DATA NETWORKING: AN ISSUE OVERVIEW

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This issue of the *AT&T Technical Journal* describes AT&T's data networking architecture, provides insight into the underlying technical motivation behind the architecture, and analyzes its key technological underpinnings, with emphasis on the physical through transport levels of the architecture.

Introduction

To date, the construction of data networks has required both art and science. Agreements remain to be reached on basic interface standards, addressing syntax, naming, features, and performance requirements that made global voice communication networks possible. AT&T is applying its broad networking experience to develop data networks, and collaborating with the rest of the industry to develop appropriate standards for the construction of open, large-scale data networks.

This issue of the *Technical Journal* highlights AT&T's data networking architecture—the Integrated Data Architecture (IDA). The IDA lets the end-to-end interconnection of conforming products and services provide efficient movement of information to meet the demanding requirements of modern data networks. It is targeted at the transport, network, and link layers of the International Organization for Standardization (ISO)[1] reference model.

The IDA is designed to achieve:

- Throughput, network delay, and reliability matched to application needs
- Synergy between premises equipment and network services
- Flexibility and modularity to allow the introduction of new technologies
- End-to-end network management, integrating premises and network capabilities
- The ability to incorporate multiple levels of security
- Compatibility with international, domestic, and de facto standards.

The IDA is part of the AT&T Systems Architecture.[2] It is a component of the overall strategy to digitize the network and implement services based on the Integrated Services Digital Network (ISDN). However, the IDA is not tied solely to the deployment of ISDNs; it also addresses the problem of migrating existing data networks toward the

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high-speed, integrated digital networks that will be the hallmark of telecommunications during the 1990s.

The papers in this issue provide background information, analytical results, and directions concerning the IDA and related AT&T networking initiatives. The papers are organized into four sections that form the mini-themes of this issue:

- Data networking architecture and directions
- Performance analysis of IDA-based networks
- Customer data network implementations
- The network management environment.

Data Networking Architecture and Directions

Data networks are systems of computers, terminals, workstations and databases connected by communications facilities. Ad hoc data networks have been in existence for the past 30 years or so. The earliest networks consisted simply of wires strung around rooms or buildings to connect local terminals to a computer. Later, remote terminals were connected to computers through analog telephone facilities such as private lines and switched connections. Today's data networks are built predominantly by interconnecting participating data devices with communications facilities designed principally to carry voice communications.

The first two papers describe the generic problem and challenges of data networking, both now and in the future. They explore AT&T's efforts to develop a data architecture that makes open, flexible data networks possible. These efforts represent not so much an evolution of voice networks as they do a revolution, one that recognizes the broader scope and more demanding requirements of data networks and has resulted in the design and development of new technologies. Because carefully designed data networks can also carry voice traffic, the future holds the promise of fully integrated voice and data traffic.

The paper by Gewirtz and Stuntebeck describes changing trends and requirements for data networking, including the migration from "dumb" terminals to intelligent workstations; growth of distributed applications; interconnection of terminals to wide-area networks

(WANs) via local network gateways; continued migration of networks to the core business infrastructure; the need for real-time control and management; increasing needs for security; and the ability to introduce new applications rapidly. These trends have strongly influenced the structure of corporate networks, particularly the long-standing tradition of constructing special data networks for each application; they have initiated a movement toward the construction of corporate backbone networks. At the same time, emerging technologies provide exciting new opportunities to meet data networking requirements. Among them are integrated data, video, and voice; the trend toward distributed processing and cheaper communications; expanding very-large-scale-integration (VLSI) capabilities; revolutionary technologies such as lightwave networking, voice recognition, and high-temperature superconductors; and, very-high-bandwidth transport.

The paper by Kaufeld, Boakye, and Palmer describes the overall IDA plan needed to develop and deploy compatible and synergistic products and services. The IDA offers a simple, yet powerful, functional model for AT&T data networking at the first four levels of the Open Systems Interconnection (OSI) model. The IDA model provides detailed specification of functions and protocols that enable AT&T's—and other vendors'—products to interconnect and form comprehensive, cost-effective, and powerful data networks. To achieve these objectives, specific goals for end-to-end delay, throughput, interworking, and standards are described, and the applicability of the IDA to local-area network (LAN) interworking is discussed.

Performance Analysis of Advanced Frame-Relay Packet Techniques

The advanced feature capabilities of the IDA are based on the use of frame-relay concepts and standard synchronous data framing techniques. The next set of papers provides the analytic, simulation and practical basis for implementations based on the IDA. The papers cover frame-relay transport and present various techniques for flow control, routing, end-user performance, and network

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integrity and analysis, as they apply to representative applications that use frame-relay transport.

Like X.25 packet networks, link-access procedures for D channel (LAPD) frame-relay networks require effective congestion control mechanisms to cope with unanticipated network component failures and overloads. Unlike X.25 packet networks, LAPD frame-relay networks perform the requisite packet-switching function *without* terminating the link- and network-layer data-transfer protocols. Thus, they cannot use a window-based flow-control mechanism for congestion control. The paper by Nguyen and Doshi reviews the routing and flow management techniques that can be used effectively to control congestion in LAPD frame-relay networks.

Development of virtual private-line networking architectures as an alternative to private-line networks has been a major thrust in data networking. It is important to understand how the end-to-end performance of virtual private-line networks, whether on private networks or on a shared public service, compares to today's private-line networks. The paper by Sheng compares the delay versus throughput performance of virtual private-line networks with conventional private-line networks for SNA™/SDLC and 3270 binary-synchronous communications applications. (SNA is a trademark of IBM Corporation. SDLC is synchronous data-link control.) In particular, the paper compares effects on end-to-end performance of various virtual private-line protocol handling capabilities to their private-line equivalents.

Beyond performance optimization, it is also important to understand the economic impact of virtual private-line networks' various protocol-handling capabilities. Taking the perspective of large business customers, Sheng discusses the effects of virtual private-line networking capabilities on total customer networking costs, comparing them to traditional private-line networking costs.

The paper by Ayanoglu and Wang addresses the design of a statistical multiplexer that concentrates data from multiple data input ports for access to a virtual-circuit packet network based on the LAPD protocol. It is assumed that the multiplexer is near a front-end processor employ-ing synchronous, and in addition, possibly, asynchronous data-link-layer protocols, with emphasis on synchronous data-link control. The authors propose and analyze a novel priority queueing strategy whose overriding objective is to reduce end-to-end delay.

Selected Customer Data Networks

AT&T's careful analysis of frame-relay techniques and its IDA data networking strategy are based on the company's experience with data networking. Lessons learned during the development of the Advanced Communications Service (ACS) and Net 1000, as well as extensive deployment of packet switching in AT&T's own data networks, are being applied to a new generation of AT&T data networks. In addition, leading-edge customer networks demonstrate a variety of AT&T data networking capabilities in the real world.

The paper by Al-Chalabi and Liss describes Bank of America's California data network (CDN). The CDN is a corporate network that consolidates 60 physical and logical networks into a single network using AT&T's Datakit® virtual-circuit-switch (VCS) technology. It is managed by the StarKeeper® network management system (NMS) and the Dataphone® II level IV system controller. The CDN's architecture is a two-level hierarchy: an access network that connects the branches to the hubs and a backbone network that interconnects the hubs and data centers.

The paper addresses three fundamental areas: optimization of the network topology and node configuration, performance analysis, and network management. Network optimization deals with determining the optimal number of nodes, access facilities engineering, and backbone configuration and routing. The performance analysis shows the end-to-end delays for the applications. Administration, disaster recovery, network monitoring, and data collection are discussed in the paper's network management section.

Introduction of ISDN into the public switched network has made it possible to combine many data networks and voice applications into a single integrated digital network. The paper by Delatore, Krause, and Wil-

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son shows how that potential has been turned into reality. At the headquarters of McDonald's Corporation in Oak Brook, Illinois, existing data networks have been integrated into an ISDN. ISDN service to McDonald's is provided by Illinois Bell Telephone through a central office implementation of the 5E4(2) Generic on the AT&T 5ESS® switch. Applications running on multiple data networks have been integrated into an ISDN, resulting in improved performance and flexibility for the end user.

Network Management Architecture

AT&T is building on the skills and techniques acquired in the management of voice networks to manage data networks with equal effectiveness. Many solutions to effective network management—such as network administration, trouble reporting and tracking, and network monitoring and provisioning—are common to both data and voice networks. On the other hand, data networks tend to have unique characteristics such as shorter provisioning intervals and a wider range of network bandwidths. Their reliability requirements call for new network management capabilities. The final data networking papers in this issue present the underpinnings of AT&T's network management strategy, including the application of expert systems techniques to network management.

Just as an overall plan is needed to interconnect the diverse elements that constitute a data network, an equally comprehensive plan is needed to manage that network. AT&T's plan for network management, the Unified Network Management Architecture (UNMA), encompasses data and voice networks and provides a framework for managing individual elements of a network as well as the network as a whole. The keys to UNMA are a common network management protocol (NMP), standard across vendors and networking domains, and the network management integrator (NMI), a system that integrates information from existing management systems to provide a unified network view. The paper by Cohen, Kan, and Pennotti provides background, models, and functional specifications to help the reader understand the UNMA. The

UNMA is focused on bringing to network managers a consistent, user-friendly view of their networks that integrates information from a variety of network equipment. Under UNMA, equipment from AT&T and other manufacturers can be integrated; the complete spectrum of equipment—from host applications to transmission services—is covered.

Marques' paper describes an expert system for managing Datakit VCS networks. The system, implemented as a forward-chaining production system, is designed for clerks, technicians, and network administrators who respond with varying skill and experience levels to end-user trouble reports and network-generated alarms. The system lets them deal with problems at a high level of abstraction. Based on input consisting of a symptom description and minimal context information, the system targets a plausible subset of all network components for analysis, formulates an agenda that specifies an optimal search order and, finally, executes the agenda-driven investigation. The system interrogates and manipulates network components via a standard login to a conventional operations support system (OSS), and tries, wherever possible, to correct encountered faults. It prescribes detailed corrective procedures when human intervention is required. Feedback from the network and end users gauges the system's effectiveness and is incorporated automatically into the planning phase of the subsequent analysis. The system can be modified to reflect experience gained from a particular data network.

References
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2. J. W. Timko, "AT&T Systems Architecture," AT&T Technology, Vol. 2, No. 3, 1987, pp. 4-13.

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