

# THE UNIVERSAL PORT CONCEPT

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Universal ports (UPs) are the interfaces by which telecommunications services customers access the rich set of network capabilities provided by Universal Information Services (UIS). The most obvious manifestation of UPs is the physical outlet into which customers plug their voice, data, and integrated voice/data terminals. Behind the physical outlet is an advanced voice/data networking protocol with sophisticated signaling capabilities that give access to the UIS network intelligence. By means of this protocol, universal ports become the vehicle by which customers achieve the high degree of service flexibility, network control, and management offered by UIS.

## Introduction

Universal ports are a family of interfaces that provide access to the wide range of voice and data networking services available both now and in the future.<sup>1</sup> The family includes present-day Integrated Services Digital Network (ISDN) interfaces that have begun to bring UIS capabilities to the customer. ISDN generally provides data speeds, performance levels, enhanced network control, and a degree of interchangeability of terminal equipment that have not been available previously. The ISDN basic rate interface (BRI) and primary rate interface (PRI) are existing industry standards for integrated access to telecommunications networks. The universal port concept takes the next step, building on ISDN capabilities, to deliver a substantially enhanced set of attributes. Where ISDN interfaces open the door for customers to access new network capabilities, the universal port of the future will swing the door wide open to allow easier, more flexible, and more feature-rich information movement and management.

The universal port is intended to provide flexible, high-performance access to the key service capabilities of UIS. These services create a need for both enhanced signaling and enhanced data communications capabilities. Specifically, the desire for increased cus-

Panel 1. Acronyms and Abbreviations in This Paper	
ACSE	application common service elements
ACSR	automatic customer station rearrangement
BRI	basic rate interface
CAD/CAM	computer-aided design/ computer-aided manufacturing
CLNP	connectionless network protocol
CPE	customer premises equipment
CRC	cyclical redundancy check
CSMA/CD	carrier-sense multiple access with collision detection
DS	directory service
DSL	digital subscriber line
FEC	front-end clipping
FTAM	file transfer access and management
ICLID	individual calling line identification
ISDN	Integrated Services Digital Network
LAN	local-area network
LAPD	link-access procedures for D channel
LLC	logical link control
MAC	media access control
MHS	message handling service
MOS	mean opinion score
OSI	open systems interconnection
PCM	pulse-code modulation
PLP	packet layer protocol
POTS	plain old telephone service
PRI	primary rate interface
TCP/IP	transmission control protocol/ internet protocol
UI	unnumbered information
UIS	Universal Information Services
UNI	UIS network interface
UP	universal port
UPA	universal port adapter
UPM	universal port module
XID	exchange identification

customer control of network resources drives the need for flexible yet powerful signaling and data communication. Increased customer control is illustrated by the following services:

- *Adaptive, logically provided services* available in real time rather than in minutes, weeks, or months. An example is multimedia teleconferencing in which high-speed, multipoint data connections for image sharing can be established in the middle of an audio conference call.
- *Bandwidth on demand*, in which high data transfer rates can be achieved for short periods, not limited by rates associated with the channelized structures used in the past for data transmission.
- *Brokering*, in which customers have convenient, user-friendly access to the wide variety of information resources and transaction services available in the marketplace.
- *Virtual private networking* for data and voice, in which the operational advantages and economies of a shared network are provided to a customer along with many of the benefits of a private network.

For all services, the UP should be application-transparent—that is, the resources obtained from and through the network should appear to a customer as if they were on customer premises. This implies high performance levels in terms of low delay, fast response, and high throughput. These performance needs strongly influence the requirements for the UP and the networking capabilities associated with it.

A key concept associated with the UP is the need for portability and interchangeability of terminal equipment so that customers can easily move terminal equipment from one location to another and achieve the same functionality. An initial step was taken in the 5ESS® switch 5E5 generic software with the automatic customer station rearrangement (ACSR) feature of ISDN.<sup>2</sup> The UP is intended to extend ACSR so that it is more flexible and ubiquitous. A minimum number of different universal

ports should be available beyond ISDN to accommodate a wide variety of terminal equipment and minimize the amount of incompatible equipment. Accordingly, a small number of standard, high-performance interfaces will be developed for the customer premises equipment (CPE) industry to build to.

Finally, universal ports are likely to yield economic benefits as well as value-added features. More efficient multiplexing of services and further integration of access create opportunities for cost savings for the customer. With electronic provisioning, there are potential savings to both the customer and the network provider. In addition, the UP will facilitate access to the network, thus stimulating the growth of new services as well as increasing network usage overall. The UP itself will provide marketable features to customers while making available the range of value-added services and capabilities associated with information movement and management.

#### Definitions of Terms

Some terms need to be defined so the reader will understand their specific use in this document:

- *Universal ports*—A select family of standard access interfaces that will enable users to connect their communications equipment, regardless of make, model, or function, to the UIS intelligent network. Universal ports will allow terminals to be moved from one network location to another while maintaining the same functionality. An analogy can be drawn to the ubiquitous electrical power outlet. Although there are multiple interfaces (e.g., 120 V and 240 V), the vast majority of appliances can be plugged in and operated with no special action on the part of the customer.
- *UIS network interface (UNI)*—A minimal number of interfaces between the network and the customer premises. These interfaces are generally subject to regulation. UNIs carry the traffic from the UPs that is destined for the network. The maximum end user information bandwidth is limited by the UNI physical

interface rate.

- *Universal port module (UPM)*—Customer location equipment that handles the protocol conversion, rate adaptation, flow control, and other functions required between the UPs and the UNI.
- *Universal port adapter (UPA)*—Converts a non-UP terminal interface to the “native” UIS UP protocol. The UP architecture is shown in Figure 1.

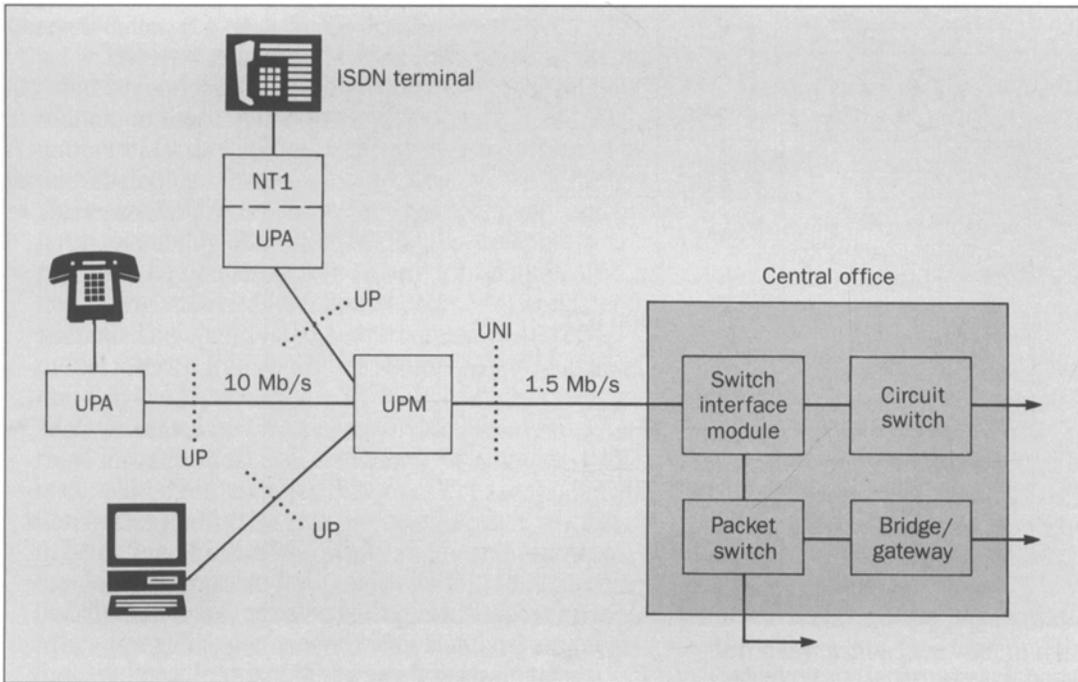
#### Evolution of the Universal Port

It is apparent from an examination of the current telecommunications network that a universal port for plain old telephone service (POTS) exists. The ubiquitous miniature modular connector for the RJ11 tip/ring interface provides readily accessible, cost-effective access to a broad range of network capabilities. As users' communications needs have advanced steadily past voice telephony, however, the limitations of the analog tip/ring interface have become constraining. First, its analog nature is inconsistent with the performance/cost advantages of an all-digital network. Second, its in-band, stimulus-based signaling scheme is not adequate to meet the increasing needs of applications requiring the interaction of distributed intelligence and control. Third, the bandwidth available is insufficient to meet the performance needs of data applications requiring low delay, high throughput, and fast response.

To meet these needs, among others, ISDN has been introduced. ISDN provides a high-speed digital interface with sophisticated, out-of-band, message-based signaling and control. As ISDN was introduced on the 5ESS switch, it provided the following customer features:

- Basic circuit-switched data
- Basic circuit-switched voice
- Basic D channel X.25 packet switching
- Intraswitch individual calling line identification (ICLID)
- Special B channel X.25 packet switching over a permanent B channel.

As the capabilities of the 5ESS switch have been



**Figure 1. Universal port architecture.**

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increased, additional capabilities are becoming available in 5E5 generic software. These include:

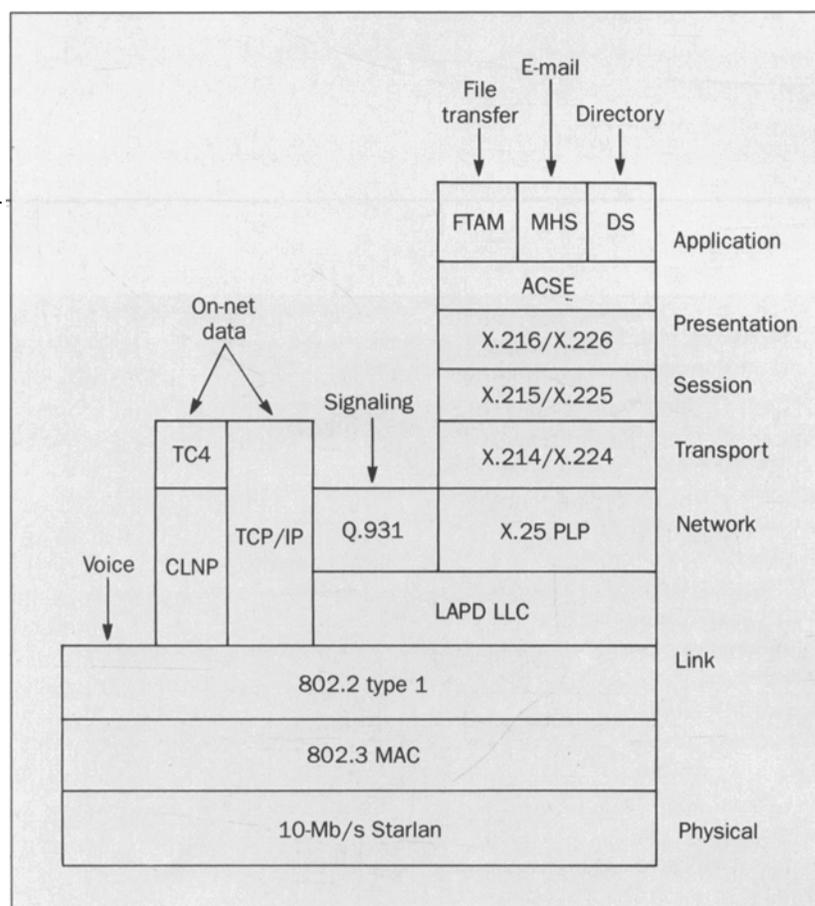
- **Multipoint digital subscriber line (DSL)**—Support is provided for connecting a maximum of eight terminals of a single customer to a single digital subscriber line. Features and services may be assigned on a per-user basis.
- **Automatic customer station rearrangement (ACSR)**—This feature rearranges customer dialing numbers automatically when a station is moved.
- **On-demand X.25 B channel packet switching**—This feature permits call setup of an X.25 packet link at customer initiation.

Even with these increased capabilities, certain aspects of the UIS vision for universal ports have yet to be realized. These include:

- **Increased bandwidth**—User applications such as

- **paging through high-definition image catalogs and conveying real-time video** will require that increasingly higher bandwidths than that of the PRI be delivered to the end user. An important aspect of the information content of such signals is the burstiness of the communication. Thus, although the average information content is on the order of kilobits, several megabits are necessary to meet the response time or delay needs of the user. Another clear trend is toward multiplexing several different types of information in a single multimedia call.
- **Local networking**—In the work area, a single interface should support multiple terminals (e.g., printer, fax, phone), much as multiple data devices are supported by local-area networks (LANs). As an evolutionary step from the ISDN passive bus, the UP should serve several terminals and allow local high-performance in-

**Figure 2. Universal port protocol stack. See Panel 1 for definitions of abbreviations.**



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terminal communication. Interterminal communication is important not only for data communication, but also for voice features such as intercom and extensions.

- **Bandwidth on demand**—A key goal of UIS is to provide customers with as much bandwidth as necessary for their applications, with the capability of billing for only the network resources used. Once again, this is an area where ISDN has made positive steps via its support of the X.25 protocol on a B channel, but further flexibility up to the physical capacity of the medium is required.
- **Nondisruptive reconfiguration of CPE**—In a multipoint arrangement, adding or removing terminals shall not cause any traffic disruption. This includes relocating terminals from one UP to another while preserving network recognition of the terminal.
- **Electronic provisioning**—It should be possible to make all changes in service or service configuration without physical rearrangement of network resources.

In meeting these additional requirements for a universal port, a smooth evolution and reasonable cost/complexity tradeoffs are of utmost importance. In fact, to satisfy all of the requirements listed above for the anticipated range of applications would require bringing fiber to the desk and defining the universal port much as it is in the work on broadband ISDN that is just now starting in domestic and international standard-making organizations. It is unlikely, however, that such an interface will be cost-effective—except for very specialized applications—for quite some time.

In view of these objectives, the next step in the universal port evolution will be to build on the strengths of ISDN at interface rates substantially below the hundreds of megabits per second associated with broadband ISDN. The intention is to achieve additional economy, flexibility, and customer control. The remainder of this paper discusses the engineering considerations that drive the UP evolution.

### Characteristics of a Next-Generation Universal Port

The next-generation UIS UP will be an evolutionary step beyond ISDN that offers customers capabilities in addition to those of the passive bus interface of ISDN. A number of factors influence the precise definition of interface attributes. These include:

- *Open standard interfaces*—For transportability and interchangeability of the widest range of customer premises equipment and to ensure a smooth evolution, using standard interfaces becomes especially important. The open systems interconnection (OSI) model offers a framework for standard interface definition (Figure 2).
- *Metallic interfaces and wiring*—While fiber is making rapid inroads, most office and loop distribution wiring is metallic. This suggests that, to effect a smooth evolution in a cost-effective manner, the interface will have to be defined for the bandwidth range and physical topology appropriate for metallic wiring. In the loop distribution plant, metallic wiring can support up to 2 Mb/s (megabits per second) with standard engineering practices. In the office environment, metallic wiring can support several megabits per second. The recently proposed standard for the Starlan local-area network supports 10 Mb/s on twisted pair.
- *Broad application support*—The interface should support a broad range of applications and performance levels in a cost-effective manner. Table I shows typical use of selected applications.<sup>3</sup> Certain more forward-looking applications, such as the catalog browsing identified earlier, require several megabits per second to meet the response time needs of the user. However, with the exception of those requiring real-time, high-quality video, it is apparent that users could benefit substantially from bandwidths in the range of a few megabits per second.
- *Smooth, cost-effective evolution*—it would doubtless be more efficient to do a “desert start,” that is, to start fresh with no accommodation of existing hardware and software. In reality, however, it is necessary to

Table I. Application Traffic Estimates

Application	Peak data rate (kb/s)	Duty factor (%)
Terminal host connection	9.6	5
Facsimile	64	20
Voice without silence detection	64	100
Voice with silence detection	64	40
Image—compressed	64	30
Personal computer file transfer	100	30
Image—noncompressed	256	10
Laser printer	256	50

evolve in such a fashion that existing capabilities are provided economically. Thus, a hard constraint on any system design is that POTS be supported efficiently.

### Interface Definition

The universal port must be defined as a full seven-layer interface with functionality as given by the OSI model. Upper layers of the protocol are application-dependent and are thus only briefly discussed here. At the lower layers of the protocol, several standards are candidates for supplying the required functionality. These include IEEE 802.3, 802.5, 802.6, and 802.9. Each has strengths and weaknesses. For the purposes of illustration, the “grandfather” of this group, IEEE 802.3 with its later modifications for running on metallic twisted pair (Starlan), will be discussed.

Starlan provides a packetized interface and thus appears to have the required attributes in terms of more efficient multiplexing, further service integration, and bandwidth on demand. It uses an inherently simple protocol and is widely supported by a number of manufacturers, so its costs are reasonable and it has an established base of users. There are, however, a number of concerns with its suitability for use as a universal port. Of these, probably the most pressing is its performance in transporting deterministic traffic, which has stringent

delay requirements.

The access control mechanism specified in the 802.3 standard is carrier-sense multiple access with collision detection (CSMA/CD). Although CSMA/CD can be shown to be fair with respect to its allocation of bandwidth, it does not guarantee bounded delay for arbitrary loads. Numerous researchers such as Maxemchuk<sup>4,5</sup> have proposed modifications of 802.3 to allow it to deal with voice and other deterministic traffic by giving this traffic higher priority through some mechanism. Some of these schemes are compatible with existing 802.3 protocols. Alternatively, if the load on the local-area network is kept to reasonable limits, the performance is adequate to support voice. For example, measurements have shown that, with a fixed number of sources generating traffic loads of up to 80 percent of total traffic capacity and each source experiencing a 6 percent collision rate, access delay does not exceed 10 ms (milliseconds), and the vast majority (99.9 percent) of delays are less than 5 ms.

**Physical Layer.** In defining a physical layer for a universal port, a number of questions must be answered. For example, what is the appropriate medium (wire, coax, fiber)? What are the distances that must be supported between a UPM and a terminal? What are the bandwidth needs of the end user? As discussed earlier, a reasonable next step in the evolution of the UP would restrict the medium to metallic wiring. The physical topology and allowable distances depend somewhat on the target market, but the star topology and wiring-closet-to-desk distances of up to 100 meters will allow near ubiquitous support of the existing embedded base.

With respect to bandwidth needs, it is prudent to allow the maximum achievable for the technology. The Manchester-encoded 10-Mb/s Starlan physical interface clearly demonstrates the feasibility of implementing a physical layer with the required attributes.

**MAC Layer.** The media access control (MAC) layer controls access to the multipoint shared transmission facility. This layer is common to all applications running on the universal port. Within an 802.3 packet, six octets are used for source and destination addresses, two octets

**Table II. Front-End Clipping Voice Performance**

	Front-end clipping duration (ms)	Proportion of speech clipped (%)	Frequency of clip occurrence (FECs/min)
Criterion	≤15	≤0.5	≤18
Measured	≅5	0.36	≅17

for length, and four octets for a cyclic redundancy check (CRC). The data field is variable up to a maximum of 1500 octets.

To transport voice on an 802.3 network, packets should be short to minimize delays from forming packets. The minimum 802.3 packet size is 64 octets. After octets for the address and other overhead items are subtracted, 46 octets remain for voice. For voice encoded by pulse-code modulation (PCM) techniques (eight pulses per sample and 8000 samples per second), each voice packet can hold approximately 5 ms of speech.

Consider a system that buffers a packet of voice at play out to allow for variability of access delays. CSMA/CD access delays greater than 5 ms will cause the packets to be dropped. The design criterion for speech packet drop rate is 0.1 percent, and no more than 10 consecutive voice packets shall be dropped.<sup>6</sup> Voice performance impairments caused by lost packets manifest themselves as front-end clipping and midspeech burst clipping. Front-end clipping occurs when the first part of the most recent speech burst is discarded. Burst clipping occurs when short speech durations in the middle of one or more contending speech bursts are discarded. Table II compares experimental data on front-end clipping with metrics for good-to-excellent performance characterized by a mean opinion score (MOS) greater than 4. For midspeech burst clipping, little or no impairment results from clipping of 1 percent or less with durations of 5 ms or less, which is compatible with the desired performance.

**Link Layer.** IEEE 802.3 specifies functionality only through the MAC layer, which provides only part of the

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traditional layer 2 functions. Additional layer 2 functionality is specified by IEEE 802.2 for logical link control. Type I operation [which includes unnumbered information (UI) frames and exchange identification (XID) frames for testing] is sufficient. At this layer of the protocol is the first case of multiple protocol stacks that depend on the application. For example, for compatibility with ISDN-connection-oriented traffic, LAPD (link access procedures for D channel) would be followed.

**Network Layer.** At layer 3 of the protocol stack, multiple protocol stacks may be required as well. ISDN Q.931 would be appropriate for real-time message-based end-customer-to-network control. With Q.931 signaling, the user has access to the existing ISDN features offered by the 5ESS switch. These features include supplementary services such as hold, conference, transfer, and drop. Additional enhancements for Q.931 would be needed to handle such things as multimedia conferencing. For data transfer, X.25 packet layer protocol (PLP) or connectionless network protocol (CLNP) would provide connection-oriented or connectionless transport respectively.

**Higher Layers.** An illustrative universal port protocol stack in Figure 2 shows a few representative applications to illustrate the use of OSI standards for networking. For example, electronic mail would utilize the message handling service (MHS) specified in CCITT X.400, riding on layers 4, 5, 6, and the lower part of layer 7 via the X.214/224, X.215/225, X.216/226, and application common service elements (ACSE) protocols, respectively. Other applications include file transfer access and management (FTAM) and the X.500 standards for directory services.

#### **Required Network Capabilities**

Network support of the universal port will require increased network intelligence and numerous advances in the way the network is controlled and maintained. Not the least of these advances is designating network elements and connectivities by virtual means as opposed to physical means. In today's network,

a user or terminal device is associated with the physical pair that provides the telecommunications service to the location. This is true for both signaling and maintenance and administrative operations. However, for portability and interchangeability of terminal equipment, the network must be able to associate a terminal with its location at any time. Likewise, bandwidth on demand implies that the network must be able to bill not only on a fixed-channel basis, but also for the network capabilities actually used in a particular interaction.

To achieve the performance needed for data applications, high-speed packet communications will have to be supported. To make high-performance packet links possible, frame relay concepts will have to be supported and advanced. To allow users to locate and access the capabilities they require in a user-friendly fashion, intelligent network concepts such as brokering will have to be supported. In addition, wide-area name servers and other directory-related functions will have to be implemented.

The architecture in Figure 1 shows a switch interface module where the loop transmission system is terminated and traffic groomed for either the circuit switch or the packet switch. Additional functionality that might be required for various user applications includes bridging or gateway functions.

While this list involves a rather substantial change in network architecture and maintenance, as can be seen in some of the accompanying papers in this issue, the change can be effected on an evolutionary rather than revolutionary basis. ISDN has made many positive steps toward the UIS vision, and the implementation of its concepts is at hand.

#### **Advantages and Benefits of the Universal Port**

Economic and applications studies have identified significant potential benefits that the universal port brings to the customer. These advantages are relevant to customers whose present mode of operation consists of separate voice and data CPE and network services. They are also relevant to customers who presently have ISDN capabilities.

The universal port provides greater effective bandwidth to the customer. For any application, virtually all the access bandwidth is available on a short-term basis for data transport. The result is faster response, higher throughput, and a wider range of applications. Applications such as compressed video, computer-aided design and manufacturing (CAD/CAM), multimedia teleconferencing, and catalog browsing benefit significantly from this feature. The enhanced signaling that provides bandwidth on demand, accommodating midcall changes in transport requirements, also benefits these applications. The access to end-to-end frame relay data networking offers similar benefits.

The integrated voice/data local-area networking features provide a convenient way to have intercom and extensions for voice service as well as an efficient means for interconnecting data equipment on the customer's premises as in traditional LANs. There are cost benefits in terms of more efficient use of premises wiring, the potential to use existing wiring, and the simplicity of adding and removing terminal equipment. The last feature leads to a significant advantage in terms of growth potential without making equipment obsolete or requiring a substantial amount of new equipment. It also leads to cost benefits, both to the end user and the network provider, by eliminating long and costly provisioning intervals to add equipment or new services.

There are other operations-related advantages beyond provisioning. There are maintenance and administration savings and benefits for those customers who prefer that the network provider be responsible for the telecommunications service, as in centrex service. There are similar benefits to the network provider resulting principally from the high degree of access integration.

Perhaps the most important advantage of the UP is that it provides a new environment for customers to access the network, one that makes utilization of the network convenient and cost-effective so that it becomes an integral part of the business operations of a company. It stimulates use of new capabilities by customers and in-

creases revenue to network service providers. It encourages network usage via usage-sensitive billing so that the customer pays only for network resources that are used. It opens the door to expanded markets for network providers and information service providers to create and deliver a multiplicity of new services.

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#### Biographies (continued)

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