NISTIR 5595

Application Software Interface: ISDN Services for an Open Systems Environment

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Executive Summary

This report focuses on a standard means of specifying the interface between applications and one of the communications subservices available in modern computer systems. This standard interface is an appropriate element of the enabling technology required for the proposed National Information Infrastructure (NII).

The NII is a vision for using presently emerging information technology to improve products and services, create new ones, compete more effectively, and empower people to be more creative and efficient. The key prerequisite for the NII is the availability of computing environments that consist of distributed, heterogeneous, networked applications, databases, and hardware. The concept of a Federal computing environment that is built on an infrastructure defined by open, consensus-based standards is well on its way to becoming a de facto means of organizing these systems. Such an infrastructure is called an Open System Environment (OSE).

An OSE supports interoperability, portability, and scalability of computerized applications across networks of heterogeneous, multi-vendor platforms by forming an extensible framework that allows services, interfaces, protocols, and supporting data formats to be defined in terms of nonproprietary specifications. Typically, these specifications have evolved through open (public), consensus-based forums.

A selected suite of specifications that defines the interfaces, services, protocols, and data formats for a particular class or domain of applications is called a profile. NIST has defined a specific federal application profile composed of publicly available specifications from industry, federal, national, international, and other sources. This profile, named the Application Portability Profile (APP), provides the functionality necessary to accommodate a broad range of federal information technology requirements.

The APP is not a standard. It is a framework, detailed in NIST Special Publication 500-210, designed to help users determine which specifications to use. The APP, however, does not imply that there is any integration of other commonality among the specifications it contains. Furthermore, the APP is not intended for use in system integration.

A specific organization will not necessarily require all of the recommended specifications in the APP. As the U.S. Government's OSE profile, this guidance is provided to assist federal agencies in making informed choices regarding the selection and use of OSE specifications, and in the development of more selective application profiles based on the APP. It is directed toward managers and project leaders who have the responsibilities of acquiring, developing, and maintaining information systems supported by heterogeneous application platform environments.

One of the specifications evaluated in the APP is the Application Software Interface (ASI) for Integrated Services Digital Network (ISDN) services. The ASI is one of the Network Services evaluated in the APP. It is an implementation agreement produced by the North American ISDN Users' Forum, based on national and international standards for ISDN. This report provides specific supplementary information to the APP so that users may make informed judgements on the applicability of the ASI specification to their environment.

The ASI fits within the architecture of the OSE Reference Model (OSE/RM) and provides services that are within the scope of the APP Network Services Functional Area. The APP defines network services for data communication, transparent file access, personal/micro computer support, and

remote procedure call. These network services provide the capabilities and mechanisms to support distributed applications requiring data access and applications interoperability in heterogeneous, networked environments. Data communication includes interface and protocol specifications for reliable, transparent, end-to-end data transmission across communications networks. The ASI architecture defines reference points that correspond to the interfaces defined in the OSE/RM for the APP data communications network services.

The ASI specification focuses on the definition of a common application interface for accessing and administering ISDN services provided by hardware commonly referred to in the vendor community as Network Adapters (NAs). It is intended to be independent of the data protocol type and it does not address either peer-to-peer protocol or interoperability issues.

While the ASI was developed for an environment that utilizes ISDN technology, the specification is also applicable to other environments that utilize other telecommunications technologies. All these technologies, including Asynchronous Transfer Mode (ATM) as well as ISDN, are rapidly becoming available in telecommunications networks throughout the United States. Since telecommunications services will be a major element of the NII, the ASI deserves consideration as an element of the enabling technology required for the proposed NII.

The key issue is to determine how the ASI fits into descriptions and specifications of the NII. The NII architecture is still under development but it is already clear that the ASI can fit into the specification of NII environments in three ways:

(1) For those environments in the NII that incorporate the OSE/RM and the APP, the ASI is automatically included.

(2) For some other NII environments, an appropriate profile can be constructed by a judicious combination of present ASI specifications with other publicly available interface specifications.

(3) Future ASI work to include additional interfaces specifications could satisfy needs for additional environments within the NII.

1. Introduction

Federal agencies are under increasing pressure to use information technology to improve efficiency and delivery of services to the public. Systems that were originally developed as isolated islands of computing no longer meet enterprise-wide needs for common application architectures, communication networks, and databases. In addition, it is no longer possible for any single vendor to supply all of the required information technology systems and services. Since very large homogeneous environments are no longer practical in many cases, users need open systems that provide interoperability of products and portability of people, data, and applications throughout heterogenous computing environments.

The need to improve portability and interoperability has resulted in widespread interest in standards such as the Portable Operating System Interface for Computing Environments (POSIX) and Government Open System Interconnection Profile (GOSIP)[1]. POSIX and GOSIP, however, are not sufficient to address the full spectrum of needs, even within their stated scopes of concern. Therefore, the National Institute of Standards and Technology (NIST) has published an Application Portability Profile (APP) to provide additional guidance to federal agencies in making informed choice regarding the selection and use of OSE specifications and in the development of OSE profiles.

The APP provides two types of guidance based on the functional service areas present in an OSE. First, specifications are provided for each functional service area described in the APP. Second, and equally as important, evaluation criteria to assist in making qualitative assessments of the recommended specifications are defined and applied. The NIST assessments are, in fact, the results obtained by applying these evaluation criteria to the recommended specifications.

Users of the APP are expected to use the evaluation criteria to make their own assessments of the recommended specifications. Further, users may choose to assign weighted values to elements of the criteria based on their own judgement of the relative importance to be given each element. Users may also require vendors to use the evaluation criteria to assess specifications that the vendors choose to propose as an alternative to the specifications recommended in this document. In any case, the user of the APP needs to have some technical knowledge of the applicable elements in a given profile.

1.1 Scope

This report provides the specific information required to evaluate the Application Software Interface (ASI) as one component of an Open System Environment (OSE) which might include POSIX, GOSIP and other specifications to provide the functionality necessary to address a broad range of federal information technology requirements.

The ASI is one of the Network Services evaluated in the APP. It is an implementation agreement produced by the North American ISDN Users' Forum, based on national and international standards for ISDN. This report provides specific supplementary information to the APP so that users may make informed judgements on the applicability of the ASI specification to their environment. The next two sections provide introductory material on the Application Portability Profile and Integrated

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[1]GOSIP is transitioning to Profiles for Open System Internetworking Technologies (POSIT), which will provide guidance but will not mandate procurement or any other form of compliance.

Services Digital Networks. Section 2 briefly describes the definition of an open system environment, the OSE Reference Model, and specific components of the Application Portability Profile while Section 3 examines the history and present status of ISDN technology. The intent is to provide context to the reader on the relationships between ISDN and the APP.

Section 4 provides an overview of the ASI and Section 5 applies the APP evaluation criteria to ASI. The API and EEI interfaces are, in general, the subject of on-going refinement. Section 6 looks at possible near term developments that are of interest.

Finally, this report includes an extensive bibliography to assist interested parties in obtaining the specifications, requirements and reports that contain detailed information on the various components of the APP and the ASI.

2. Open System Environment

An Open Systems Environment (OSE) is a computing infrastructure that supports portable, scalable, and interoperable applications through standard services, interfaces, data formats, and protocols. The standards may consist of international, national, industry, or other open (public) specifications that are available to any user or vendor for use in building systems and products that meet OSE criteria. In an OSE, users will be able to buy and use applications that

- Execute on any vendor's platform and use any vendor's operating system;
- Communicate and interoperate over any vendor's networks;
- Access any vendor's database; and
- Interact with users through a common human/computer interface.

Applications in an OSE are scalable among a variety of platform and network configurations, from stand-alone microcomputers, to large distributed systems that may include microcomputers, workstations, minicomputers, mainframes, and supercomputers, or any configuration in between. Thus, an application will run in an OSE irrespective of the amount of resources available in that environment. Of course, the user will find that satisfactory performance will require the availability of sufficient resources in the OSE. For example, the available data processing power and communications bandwidth are significant factors in determining the speed of response for many applications.

Applications interoperate by using standard communication protocols, data interchange formats, and distributed system interfaces to transmit, receive, understand, and use information. The process of moving information from one platform, through a local area network, wide area network, or combination of networks to other platforms should be transparent to the application and the user. Locations of other platforms, users, databases, and programs should also be transparent to the application. In short, an OSE supports applications through the use of well-defined components: that can be used as system building-blocks.

2.1 OSE Reference Model

The Institute of Electrical and Electronics Engineers (IEEE) POSIX Working Group P1003.0 describes an OSE Reference Model (OSE/RM) that provides a framework and a terminology for describing open system concepts.

As shown in Figure 1 below, the OSE/RM is composed of three entities with two interfaces.

- The **Application Software Entity** consists of the programs that perform specific tasks for the user. The application software also includes any associated data, documentation, and training.
- The **Application Platform Entity** is the integrated system of hardware and software components that provide the services used by application software.

- The **Platform External Environment** consists of those system elements that are external to the application software and the application platform (e.g., services provided by other platforms or peripheral devices).

- The primary function of the **Application Program Interface (API)** is to support portability of applications. The OSE/RM defines API services for (1) the internal system, (2) communication, (3) information interchange, and (4) the human/computer interface.

- The **External Environment Interface (EEI)** supports information transfer between both (1) the application platform and the external environment and (2) applications executing on the same platform. Mainly concerned with interoperability, the EEI provides services for (1) communication with other application platforms, (2) information transfer to and from external data stores, and (3) information exchanges between human users and the computer.

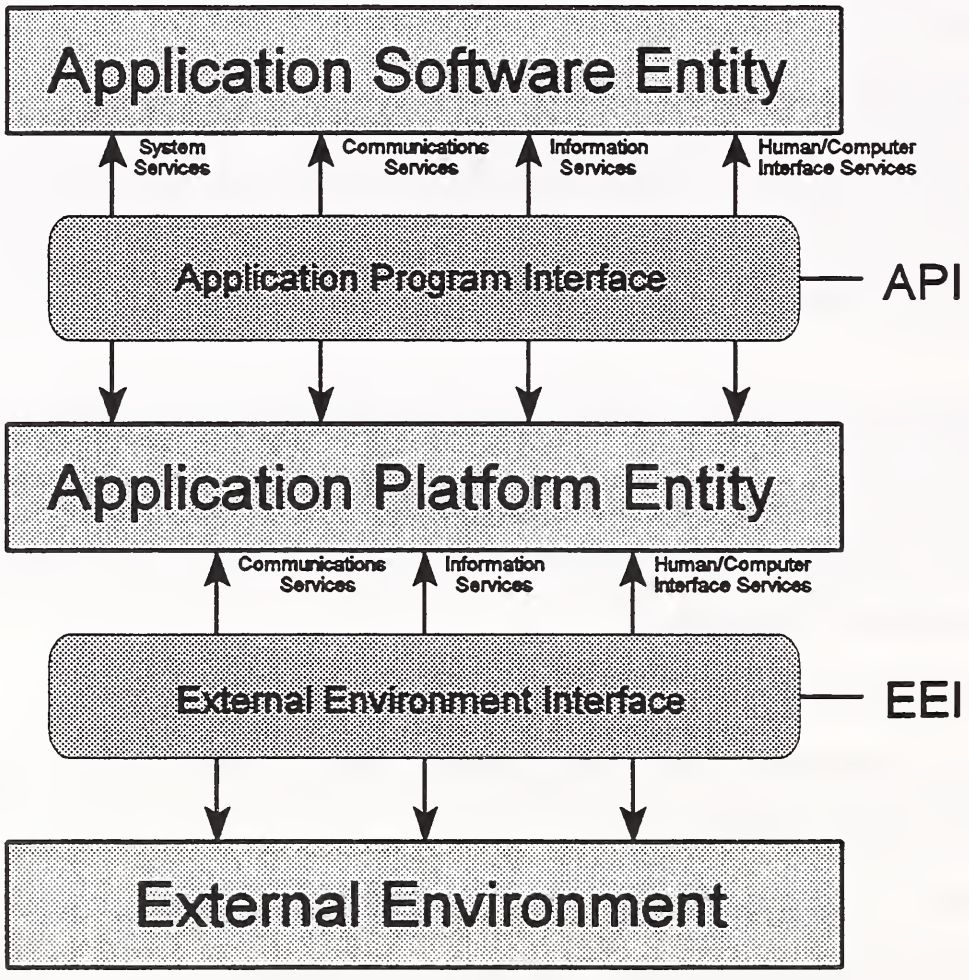

Figure 1. Open System Environment Reference Model (OSE/RM)

In its simplest form, the OSE/RM illustrates a straightforward user-supplier relationship: the application software entity is the user of services and the application platform and external environment entities are the suppliers. The interfaces between the three entities define the services that are provided, as seen at two distinct places within the reference model.

2.2 Application Portability Profile

An OSE profile is composed of a selected list of open (public), consensus-based standards and specifications that define services in the OSE/RM. The selected list of standards and other specifications define a set of complementary services that are made available to applications in a specific domain. Examples of domains might include a workstation environment, an embedded process control environment, a distributed environment, a transaction processing environment, or an office automation environment, to name a few. Each of these environments has a different cross-section of service requirements that can be specified independently from the others. Each service, however, is defined in a standard form across all environments.

The Application Portability Profile is an OSE profile designed for use by the U.S. Government. It covers a broad range of application software domains of interest to many federal agencies, but it does not include every domain within the U.S. Government's application inventory. Detailed descriptions of the APP services are available in NIST Special Publication 500-210 Application Portability Profile (APP). The individual standards and specifications in the APP define data formats, interfaces, protocols, or a mix of these elements.

2.2.1 APP Service Areas

The APP defines seven service areas that are closely related to the OSE/RM. As shown in Figure 2 below, the seven areas are: (1) operating system services, (2) network services, (3) data management services, (4) human/computer interface services, (5) graphics services, (6) data interchange services, and (7) software engineering services. (Several of the services areas appear at both the API and the EEI and software engineering services are applicable in all areas of the API and EEI.)

Each of the APP service areas addresses specific components around which interface, data format, or protocol specifications have been or will be defined. In addition, security and management services are common to all of the service areas and pervade these areas in one or more forms.

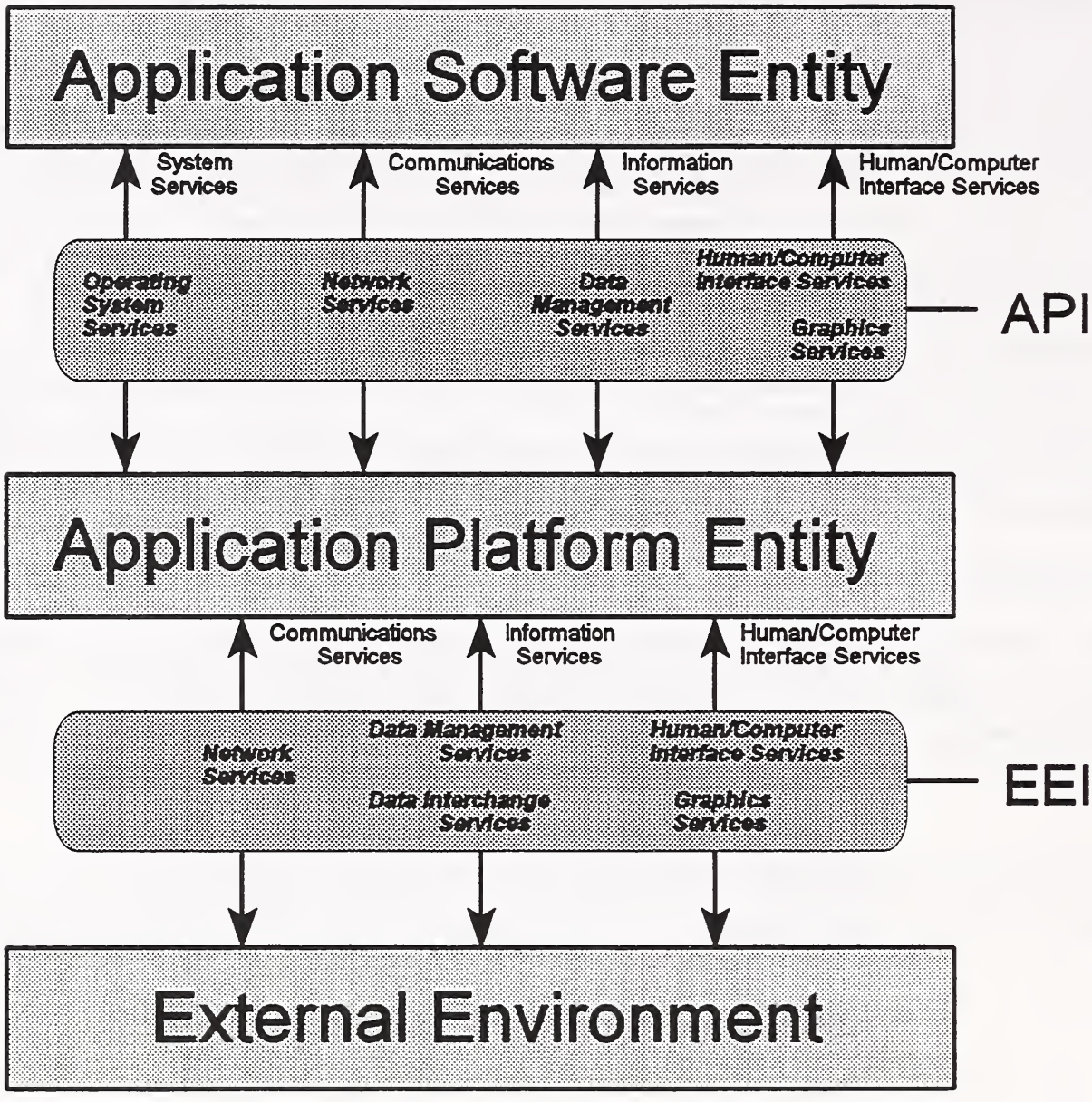

Figure 2. APP Service Areas and the OSE/RM

2.2.2 Evaluation Criteria

The APP defines evaluation criteria to assist in making qualitative assessments of the APP specifications. Users of the APP are expected to use these evaluation criteria to make their own assessments of the recommended specifications. Further, users may choose to assign weighted values to elements of the criteria based on their own judgement of the relative importance to be given each element. Users may also require vendors to use the evaluation criteria to assess specifications that the vendors choose to propose as an alternative to the specifications recommended in this document. In any case, the user of the APP needs to have some technical knowledge of the applicable elements in a given profile.

Each service area in the APP is preceded by a summary status report of all specifications reviewed. The summary status report in the APP relates the results of major evaluation criteria (e.g., level of consensus, completeness, etc.) to a graphic representation. With one view, all of the specifications in a particular service area can be compared to determine relative coverage of the area. Users may use this information to determine where they should concentrate their efforts in tailoring and augmenting application and organizational profiles.

The APP entry for ISDN ASI is shown in Figure 3. The seven specific evaluations of the ASI are also described in paragraphs of the APP.

SPECIFICATION	LOC	PAV	CMP	MAT	STB	DFU	PRL
ISDN ASI	●		○	●	○	○	○

Legend: ●-high evaluation ○-average evaluation blank-low evaluation

LOC -- Level of consensus
PAV -- Product availability
CMP -- Completeness
MAT -- Maturity
STB -- Stability
DFU -- De facto usage
PRL -- Problems/limitations

Figure 3. ASI Summary Status Report in the APP.

2.2.3 Strategic Evaluations

The APP provides guidance to the users on the strategic value of each specification. The valuations are made according to the following guidelines:

- Strategic now—In selecting these specifications, users would be reasonably safe in making substantial investment and long-term plans covering mission-critical systems and the infrastructure needed to support them. Changes are expected to be upwardly compatible.

- Strategic in the future—Specifications that are subject to change but appear to be headed for standardization fall into this category. Existing standards that may be subject to changes that are not entirely upwardly compatible also fall into this category. There are some long-term risks involved, but the actions of the consensus-building process will tend to minimize them. Users should select these specifications where strategic specifications are unavailable and an investment must be made, but should plan for possible evolution in the future.

- Nonstrategic—These specifications are stop-gap measures recommended with the warning that any user investment will be at significant risk. They are not appropriate for long-term planning. Users should, for these reasons, minimize their risk by minimizing investment.

The APP evaluates the ASI as strategic in the future.

3. Integrated Services Digital Networks

NIST has identified the deployment of Integrated Services Digital Network (ISDN) technology as the next step in the evolution of the telecommunications industry. This emerging technology offers immense potential benefits to govemment, industry and personal users through its capability to exchange voice, data and image information concurrently over telephone lines. With ISDN, computer and communication technologies converge to speed and simplify the flow of information between sender and receiver in ways that were not previously possible.

ISDN is a set of integrated telecommunications services, available over public and private telecommunications networks. The services are defined over a digital point-to-point circuit-switched medium. Thus, unlike a packet-switched medium like X.25, ISDN establishes a dedicated circuit between two machines (e.g., computer or bridges). It can transmit either packetized or asynchronous digital information without a modem, so it can be used for anything a modem can, including connecting two LANs. For instance, work at home applications that respond too slowly even over high speed modems can use ISDN services that interface directly into a departmental LAN and use the same software and provide access to all the data as if the worker was in the office. With ISDN, still and motion video pictures can be sent between two or more parties without the need for special conference rooms full of expensive equipment and colleagues can jointly edit a report, graphics and/or a spreadsheet while talking on the telephone, even though they are hundreds of miles apart.

A key feature of ISDN is the use of a separate channel for control information: call setup, network management, Automatic Number Identification (ANI, also known as Caller ID), and so forth. This feature gives ISDN's one of its most notable advantages over high-speed modems, which otherwise approach it in terms of raw speed. The separate control channel noticeably reduces the time to make a connection. It takes only a fraction of a second to establish a local ISDN connection and only 2 to 5 seconds for a long distance connection. This compares favorably with up to 90 seconds for a modem connection over any distance.

Since ISDN is a switched digital service, its ability to provide bandwidth on an as-needed basis to support digital connections makes it an essential building block of the nation's information infrastructure. The ability of ISDN to set up a connection so quickly makes it ideal for on-demand LAN-to-LAN connectivity. Rather than paying for dedicated digital lines that the LAN's sporadic activity leaves unused much of the time, an ISDN bridge or network interface card can connect the remote computer to the LAN on demand. The ISDN device monitors LAN traffic, and when it detects a packet addressed to a remote LAN, the connection is made, the data transferred, and the connection closed without any knowledge or action by the user.

For convenience in providing the appropriate voice and data services, ISDN divides its total information transmission capacity into channels that either provide bandwidth to send user data or to open, control and close the connection. ISDN further defines two service interfaces, known as the Basic Rate Interface (BRI) and the Primary Rate Interface (PRI).

The BRI consists of two 64 kbps data channels, called B channels, and one 16 Kbps out-of-band control channel, called the D channel. The combination is called 2B+D. The two B channels can be combined into one 128 Kbps data channel, or kept divided to simultaneously make a digital phone call on one B channel while using the other for data communications or video conferencing.
B channels can alternate between voice and circuit-data. The BRI D channel bandwidth is also available for user packet-data messages when it is not being used for call control.

Primary Rate ISDN (PRI) combines 23 B channels and one 64-Kbps D channel, yielding the same capacity as a T1 line, only with far more flexibility. In PRI, B channels can be assigned on a call-by-call basis and the D channel is only used for call control; packet-data is not supported. "Multirate" calls can also be placed over PRI. Multirate ISDN calling provides wideband channels at any multiple of 64 kbps B channels ("N by 64").

3.1 ISDN Standards

The ISDN is defined by a number of standards for the exchange of many types of information (voice, image, and data) independent of any manufacturer, service provider, or implementation technology. ISDN standards fall into two categories based on the speed of information transfer. The initial set of Narrowband ISDN standards, for transmission rates up to 1.5 Mbps, have been available since the late 1980s. Broadband ISDN standards, for higher transmission rates up to several Gbps, are now emerging.

In North America, ISDN standards are developed by T1, a committee accredited by the American National Standards Institute (ANSI). Within Committee T1 there are various Technical Sub-Committees (TSCs) which have developed and continue to develop the standards that are the basis for interoperable ISDN products.

International ISDN standards are the province of ITU-T, formerly CCITT. The TSCs of Committee T1 provide, through the State Department, the technical work for the United States' positions on ISDN standards in the international arena. Whenever possible, the ITU-T recommendations are accepted as applicable for ISDN in North America. For special situations that are only relevant to North America, the ITU-T recommendations are modified as necessary and issued as standards by Committee T1. Of course, the goal of international ISDN is promoted by using the ITU-T recommendations to the greatest extent possible.

3.2 NIUF

In an effort to overcome the barriers to the widespread acceptance and use of ISDN technology, the Advanced Systems Division within NIST collaborated with industry in 1988 to establish the North American ISDN Users' Forum (NIUF). The NIUF brings together the communities involved in progressing ISDN, including users, service providers, network equipment manufacturers, customer premises equipment manufacturers, and applications software developers.

The NIUF is composed of two workshops: the ISDN Users' Workshop (IUW) and the ISDN Implementors' Workshop (IIW). The IUW produces Application Requirements which describe potential applications of ISDN and the features which may be needed. The IIW develops Application Profiles, Implementation Agreements, and Conformance Criteria which provide the detailed technical decisions necessary to implement an Application Requirement in an interoperable manner.

Each workshop is further subdivided into groups to accomplish specific tasks. For example, the Application Analysis Group provides initial analysis of potential user ISDN applications and provides support in the development of user requirements. The Signaling Experts Working Group (SWG) writes Implementation Agreements based on relevant ANSI standards for ISDN call control and signaling functions. The ISDN Conformance Testing Group (ICOT) addresses the testing methodology required to ensure proper implementation of applications and implementation agreements. The Application Software Interface Expert Group has produced a specification of the interface between applications that use ISDN services and the device that provides the access to

those services. It is worth noting that the NIUF intends to be neither a standards-making body nor a testing and certification organization.

The deployment of BRI and PRI in North America is finally occurring, even though it still is not proceeding fast enough to satisfy its proponents. A wide variety of ISDN-compatible products are now available. These devices range from ISDN digital telephones to PC add-in cards that expand local area network connections across town or across the country. Many local telephone companies are making ISDN widely available. Pricing for ISDN services has been established in most locations. And now, these local telephone companies are improving customer service as they make more of their central offices "ISDN ready". The ability to connect these local switches with a long distance carrier is also being accommodated.

4. Application Software Interface

4.1 Introduction To The ASI

The Application Software Interface (ASI) is a specification defined by the Application Software Interface Expert Group of the North American ISDN Users' Forum (NIUF). It is a way for an application and an entity that provides ISDN services to communicate within an operating environment (the operating environment includes the operating system, hardware platform, bus, etc.). The ASI is defined as the interface between applications that use ISDN services and the network adaptor (NA) that provides the access to those services. The translation of the ASI message set, to and from the instructions needed to operate any hardware interfaces, is accomplished by software (e.g., a device driver supplied by the NA vendor).

A NA is typically implemented as a card that plugs into the input/output bus of a computer system. Today, manufacturers are producing an ever increasing number of NAs that offer a common basic subset of ISDN services plus those additional features that differentiate their product from the competition. There is, however, little commonality in the software interface that these NAs currently present to an application. Each NA vendor provides the ISDN service access through a proprietary interface that, done in isolation, differs from the interface provided by other vendors. This complicates the design of the application. The developer is faced with the task of (1) binding with an initial NA and, once the application is fielded, (2) working to enhance the application product to interface with other NAs as well. Exemplifying this process are products in the market today that advertise that they "currently work with" a specific set of network adaptors and " will support" other specific network adaptors.

The ASI specification significantly reduces complexity through a common interface for accessing the ISDN services provided through the NA . The availability of NAs built to ASI specifications enables the design of applications that are independent of the particular NA with which they are used. Within a given operating environment, applications can run on any ASI-compliant NA.

Since the ASI specifies a common set of services which are applied across a broad range of environments, it is much easier to implement applications that are portable across operating environments. Portability favors the application developer by making the application available for a wider audience and, at the same time, widespread application availability increases the demand for ISDN services, hastening deployment of ISDN lines, and thus ultimately benefitting the hardware (or ISDN-capable computer platform) vendors as well.

The ASI places emphasis on a common application interface as opposed to a common hardware device interface for two main reasons:

- Maximum benefit to the user is derived from a large selection of commercially available ISDN applications which can operate over a correspondingly large selection of NAs. The number of applications will be most influenced by the existence of a common application interface that allows the application provider to easily migrate applications to different NAs and to different environments.

- It is much more difficult to specify a standard hardware device interface. Vendors provide different NA hardware interfaces to appeal to different markets. For example, some NAs will be built for performance while others will be built for low cost.

Objective

The primary goal of the ASI is to provide a portable, extensive, and layered software interface to ISDN hardware, call control, and services. The ASI is a consistent set of implementation agreements on a common set of ISDN services, enabling an application written against the ASI specification to communicate with any ASI-compliant ISDN NA.

The ASI promotes the development of application software that can utilize ISDN services provided by a broad range of ISDN vendor products on a variety of application platforms. Applications written against the ASI specification should run on a computer platform employing ISDN interface hardware from different vendors without recompilation or linking. The same application should be portable to a different computer platform (with the same operating system) by recompiling, with no changes required to the source code. For a different operating system, there may be some code changes to accommodate differences in the access method. The ASI is designed to be as independent as possible of:

- Hardware Platform,
- Operating System,
- Data Protocol Type,
- Programming Language, and
- Compiler.

Scope

The ASI is defined in terms of services and facilities consistent with OSI layer interface standards and it is designed to be (1) portable across the broadest range of system architectures, (2) extensible, and (3) abstracted beyond ISDN to facilitate interworking.

The ASI specifies interactions at the abstract boundary between an application and a NA within an operating environment (the operating environment includes the operating system, hardware platform, bus, etc.). The ASI does not address interoperability between the applications that utilize the services offered by the NAs.

Approach

The implementation of the common ASI services is the job of the NA designer. NA vendors are accustomed to providing either device drivers or libraries which provide the interface to their specific hardware implementation.

Access methods, however, are operating system dependent. The application developer should have to do as little as possible to port an application written for one operating system to a different operating system (e.g., to re-compile or re-link is perceived as minimal effort). Also, within one operating system, the application developer should be able to design applications independently of the NA (i.e., the application should work the same and without modification on the variety of NAs available), assuming the NA provides equivalent services.

Several assumptions have gone into the development of the Version 1 ASI specification. Two main assumptions are:

- ISDN primary rate and basic rate access are assumed to be the network interface to the NA. This does not preclude application of this interface to NAs which interface to other ISDN access methods.

- No default values for parameters are assumed by the interface. All parameter values necessary for a message must be supplied in the applicable data structures.

4.2 Technical Overview

The ASI is positioned at the Service Access Point (SAP) between layers 3 and 4 in the OSI Reference Model. Conceptually, the ASI is an asynchronous message stream between the ISDN network services provider (layers 1 - 3) and the user (layers 4+) of those services.

Since the ASI is a local interface between layer 4 and layer 3, it is neither a layer within the OSI Reference Model nor an end-to-end protocol. Such features as interoperability or end-to-end integrity must be provided by protocols above the ASI, using ISDN network services accessed through the ASI. If a non-empty transport layer protocol is positioned above the ASI, then that transport protocol, and not the higher layer application, is the actual user of the ISDN bearer services provided through the ASI. The ASI specifies a complete interface composed of

- A message set that is independent of the operating system,

- A message encoding method that is independent of the operating system, and

- An access method that is not independent of the operating system.

The partitioning of the ASI in terms of the operating system dependent access methods allows the rest of the ASI to exist independent of the operating system. The use of an identical message set and identical encoding method for the different operating systems greatly simplifies application portability.

The ASI specification is composed of four parts. The first part provides an initial specification intended to allow implementors to begin using the ASI for implementations of applications requiring a limited subset of ISDN services within a limited set of operating systems. The other parts specify the access methods for specific operating systems.

ASI Part 1: Overview and Protocols (Version 1.0) was initially approved by the NIUF in October 1991 and an update was approved in October 1992. This document includes (1) an introduction to the ASI concepts, (2) a description of the ASI architecture, and (3) a description of the ASI access functionality.

Parts 2, 3 and 4 of the ASI provide the ASI access method for DOS, Windows, and Unix respectively. ASI Part 2: MS-DOS Access Method (Version 1) was approved by the NIUF in June 1992. ASI Part 3: Enhanced DOS/Protected Mode Shell Access Method (Version 1) was also approved in June 1992 and an update was approved in October 1992. ASI Part 4: Unix Access Method (Version 1) was also approved by the NIUF in October 1992.

Concepts

Telecommunication standards identify three distinct services for the transmission of management, control, and user information. These services are represented by three planes in the general teleservices architecture:

- The management plane service supports the exchange of all information associated with operation, administration, and maintenance (configuration data, provisioning data, etc.) of the interface and modules that support the interface.

- The control plane service provides the capability to establish, control and release network connections, manage the use of shared resources, modify service characteristics, and provide supplementary services.

- The user plane service passes user data between the two sides of a connection. Use of the user plane is dictated by a connection's bearer service. These services are based on the ISDN protocol reference model defined in ITU-T Recommendation I.320.

ASI focuses on the control plane service. The ASI message set and operating system specific access methods provide an asynchronous interface to ISDN call control. The application makes requests through the ASI, and the ISDN call control beneath the ASI transmits confirmation messages and event indication messages back through the ASI as appropriate. After issuing the request, the application can continue execution while it awaits the response to the request.

Any blocking or synchronous interface to the ISDN call control can be provided as a library of function calls on the application side of the ASI. To implement a blocking call request, the application sends the connection request message, and awaits the connection confirmation response.

Teleservices Architecture

The ASI, based on experience with the OSI Reference Model and numerous examples in distributed computing, models the environment as composed of protocol layers bounded by intefaces. In this case, the teleservices architecture is split into several abstract layers that define functionality. The layers, however, do not imply correspondence to those of the OSI Reference Model.

The key element in the ASI architecture is a generic teleservices server. Such a server offers teleservices to applications on the local machine and/or on the local area network without requiring the applications to implement the details of ISDN, Plain Old Telephone Service (POTS), (The Public Switched Telephone Network (PSTN), or other possible teleservices media.

While the ASI architecture establishes a client-server relationship, it neither supports nor precludes multi-tasking. A multi-tasking operating system makes it possible for multiple processes to access ISDN services through a server architecture that minimizes the ISDN-specific knowledge required of the application. This server, or the single application in a single threaded operating system, communicates with ISDN call control over a lower level interface which more closely mirrors the ISDN protocol. In this architecture, it is the responsibility of a server interface definition to provide the capability for multiple client applications to access the services provided by a single interface adaptor.

The ASI defines reference points and message protocols across the reference points. The reference points above the generic server provide generic telephony interface functions, while the lower level reference points more closely match ISDN-specific message and event types. The architecture

defines a total of five reference points to accommodate the range of functionality that the interface must support. The architecture with its reference points is shown in Figure 4 below.

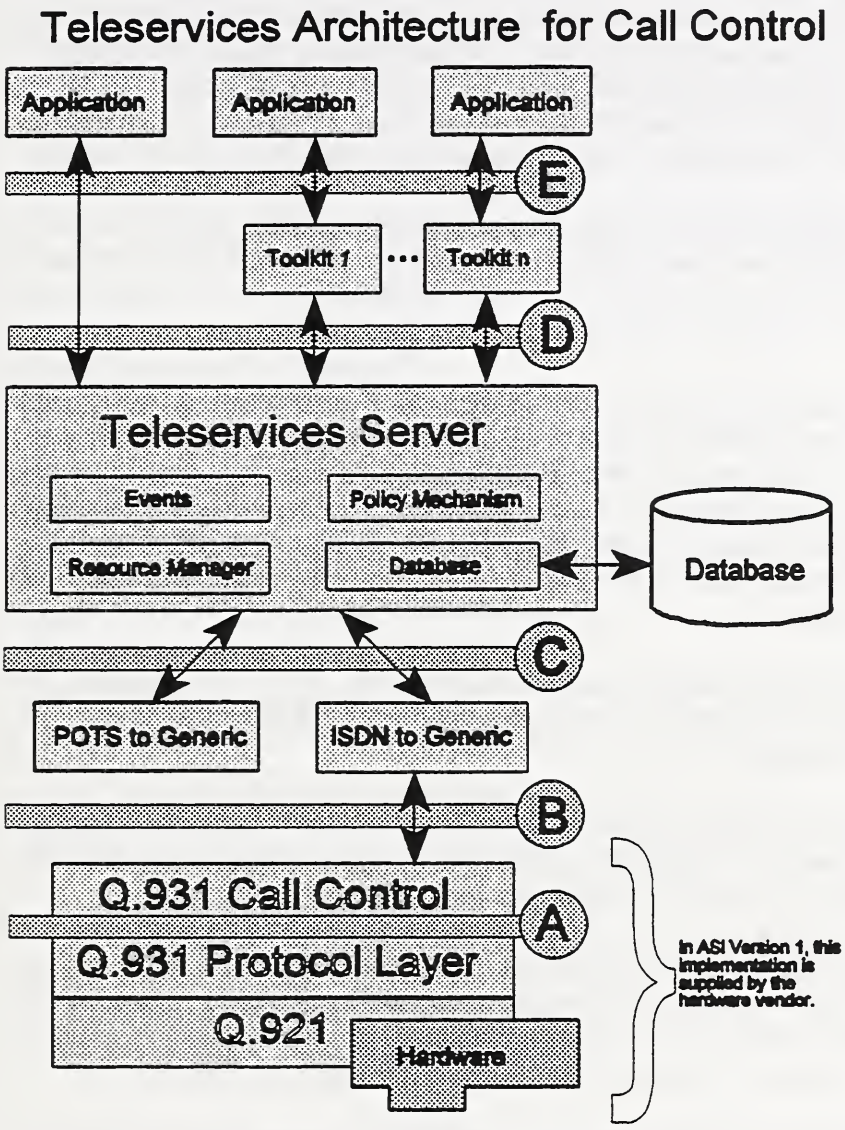

Figure 4. ASI Architecture

In ASI Version 1, the **A** reference point is not an exposed interface. It is defined to be the interface between the "standard" portions of Q.931 and the non-standard portions. Only the non-standard portions of ISDN need to be customized for each market.

The **B** reference point is the interface between a server or dedicated application and the ISDN signaling, management and user planes. Direct multi-client access is not allowed.

The **C** reference point presents a generic teleservices interface to the server or dedicated application.

The **D** reference point allows a server to provide a generic teleservices interface to multiple client applications. This interface also presents a simplified programming model to the application or toolkit developer.

The **E** reference point is the programming interface provided by a high level library. This interface is the one most desired by typical applications developers.

The current release of the ASI specification defines the core subset of the lower level reference point. Version 1 ASI is identified as the message stream at reference point **B** in this architecture. It is to this reference point which vendors must supply ASI support. No vendor-specific software need operate above this reference point, although a vendor may choose to provide higher level support for added value to an ISDN product.

In an OSE where the application platform (see Figure 2) provides generic teleservices, the ASI architecture fits into the network services portion of the OSE/RM with reference points **A**, **B** and **C** describing elements of the EEI and reference points **D** and **E** describing elements of the API.

ASI Sessions

The application and the NA communicate across the ASI by reference to a local virtual path called a session. A session carries all requests and responses for a given instance of a service, e.g., a voice call. Sessions are created dynamically by either the application or the NA according to the rules defined by the ASI protocol. Once established, a session is referred to by a session ID that consists of a pair of values. One value is determined by the application program entity and the other by the NA entity. To allow for dynamic creation of sessions by either side, each side may create its part of the session ID without consulting the other side. Either side may refer to a session by using the other's part of the ID. An ID of all zeros indicates that the other side's ID is unknown or is not used. Retiring and reuse of old IDs is carefully managed by the protocol.

The ASI uses Session Blocks to specify sessions. These blocks are implicitly created when a connection is established. Session Blocks have pre-defined attributes to use various teleservices.

Messages

ASI transfers information in messages using an asynchronous mode of operation that, in non-multi-tasking operating systems, prevents the processor from being blocked waiting for a response from the NA. When an application sends a message to the NA by calling a function, control returns immediately to the application and, at some later time, the NA sends a message to the application informing it of an event (possibly related to the earlier application message). For example, a connect request returns immediately to the application. Some time later, the application receives the asynchronous connect confirm message.

In order to meet the portability and network transparency requirements of the architecture, all messages are required to be self contained. Furthermore, messages shall not contain pointers, or other references, to external data structures.

Message definition is specified in Abstract Syntax Notation Number One (ASN.1). Actual message encoding, however, uses an ASI specific method that promotes ease of implementation and improves performance while providing for future expansion of the protocol.

The ASI acknowledges the transfer of messages across the interface, indicating success or reason for failure to transfer the message. The messages are thus transferred across the interface in an acknowledged or synchronous fashion even though the mechanism with respect to the ISDN is asynchronous.

Management plane services (e.g., protocol parameters for terminal adaptation) are presently provided in ASI by using a control part of the user plane. The philosophy is to maximize the potential performance of the ASI by minimizing the protocol overhead. The ASI simply moves buffers of data. If a protocol is implemented on the B channel, then this is done either entirely below the ASI or entirely above the ASI.

The ASI defines the method of transferring data as:

(1) The application program calls the data transfer function in the ASI, passing it a reference (pointer) to the data and

(2) The ASI then copies the data and returns to the application.

The ASI specification does not address peer-to-peer protocols across the ISDN. No messages for sending data over the B channel are defined in the ASI. However, the operating system dependent parts of the ASI specification do define a method to obtain the address of a function in the user plane for the purpose of transferring data. In DOS, for example, the ASI defines two character device drivers collectively called the Address Resolution Device Driver (ARDD). The application and the NA use one device driver to obtain addresses for the management/control function and the other device driver to obtain addresses for the user plane function.

Access Method Functionality

The access method provides mechanisms to transfer management, control and user information (commands, events, data, etc.) across the ASI. These services are common to all operating system environments and consistent with the ISDN protocol reference model. However, since the implementation of these mechanisms is operating system dependent, the access method is also operating system dependent.

Even though the ASI includes access method definitions specific to each operating system environment (i.e., DOS, UNIX, OS/2, etc.), each of these access methods uses a software structure that is consistent across all operating system environments. This produces an access method which is optimal for its operating system environment by applying a system dependent wrapper around an ASI software module that is operating system independent.

4.3 Summary of ASI Features

The current version of the ASI is designed to support:

- A language independent implementation.
- The highest level of performance possible.
- Minimal use of system resources (memory, soft interrupts, etc.).
- Simple system administration.
- A binary compatible interface that requires no linkage or recompilation.
- A bidirectional asynchronous operation across the interface.
- The dynamic allocation of resources within the NA and its associated software.
- A simplified implementation of the application program's ASI interface.

Future versions of the ASI may include the following features:

- The existence and concurrent operation of multiple network adaptors.
- The existence and concurrent operation of multiple application programs.
- Any combination of multiple/single networks, NAs, and/or application programs.

- The concurrent operation of the ASI NA and other types of adaptors such as Local Area Network (LAN) adaptors.

5. Evaluation of the ASI

This section evaluates the Application Software Interface (ASI) as one element of an Application Portability Profile (APP) for an Open Systems Environment (OSE).

An OSE is a computing infrastructure that supports portable, scalable and interoperable applications through standard services, interfaces, data formats and protocols. In an OSE, users will be able to buy and use applications that

- execute on any vendor's platform and use any vendor's operating system;
- communicate and interoperate over any vendor's networks;
- access any vendor's database; and
- interact with users through a common human/computer interface.

The ASI fits within this architecture of the OSE Reference Model (OSE/RM) and provides services that fit within the scope of the APP Network Services Functional Area. The relationship can be seen by comparing Figure 2 and Figure 4 of this report.

In Figure 2, the APP network services defined at both the API and the EEI provide the capabilities and mechanisms to support distributed applications requiring data access and applications interoperability in heterogeneous, networked environments. There are four network services defined in the APP.

- **Data communication** includes API and protocol specifications for reliable, transparent, end-to-end data transmission across communications networks.

- **Transparent file access** to available files located anywhere in a heterogeneous network.

- **Personal/micro computer support** for interoperability with systems based on other operating systems, particularly microcomputer operating systems, that may not be formally standardized in a national or international standard.

- **Remote Procedure Call** services include specifications for extending the local procedure call to a distributed environment.

In Figure 4, reference points A, B and C correspond to the EEI of the OSE/RM and reference points D and E correspond to the API of the OSE/RM for the APP data communications network services. The ASI focuses on the definition of a common application interface for accessing and administering ISDN services provided by hardware commonly referred to in the vendor community as Network Adapters (NAs). It is intended to be independent of the data protocol type and it does not address either peer-to-peer protocol or interoperability issues.

5.1 Level of consensus

Specifications that are proprietary or are used by a very limited or specialized group of users, such as vendor consortia are given a low evaluation; a high evaluation is given for a specification that has already become a national or international standard; average evaluations are assigned for public domain specifications that are not standard, or that may be in the process of becoming a standard

(i.e., standards committee work-in-progress), or that are widely available across various hardware/software platforms.

ASI Evaluation

The APP has given the ASI a high evaluation. The ASI is a set of implementation agreements produced by the North American ISDN Users' Forum (NIUF). These agreements are, in general, based upon relevant national and international standards. While there has been interest within the NIUF in submitting the ASI specification to the standards bodies, the resources required for these activities have not been found. Therefore, incorporation of the ASI into ISDN standards is not underway at this time and there is no known plan to undertake this work in either national or international standards groups.

5.2 Product availability

A low evaluation is given to specifications for which only a very few proprietary products are available; high evaluations are given to specifications for which there is a wide variety of products available from various vendors across different application platforms; average evaluations are assigned to specifications that may be proprietary but have many products available from a variety of vendors, or that are public domain specifications with products readily available.

ASI Evaluation

Current NA products are based on proprietary specifications. Several companies have indicated that new products will incorporate ASI Version 1 principles. The APP has given the ASI a low evaluation.

5.3 Completeness

A specification is evaluated on the degree to which it defines and covers key features necessary in supporting a specific functional area or service. For example a network security specification that includes all of the components described would be evaluated higher than others that do not include all of the features.

ASI Evaluation

The ASI specification provides all the information required for the implementation of network adaptors for many current computer systems that use the DOS, Windows or Unix operating systems. The APP has given the ASI an average evaluation.

Version 1 of the ASI specifies the call control service at the interface between a computer system and the network adaptor. This is one element of the EEI in the OSE/RM. The API and other elements of the EEI are not specified in Version 1 of the ASI.

5.4 Maturity

According to the underlying technology of a specification, a high evaluation indicates that it is well-understood (e.g., a reference model is well-defined, appropriate concepts of the technology are in widespread use, the technology may have been in use for many years, a formal mathematical model

is defined, etc.). A low evaluation indicates that it may be based on technology that has not been well-defined and may be relatively new.

ASI Evaluation

The APP has given the ASI a high evaluation. ISDN technology is well defined and understood. Widespread deployment of ISDN services has not been available in the past so there has not been a large market for ASI products. The ASI will be considered mature as soon as there is sufficient implementation and use of ASI products.

5.5 Stability

A high evaluation means that the specification is very stable, that no changes are expected within the next 2 years. A low evaluation indicates that significant or many changes are expected within a relatively short time (1 to 2 years), or that incompatibilities exist between current and expected releases of the specification. An average evaluation is given to those specifications that may have known changes forthcoming to replace features in the existing specifications.

ASI Evaluation

This specification is an evolving interface and changes may be required to incorporate new features. These changes are primarily due to additional ISDN features as specified by ANSI and the NIUF. Any changes are expected to be in the form of additions to the existing specification, not a replacement. The APP has given the ASI an average evaluation.

5.6 De facto usage

This evaluation criterion estimates the likelihood that a vendor will independently propose products that conform to this specification, whether or not a reference specification is stated in the procurement documents. A high evaluation indicates that most proposed products will conform to the specification. A low evaluation indicates that it is unlikely that the vendor will propose products based on the specifications. An average evaluation indicates that vendors are just as likely to propose products based on the specifications as not (i.e., no clear determination exists). In the cases of low or average evaluations, it is imperative that users include a specification in procurement documentation. A low evaluation does not necessarily mean that products implemented on the specification do not exist. It can also mean that some vendors would rather provide products that are not based on the recommended specifications, such as proprietary implementations.

ASI Evaluation

The APP has given the ASI an average evaluation. If users do not reference this specification in procurement documents, vendors are not likely to propose products that either meet this specification or are compatible with the specification.

5.7 Known problems/limitations

Lower evaluations are assigned to specifications with severe restrictions on use or capabilities (e.g., licensing restrictions) or known problems that tend to be too difficult and too numerous to overcome (e.g., new releases of the specification are not compatible with previous releases, or not enough is

covered in the standard to be useful). An average evaluation is given to those specifications that require some minor additional facility in order to be fully effective in their intended environment. This additional facility may be provided by a related standard or other specification.

ASI Evaluation

The relationship of the ASI to GOSIP needs to be clarified, particularly in regard to the type of ISDN service provided. The ASI specifies both circuit-switched and packet services while GOSIP specifies only the X.25 packet service for ISDN. Since the APP does not require GOSIP, both services are implicitly recommended in the APP. Thus, the ASI includes services that are beyond the scope of GOSIP. It is not clear whether there is a need to provide a different implementation of the ASI for environments that meet GOSIP. No implementation of the ASI tailored for GOSIP is either known to be available or planned to be marketed.

The present version of the ASI is directed toward the personal computer environment (with or without Windows) and is limited to the Unix , DOS, and OS/2 operating sytems.

5.8 Conformance testing

Provides information about current and future plans for conformance testing of products based on the recommended specification. In the case of Federal Information Processing Standards (FIPS) testing, each FIPS Publication describes the requirements for testing and the policies that affect such testing. For other specifications, testing may or may not be described in the specification recommended.

ASI Evaluation

Conformance tests are not included in ASI Version 1 and there are no known plans to add conformance tests to the ASI specifications. Furthermore, since ASI is not a standard, conformance tests are meaningless.

5.9 Future plans

Published or otherwise-announced directions and long-term plans for individual specifications.

ASI Evaluation

The present ASI documents include plans for future work to include (1) additional ISDN services, (2) device control and (3) additional higher level interfaces. In addition, the ASI could be submitted for consideration as an ANSI standard. None of these activities are underway at this time and there are no known plans for these activities.

5.10 Alternative specification

In some instances, other specifications exist besides the recommended specification. Users may want to review these alternatives before selecting a specification on which to standardize.

ASI Evaluation

Although there are a number of specifications which may be useful in place of the ASI, there is no clear alternative to it in an open systems environment. In general, there is a lack of information on these specifications and a lack of analysis on their utility as an alternative to the ASI.

6. Future Considerations

While the ASI was developed for an environment that utilizes ISDN services, the specification is also applicable to other environments that utilize other telecommunications services. All these services, including Asyncronous Transfer Mode (ATM) as well as ISDN, are rapidly becoming available in telecommunications networks throughout the United States. Since these telecommunications services will be a major element of the National Information Infrastructure (NII), the ASI deserves consideration as an element of the enabling technology required for the proposed NII.

The NII is a vision for using presently emerging information technology to improve products and services, create new ones, compete more effectively, and empower people to be more creative and efficient. The federal initiative for a NII envisions a seamless web of communications, networks, computers, databases and consumer electronics that will provide vast amounts of easily accessible information to its users. The NII is expected to make this information available in the form of video programming, scientific and business databases, images, sound recordings, library archives and other media. Applications and software will enable users to access, manipulate, organize and digest the information.

The most important prerequisite for the NII is the availability of computing environments that consist of distributed, heterogeneous, networked applications, databases, and hardware. The concept of a federal computing environment that is built on an infrastructure defined by open, consensus-based standards is well on its way to becoming a de facto means of organizing these systems.

The key issue is to determine how the ASI fits into descriptions and specifications of the NII. This is an architectural issue addressed in NISTIR 5478 *Framework for National Information Infrastructure (NII) Services*. The Service Framework presents a "bottom up" view of the Services Architecture from the perspective of the networks providing bitway-type services. As such, it provides a point of departure for discussing the definition, scope, and alignment of NII services.

Initial architectural models of the NII consisted of three layers: applications, services and networks (also called bitways). The National Research Council has refined this model to the four layer Open Data Network (ODN) architecture. This architecture includes the ODN Bearer Service, an abstract representation of the bit-level network services that provides a critical separation between the actual network technology and the higher-level services that are available to the user. The Service Framework advances the ODN view by defining a NII Services Model that provides the next level of detail in the interfaces between (1) the bitways and the services and (2) the services and the applications.

The NII architecture may continue to undergo further refinement but, at this point, it is already clear that the ASI can fit into the specification of NII environments in three ways:

(1) For those environments in the NII that incorporate the OSE/RM and the APP, the ASI is automatically included.

(2) For some other NII environments, an appropriate profile can be constructed by a judicious combination of present ASI specifications of the B reference point for the EEI with other publicly available specifications for the API.

(3) Future ASI work on specifications for the other reference points in the ASI architecture could satisfy needs for additional environments within the NII.

Bibliography

National Institute of Standards and Technology

[1] NIST Special Publication 500-183, *Stable Implementation Agreements for Open Systems Interconnection Protocols*, Version 4, Edition 1, December 1990.

[2] NIST Special Publication 500-189, *Security in ISDN*, NTIS, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161, September 1991.

[3] NIST Special Publication 500-194, *ISDN Conformance Testing Layer 1 — Physical Layer — Part 1 Basic Rate S/T Interface, User Side*, NTIS, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161, October 1991, (Order Number PB92-102201).

[4] NIST Special Publication 500-210, *Application Portability Profile (APP) the U.S. Government's Profile OSE/1 Version 2.0*, June 1993.

[5] NIST Special Publication 823-1, *Overview of ISDN Conformance Testing*, NTIS, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161, March 1992, (Order Number PB92-181015).

[6] NIST Special Publication 823-2, *ISDN Conformance Testing Layer 1 — Physical Layer — Part 2 Basic Rate U Interface, User Side*, NTIS, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161, March 1992, (Order Number PB92-181114).

[7] NIST Special Publication 823-3, *North American ISDN Users' Forum Agreements on Integrated Services Digital Networks*, Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, January 1993, (GPO Number SN003-03197-6).

[8] NIST Special Publication, *ISDN Conformance Testing Layer 1 — Physical Layer — Part 3 Primary Rate Access Customer Installation*, To be published.

[9] NIST Special Publication, *ISDN Conformance Testing Layer 2 — Data Link Layer — Part 1 Basic Rate Interface, User Side*, To be published.

[10] NIST Special Publication, *ISDN Conformance Testing Layer 3 — Network Layer — Part 1 Basic Call Control Procedures, Basic Rate Interface/Class 1, User Side*, To be published.

[11] NIST Special Publication, *Application Software Interface Specification — Part 1 — Overview and Protocols (Version 1)*, To be published.

[12] NIST Special Publication, *Application Software Interface Specification — Part 2 — MS-DOS Access Method (Version 1)*, To be published.

[13] NIST Special Publication, *Application Software Interface Specification — Part 3 — Enhanced DOS/Protected Mode Shell Access Method (Version 1)*, To be published.

[14] NIST Special Publication, *Application Software Interface Specification — Part 4 — Unix Access Method (Version 1)*, To be published.

[15] NIST Special Publication, *Guide for DoD Implementation of Integrated Services Digital Network*, To be published.

[16] NISTIR 5478, *Framework for National Information Infrastructure Services,* July 1994.

[17] FIPS 100-1, *Interface Between Data Terminal Equipment (DTE) and Data Circuit—Terminating Equipment (DCE) For Operation with Packet Switched Data Networks (PSDN), or Between Two DTE's, by Dedicated Circuit*, NTIS, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161, 1989.

[18] FIPS 146-1, *Federal Information Processing Standard for Government Open Systems Interconnection Profile (GOSIP)*, April 1991 (under revsion).

[19] FIPS 178, *Video Teleconferencing Services at 56 to 1,920 kb/s*, NTIS, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161, 1992.

[20] FIPS 182, *Federal Information Processing Standard for Integrated Services Digital Network (ISDN)*, NTIS, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161, October 1993.

[21] Stokesberry, Dan and Shukri Wakid, "ISDN in North America," IEEE Communications Magazine, May 1993.

American National Standards Institute

[1] ANS T1.216-1991, *ISDN Management—Basic Rate Physical Layer.*

[2] ANS T1.217-1991, *ISDN Management—Primary Rate Physical Layer.*

[3] ANS T1.218-1991, *ISDN Management—Data Link and Network Layers.*

[4] ANS T1.403-1989, *Telecommunications—Carrier to Customer Installation—DS1 Metallic Interface.*

[5] ANS T1.408-1990, *Telecommunications—Integrated Services Digital Network (ISDN)—Primary Rate-Customer Installation Metallic Interfaces—Layer 1 Specification.*

[6] ANS T1.601-1992, *Telecommunications—Integrated Services Digital Network (ISDN)—Basic Access Interface for Use on Metallic Loops for Application on the Network Side of the NT—Layer 1 Specification.*

[7] ANS T1.602-1989, *Telecommunications—Integrated Services Digital Network (ISDN)—Data-Link Layer Signalling Specification for Application at the User-Network Interface.*

[8] ANS T1.603-1990, *Telecommunications—Integrated Services Digital Network (ISDN)—Minimal Set of Bearer Services for the Primary Rate Interface.*

[9] ANS T1.604-1990, *Telecommunications—Integrated Services Digital Network (ISDN)—Minimal Set of Bearer Services for the Basic Rate Interface.*

[10] ANS T1.605-1989, *Telecommunications—Integrated Services Digital Network (ISDN)—Basic Access Interface at S and T Reference Points—Layer 1 Specification.*

[11] ANS T1.607-1990, *Telecommunications—Integrated Services Digital Network (ISDN)—Digital Subscriber Signalling System Number 1 (DSS1)—Layer 3 Signalling Specification for Circuit Switched Bearer Service.*

[12] ANS T1.608-1991, *Telecommunications—Integrated Services Digital Network (ISDN)—Digital Subscriber Signalling System Number 1 (DSS1)—Signalling Specification for X.25 Packet Switched Bearer Service.*

[13] ANS T1.610-1990, *Telecommunications—Integrated Services Digital Network (ISDN)—Digital Subscriber Signalling System Number 1 (DSS1)—Generic Procedures for the Control of ISDN Supplementary Services.*

[14] ANS T1.612-1990, *Telecommunications—Integrated Services Digital Network (ISDN)—Terminal Adaption Using Statistical Multiplexing.*

[15] ANS T1.613-1990, *Telecommunications—Digital Subscriber Signalling System Number 1 (DSS1)—ISDN Call Waiting.*

[16] ANS T1.615-1990, *Telecommunications—Digital Subscriber Signalling System Number 1 (DSS1)—Layer 3 Overview.*

[17] ANS X3.100-1989, *Interface Between Data Terminal Equipment (DTE) and Data Circuit-Terminating Equipment (DCE) for Operation with Packet Switched Data Networks (PSDN) or Between Two DTE's, by Dedicated Circuit.*

ITU-T (CCITT)

From ITU-T (CCITT) Blue Book, IXth Plenary Assembly, November 1988

[1] ITU-T Recommendation I.110, *Preamble and General Structure of the I-Series Recommendations for the Integrated Services Digital Network (ISDN).*

[2] ITU-T Recommendation I.231, *Circuit Mode Bearer Service Categories.*

[3] ITU-T Recommendation I.232, *Packet Mode Bearer Service Categories.*

[4] ITU-T Recommendation I.251, *Number Identification Supplementary Services.*

[5] ITU-T Recommendation I.252, *Call Offering Supplementary Services.*

[6] ITU-T Recommendation I.253, *Call Completion Supplementary Services.*

[7] ITU-T Recommendation I.254, *Multiparty Supplementary Services.*

[8] ITU-T Recommendation I.255, *Community of Interest Supplementary Services.*

[9] ITU-T Recommendation I.256, *Charging Supplementary Services.*

[10] ITU-T Recommendation I.324, *ISDN Network Architecture,*

[11] ITU-T Recommendation I.330, *ISDN Numbering and Addressing Principles.*

[12] ITU-T Recommendation I.331, *Numbering Plan for the ISDN Area.*

[13] ITU-T Recommendation I.332, *Numbering Principles for Interworking Between ISDNs and Dedicated Networks With Different Numbering Plans.*

[14] ITU-T Recommendation I.333, *Terminal Selection in ISDN.*

[15] ITU-T Recommendation I.334, *Principles Relating ISDN Numbers/Subaddresses to the OSI Reference Model Network Layer Addresses.*

[16] ITU-T Recommendation I.411, *ISDN User-Network Interfaces—Reference Configurations.*

[17] ITU-T Recommendation I.412, *ISDN User-Network Interfaces—Interface Structures and Access Capabilities.*

[18] ITU-T Recommendation I.430, *Basic User-Network Interface Layer 1 Specification.*

[19] ITU-T Recommendation I.431, *Primary Rate User-Network Interface Layer 1 Specification.*

[20] ITU-T Recommendation I.460, *Multiplexing, Rate Adaption and Support of Existing Interfaces.*

[21] ITU-T Recommendation I.464, *Multiplexing, Rate Adaption and Support of Existing Interfaces for Restricted 64 kbits/s Transfer Capability.*

[22] ITU-T Recommendation I.465, *Support By An ISDN of Data Terminal Equipment with V-Series Type Interfaces With Provision For Statistical Multiplexing.*

[23] ITU-T Recommendation Q.920, *ISDN User-Network Interface—Data Link Layer—General Aspects.*

[24] ITU-T Recommendation Q.921, *ISDN User-Network Interface—Data Link Layer—Specification.*

[25] ITU-T Recommendation Q.930, *ISDN User-Network Interface—Layer 3—General Aspects.*

[26] ITU-T Recommendation Q.931, *ISDN User-Network Interface—Layer 3— Specification for Basic Call Control.*

[27] ITU-T Recommendation Q.932, *ISDN User-Network Interface—Layer 3—Generic Procedures for the Control of ISDN Supplementary Services.*

[28] ITU-T Recommendation Q.940, *ISDN User-Network Interface Protocol for Management—General Aspects.*

[29] ITU-T Recommendation V.120, *Support by an ISDN of Data Terminal Equipment with V-Series Type Interfaces with Provision for Statistical Multiplexing.*

[30] ITU-T X.2, *International Data Transmission Services and Optional User Facilities in Public Data Networks and ISDNs.*

[31] ITU-T Recommendation X.25, *Interface Between Data Terminal Equipment (DTE) and Data Circuit-Terminating Equipment (DCE) for Terminals Operating in the Packet Mode and Connected to Public Data Networks by Dedicated Circuit.*

[32] ITU-T Recommendation X.31, *Support of Packet Mode Terminal Equipment by an ISDN.*

North American ISDN Users' Forum (NIUF)

[1] NIUF 90-002 (NIU/IIW/ICOT/90-40), *Integrated Services Digital Network (ISDN) Conformance Testing, Layer 1 Basic rate S/T Interface, User Side*, 1990.

[2] NIUF 91-002, *Building Controls Application Profile*, see [NIST 6].

[3] NIUF 90-003, *ISDN Call Management: Incoming Call Management Application Profile*, see [NIST 6].

[4] NIUF 91-003, *ISDN Network Interconnectivity: Data Conferencing Point-to-Point Application Profile*, see [NIST 6].

[5] NIUF 91-004, *ISDN Station Event Recording (ISER) Application Profile*, see [NIST 6].

[6] NIUF 91-006,(NIU/IIW/ICOT/90-60), *Integrated Services Digital Network (ISDN) Conformance Testing, Layer 1 Basic Rate U Interface, User Side*, 1990.

[7] NIUF 91-007 (NIU/IIW/ICOT/ACT23/91-22.2 V1.2), *Integrated Services Digital Network (ISDN) Conformance Testing, Layer 2 Basic Rate Interface, Link Access Procedure, D-channel (LAPD), User Side.*

[8] NIUF 91-009 (NIU/IIW/ICOT/ACT23/91-10.3 R4), *Integrated Services Digital Network (ISDN) Conformance Testing, Layer 3 Basic Call Control Procedures, Basic Rate Interface/Class 1, User Side.*

[9] NIUF 91-010 *Interface to Voice Messaging Systems Applications Profile,* see [NIST 6].

[10] NIUF 89-103 *Implementation Agreement of the North American ISDN Users' Forum, Carrier to Customer Installation DS1 Metallic Interface Specification*, 1989.

[11] NIUF 91-103R1, *Implementation Agreement of the North American ISDN Users' Forum, Layer 1 PRI S, T & U Reference Points*, 1991.

[12] NIUF 89-105, *Implementation Agreement of the North American ISDN Users' Forum, Basic Access Interface at S and T Reference Points—Layer 1 Specification*, 1989.

[13] NIUF 89-210, *Implementation Agreement of the North American ISDN Users' Forum, Data Link Layer Signalling Specification for Application at the User-Network Interface*, 1989.

[14] NIUF 90-301, *Implementation Agreement of the North American ISDN Users' Forum, Layer 3 Signalling Specification for the Minimal Set of Circuit Switched Bearer Services for the ISDN Basic Rate Interface/Class I*, 1990.

[15] NIUF 90-302, *Implementation Agreement of the North American ISDN Users' Forum, Layer 3 Signalling Specification for the Minimal Set of Circuit Switched Bearer Services for the ISDN Primary Rate Interface/Class II*, 1990.

[16] NIUF 90-311, *Implementation Agreement of the North American ISDN Users' Forum, Generic Procedures for the Control of ISDN Supplementary Basic Rate Interface/Class 1,* 1990.

[17] NIUF 89-320, *Implementation Agreement of the North American ISDN Users' Forum, Packet Switched Call Control Procedures Basic Call Control Procedures*, 1989.

[18] NIUF 401-92, *ISDN CPE Compatibility: Telephone/ISDN Workstation Integration Application Profile,* To be published, contact NIUF Administrator, (301) 975-2937.

[19] NIUF 402-92, *ISDN Network Interconnectivity: Data Conferencing-Multipoint (Phase 2) Application Profile*, To be published, contact NIUF Administrator, (301) 975-2937.

[20] NIUF 403R1-92, *Application Software Interface specification—Part 1—Overview and Protocols (Version 1)*, To be published, contact NIUF Administrator, (301) 975-2937.

[21] NIUF 404-92, *Application Software Interface Specification—Part 2—MS-DOS Access Method (Version 1)*, To be published, contact NIUF Administrator, (301) 975-2937.

[22] NIUF 404-92, *Application Software Interface Specification—Part 3—Enhanced DOS/Protected Mode Shell Access Method (Version 1)*, To be published, contact NIUF Administrator, (301) 975-2937.

[23] NIUF 405-92, *ISDN CPE Compatibility: Engineering Workstation Interface Application Profile*, To be published, contact NIUF Administrator, (301) 975-2937.

[24] NIUF 406-92, *ISDN Security: Secure Voicemail Application Profile*, To be published, contact NIUF Administrator, (301) 975-2937.

[25] NIUF 407-92, *ISDN Call Management: At Home Agents Application Profile*, To be published, contact NIUF Administrator, (301) 975-2937.

[26] NIUF 409-92, *Implementation Agreement of the North American ISDN Users' Forum, Basic Access Interface for Use on Metallic Loops for Application on the Network Side of the NT—Layer 1 Specification*, 1992.

[27] NIUF 410-92, *Implementation Agreement of the North American ISDN Users' Forum, Layer 1 PRI S, T, & U Reference Points*, 1992.

[28] NIUF 411-92, *Application Software Interface Specification—Part 4—Unix Access Method (Version 1)*, To be published, contact NIUF Administrator, (301) 975-2937.

[29] NIUF 415-92, *A Catalog of National ISDN Solutions for Selected NIUF Applications*, NTIS, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161, February 1993, (Order Number PB93-162881).

[30] NIUF 416-92, *Unified Message Notification Application Profile,* To be published, contact NIUF Administrator, (301) 975-2937.

[31] *First Draft of A Catalog of National ISDN Solutions for Selected NIUF Applications—Second Edition*, June 1993.

[32] NIUF, *The Fourteenth North American ISDN Users' Forum (NIUF),* contact NIUF Administrator, (301) 975-2937.

Department of Defense

[1] MIL-STD-188-194, *Military Standard Integrated Services Digital Network Profiles (ISDNP)*, 15 June 1992.

Bellcore

[1] Bellcore TR-TSY-000268, *ISDN Access Call Control Switching and Signalling Requirements*, Issue 3, May 1989, Supplement 1, June 1990.

[2] Bellcore TR-TSY-000301, *Public Packet Switched Network Generic Requirements (PPSNGR)*, Issue 2, December 1988.

[3] Bellcore TR-NWT-000393, *Generic Requirements for ISDN Basic Rate Access Digital Subscriber Lines*, Issue 2, January 1991.

[4] Bellcore TR-NWT-000397, *ISDN Basic Access Transport System Requirements*, Issue 2, January 1991, Supplement 1, June 1992.

[5] Bellcore TR-TSY-000754, *ISDN Primary Rate Access Transport System Requirements*, Issue 1, July 1990.

[6] Bellcore TR-TSY-000793, *ISDN D-Channel Exchange Access Signaling and Switching Requirements (Layer 2)*, Issue 1, October 1988.

[7] Bellcore TR-TSY-000845, *User-to-User Signaling with Call Control*, Issue 1, December 1988, Supplement 1, June 1990.

[8] Bellcore TR-TSY-000861, *ISDN Layer 3 Protocol Details for the Support of Supplementary Services*, Issue 1, December 1988, Supplement 1, June 1990.

[9] Bellcore TR-NWT-001268, *ISDN Primary Rate Interface Call Control Switching and Signaling Generic Requirements for Class II Equipment*, Issue 1, December 1991, Revision 1, December 1992.

[10] Bellcore SR-NWT-001937, *National ISDN-1*, Issue 1, February 1991, Revision 1, February 1993.

[11] Bellcore SR-NWT-001953, *Generic Guidelines for ISDN Equipment on Basic Access Interfaces*, June 1991, Revision 1, December 1991.

[12] Bellcore SR-NWT-002006, *National ISDN*, Issue 1, August 1991.

[13] Bellcore SR-NWT-002102, *ISDN Deployment Data*, Issue 3, March 1993.

[14] Bellcore SR-NWT-002120, *National ISDN-2*, Issue 1, June 1992, Revision 1, June 1993.

[15] Bellcore SR-NWT-002361, *Generic Guidelines for ISDN Terminal Equipment on National ISDN-2 Basic Rate Interfaces*, Issue 1, December 1992.

ISO

[1] ISO 9646, *Information Processing Systems, OSI Conformance Testing Methodology and Framework.* Parts 1-5, 1989.

[2] ISO 8877, *Interface Connector and Contact Assignments for ISDN Basic Access Interface Located at Reference Points S and T*, 1992.

Other

[1] Kessler, Gary C., ISDN, McGraw-Hill, New York, 1990.

[2] Stallings, William, ISDN: An Introduction, Macmillan Publishing Company, New York, 1989.