AT&T can strategically and selectively locate the service-control logic to increase the network's flexibility and functionality. An example of this is the ability to deploy processing nodes on a variety of network elements to support database and signaling applications. With such processing nodes available, it is easier to deploy service-control logic in an optimal network arrangement. In addition, distributing the service-control logic this way will extend the capacity of network elements that currently provide AT&T direct-services-dialing-capability (DSDC) services.

Figure 4. Private network evolution; EPSCS (Enhanced Private Switched Communications Service) will be modernized and integrated with an AT&T switched offering. CP = customer premises; DNHR = dynamic nonhierarchical routing; NCP = network control point; PL IMT = private line intermachine trunks; PNI = private network interface; PRI = primary rate interface.



Routing and numbering plan. AT&T will develop a comprehensive and robust routing and numbering plan to meet the needs of advanced services into the twenty-first century.

The future's routing and numbering plans must satisfy customer needs, as well as technological and legal or regulatory forces over the planning period. Because network architectures are moving toward integrated services and capabilities, we are studying a class of service-routing capability as a way to accommodate the routing of various services and types of traffic in an integrated architecture environment.

A related architectural direction is the expansion of numbering plans. This will accommodate the large trunk-group requirements of the next-generation interconnection system and give customers flexibility in the design of internal numbering plans.

Modernized private networks. AT&T will modernize

private switched networks to meet increasing customer expectations and give customers of such networks a pathway to ISDN. To do this, we will integrate private-switched-network functionality with the AT&T switched network.

To meet customer needs for advanced technologies, AT&T will use the digital technology of the 5ESS™ switch—beginning in 1988—to modernize the Enhanced Private Switched Communications Service (EPSCS) network. To provide a pathway to ISDN for the EPSCS customer, we will integrate the modernized EPSCS and an AT&T switched-network offering. As Figure 4 shows, the private network interface (PNI) allows the customer to obtain both ASN capabilities and modernized EPSCS capabilities.

Full feature transparency, which is a complementary feature set among switches in the integrated network, will provide the service capability of this AT&T switched

offering that combines the virtual private-network capability of the software defined network (SDN) with EPSCS-like features. A hybrid 4ESS/5ESS switch network will provide the initial functionality. This is an interim step toward integrating the architectures of the AT&T switched network and the private switched network.

Data Networking. AT&T will develop data networking capabilities that are comparable to the existing feature-rich voice capabilities.

Architectural efforts are focusing on giving AT&T customers end-to-end data networking capabilities. The capabilities planned in this architecture will provide an end-user data networking AT&T service that focuses on low latency, statistical multiplexing, routing, customer network management, and operations capabilities. This architecture will offer AT&T customers an end-to-end intelligent data capability on a flexible network, in addition to the digital-transport-based services that are currently offered.

International. AT&T will extend domestic capabilities to the international arena.

The need for global service architectures is increasing. To meet this need, AT&T will seek feature transparency of advanced services capabilities across national boundaries to provide for the evolving needs of the multinational information movement and management marketplace. A key feature of this global architecture is the introduction of international digital facilities (e.g., the TAT-8 transatlantic and HAW-4/TPC-3 transpacific cables shown in Figure 5), as well as the international introduction of CCITT7-based signaling protocols.

Support Systems. AT&T will continue to evolve its workcenter and operations system (OS) architectures to ensure continued support for its strategic objectives.

To support these objectives and accommodate changes in technology, we expect workcenter and OS architectures to change significantly over the next decade. Customers will be provided with a single contact to meet their service-related needs. We are also integrating plans for network and CPE workcenters to provide end-to-end coordination of workcenter functions.

Over the next decade, the general trends in OS architecture will be:

- Become UNIX® system based.
- Use more graphics workstations.
- Employ distributed processing techniques.
- Introduce the use of artificial intelligence.

In this issue, Merski and Parrish discuss an advanced operations system.⁸

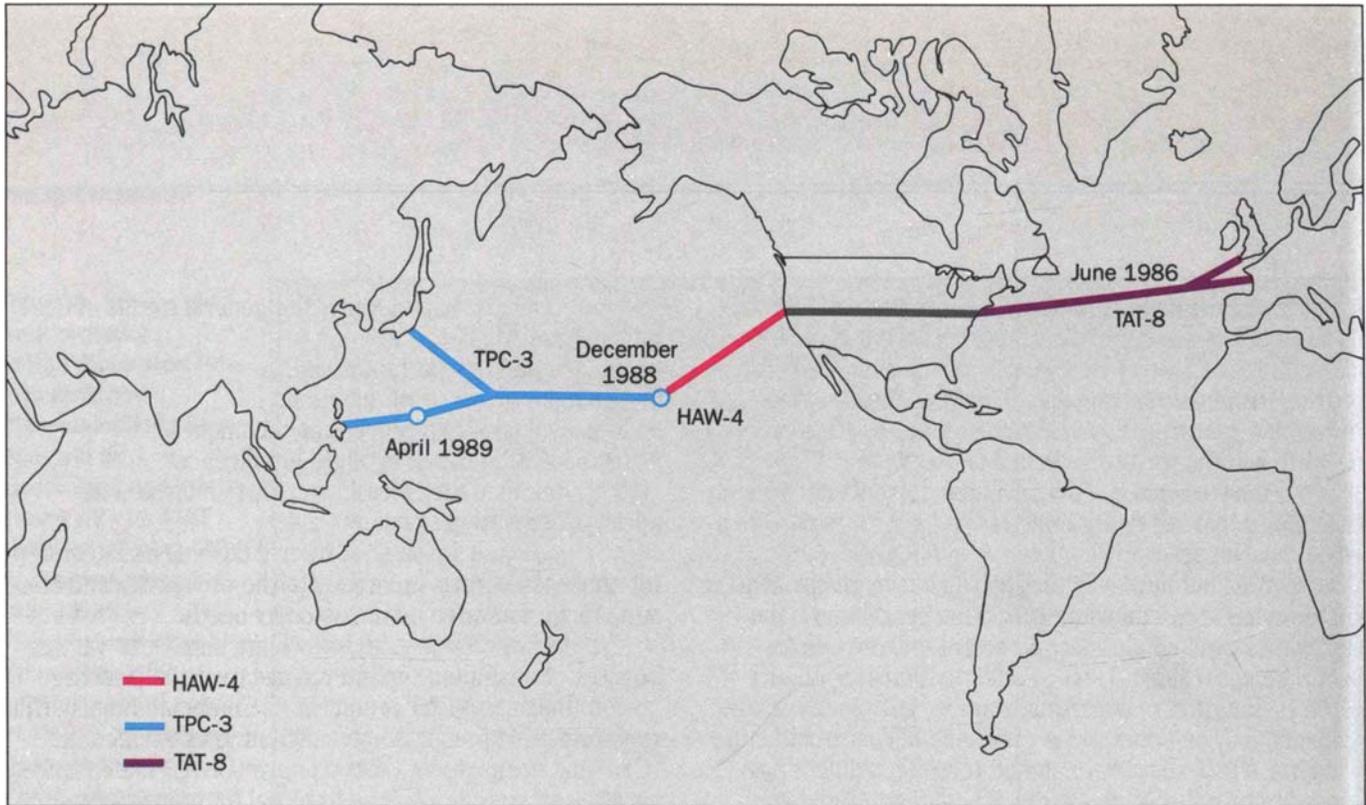
Enhanced Services. AT&T will develop architectures for enhanced services that involve the processing and storage of information to meet customer needs.

Enhanced services, which are subject to varying degrees of regulation, will be offered over the planning period. Because AT&T is subject to Computer Inquiry III's requirements for comparably efficient interconnection (CEI) and open network architecture (ONA), the enhanced services architecture will be external to the network elements that provide basic services. The equipment to provide enhanced services will connect to the network via basic, tariffed interfaces.

If, in the future, the FCC grants relief from CEI and ONA, a network-based enhanced services architecture could be used when appropriate. A new network element, called an Enhanced Network Services Complex, is being studied as part of the enhanced services architecture. Such a network element could provide storage and forwarding of voice and data messages, attendant-based product information, speech response, and entertainment services. This complex would have processors, voice recognition and synthesizing, announcement, storage, and other appropriate equipment.

Future Directions

As we extend the planning horizon beyond 1995, new technology trends emerge. During this period, customers will continue to require increasingly complex features and functions. To ensure AT&T's competitive position in the future, its network architecture must continue to meet long-term evolving customer needs while capitalizing on technological advances that occur in the



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Figure 5. Digital connectivity in the Atlantic and Pacific basins using the TAT-8 and HAW-4/TPC-3 undersea cable systems.

period. The work of defining this architecture beyond 1995 is under active research, using assumptions about technology trends and customer needs, combined with assumptions about the corporate, competitive, and regulatory environment.

Technology Trends. As noted above, the long-term needs of AT&T's customers, modulated by the effect of regulatory constraints, will set the direction of AT&T's network architecture. A key element of the architecture is the technology that will be available to meet customer needs.

The new technologies and capabilities that they offer will have a significant effect on the future architecture. Significant advancements are expected in three areas: fiber, switching, and processing and storage technology. The key technological trends and their effect on the architecture are summarized below.

Fiber. Long-haul fiber facilities from 1.7 Gb/s to at

least 10 Gb/s will be available. Fiber is the facility of choice for the future. But where fiber is not practical or economical, digital radio systems will continue to be used in the AT&T network. The percentage of coaxial cable in the network will be decreasing.

The trend is for transmission costs to continue to drop rapidly, so high-capacity transport will be available at relatively low costs. As a result, AT&T's customers should begin to desire higher bandwidth services. This will clearly affect the hierarchy of transmission rates and the cross-connect and switching rates that the network supports.

In addition, a large fiber deployment will make it necessary for the network to support rapid restoration capabilities in cases where fibers are cut.

Switching. For switching systems, improved electronic nonblocking switching fabrics will be available. Purely photonic switching systems (photonic switching driven by photonic control) are not expected to be available for commercial use before the year 2000. But electronically controlled optical systems may be available in the late 1990s.

Switching systems are expected to perform

switching and cross-connect functions to support the high-bandwidth circuit and packet traffic that customers generate. Photonic cross-connects are expected to be used to handle facility restoration. (Hinton's paper on wideband switching⁶ discusses optical switching and related technologies.)

Processing and storage. Processing and storage technology to support basic and enhanced services will also advance. The scale and complexity of integrated circuit devices will continue to increase, but the physical volume required to store data will decrease (especially with the development of optical disk storage). In addition, high-speed processors for commercial use will reach 100 to 1000 million instructions per second.

As software-development techniques advance, software productivity will also improve (though less rapidly). Overall software costs (including testing and maintenance) will continue to increase, indicating the cost benefits of using special-purpose hardware. During this period, advancements will be made in the development of expert systems, object-oriented languages, and artificial intelligence.

Advances in processing and software technology will dictate the control structure for future network elements. Most likely, the various fabrics will be controlled by high-capacity processors that run component-based software in a distributed-processing environment. Modular hardware and software that is easily modified and growable is seen as one key to AT&T's ability to respond rapidly to changing customer needs.

Preliminary AT&T Architecture Beyond 1995. The AT&T network beyond 1995 is envisioned to consist of modular network elements aimed at providing a highly flexible and intelligent network that meets customer needs for end-to-end service in a cost-effective way. This network will provide customers with increased capabilities to control their telecommunications services. Hardware and software modularity will simplify the introduction of new network elements and services. Integration of the various special-purpose networks will result in reduced operations costs

and increased flexibility to meet customer needs with high-quality services.

The AT&T network will have access and egress points to local exchange carriers, foreign administrations, enhanced service providers, and customer premises equipment. At these access and egress points, the network will support standard interfaces for packet data, narrowband circuits (1.5 Mb/s and below), and wideband circuits (45 Mb/s and above). Ultimately, interconnect vehicles that integrate the control of various fabrics will provide the wide range of switching, cross-connect, and selected multiplex functions that customers will require from the network. In addition, the interconnect vehicles will handle restoration and rearrangement of the high-bandwidth facilities, caring for the various transmission rate traffic types.

The network will also support specialized database functions that will give the customer increased customization capabilities.

In this period, the signaling protocol used will focus on permitting more advanced user-to-user and user-to-network capabilities. It will also take advantage of the characteristics of fiber transmission facilities to allow increased signaling rate and better error performance.

The network will contain customer interfaces that will interpret customer-controlled input and provide that input to the relevant service operations systems. The service operations systems will then translate the input into actions in the network. Correspondingly, the customer will receive data from the customer interfaces via the service operations center.

The architecture for AT&T's network beyond 1995 is intended to provide a target for the on-going AT&T network evolution. It should guide that evolution to ensure that new technology is developed and deployed optimally to meet customer needs for end-to-end basic and enhanced services.

Conclusion

AT&T's network architecture embodies the directions and changes planned in response to customer needs,

competitive challenges, and corporate objectives for 1986 to 1995. The essence is to ensure that its 1995 network is intelligent, software driven, and digital—enabling AT&T to adapt rapidly to customer needs.

The planning horizon has also been expanded beyond 1995. As we determine the technology and architecture that lead to the network of the 1990s, we further envision a graceful evolution to the network of the twenty-first century.

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Biographies (continued)

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