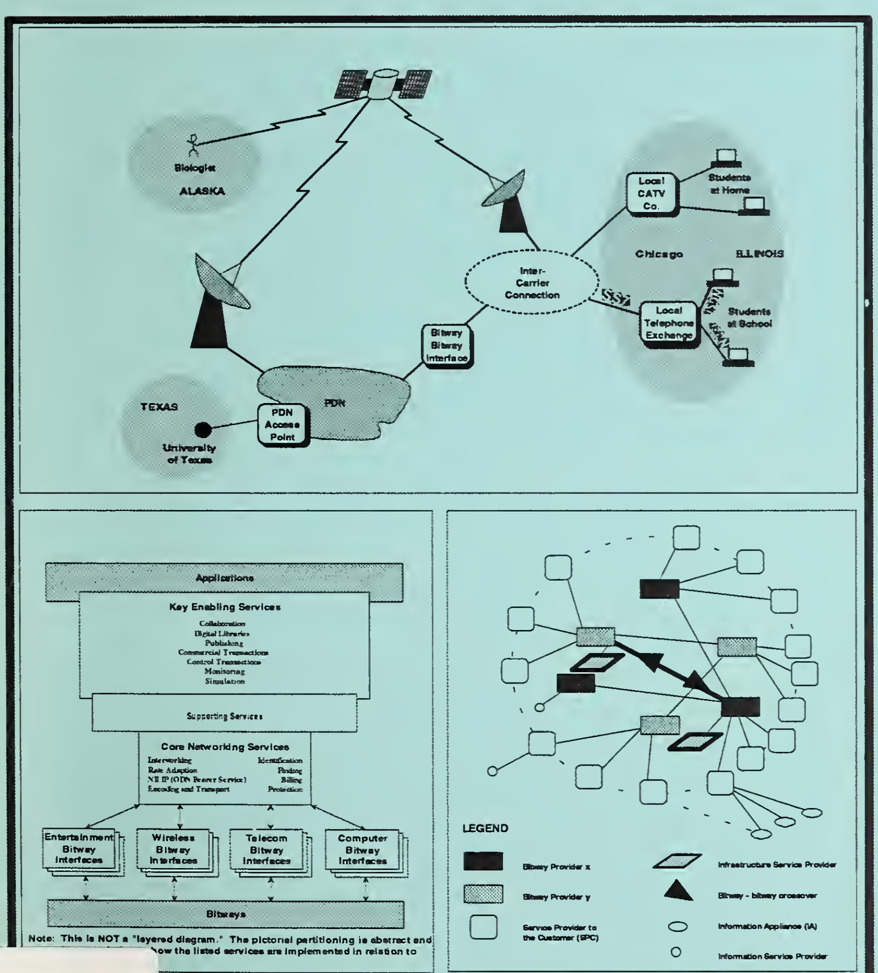
NISTIR 5478

Framework for National Information Infrastructure Services



U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Institute of Standards and Technology
Computer Systems Laboratory
Gaithersburg, MD 20899

July 1994

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The efforts of all of the above individuals are gratefully acknowledged.

Oscar Farah
Technical Editor

PREFACE

This framework document is one of a series of reports which together will provide a comprehensive overview of the National Information Infrastructure (NII) issues from the different perspectives of the three-layer model defined by the Information Infrastructure Task Force (IITF). The May 1994 IITF report "Putting the Information Infrastructure to Work" provides a "top-down" upper layer (applications) perspective. A "bottom-up" view of the Services Architecture from the perspective of the lower (bitways) layer is presented here. A third report (scheduled for completion in late summer 1994), "Open System Environment Architectural Framework for the NII," will present the third perspective, a services/interfaces-centric view of the NII. Each of these reports by itself provides a critical view of the NII services and architectural framework, but it is only when viewed from all three perspectives that the true complexity and scale of the NII challenge emerge.

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EXECUTIVE SUMMARY

INTRODUCTION

The Services Framework as presented herein is intended to serve as a point of departure for discussing the definition, scope, and alignment of NII services. It should stimulate discussions among industry, academe, government, and other elements of the private sector. The widest possible audience needs to consider implementation of services, issues requiring legal resolution or governmental policy, the scope and responsibilities of service providers, and the refinement of NII goals and objectives regarding smooth interworking of the information infrastructure.

While representatives of Federal government agencies wrote this initial version of the Services Framework, it does not express definite government requirements, nor does it dictate the development of NII services solely from a government perspective, although it applies equally to the government services sector. Contributions and comments from the private as well as other public sectors will help refine the Services Framework. It is hoped that this approach will lead to ultimate harmony among today's diverse views of NII services.

Industry will develop most of the NII through investments in wireless communications, broadcasting (cable and over the air), telecommunications, and computer technologies. Industry, academe, and government need to collaborate in writing the next version of this document to reflect consensus positions. This effort will iterate to develop the Services Framework until a consensus NII Services Architecture evolves.

MODELING NII SERVICES

Arrangement of NII Services

From a business perspective, the context for provision of NII services can be represented as in Figure ES-1.

The key elements in the figure are defined as follows: a bitway is a network, or the various components required to transmit and manage digital data across the physical pathways of the infrastructure; an information appliance is a customer-controlled device used to access services, and the service provider to the customer (SPC) is the implementor of an information appliance access point. The bitway-bitway crossover represents interworking between bitways; such crossovers will be essential to seamless connectivity across the NII. Finally, the information service provider provides services, such as a bulletin board or a yellow-pages service, that can be viewed as being outside or within the NII scope.

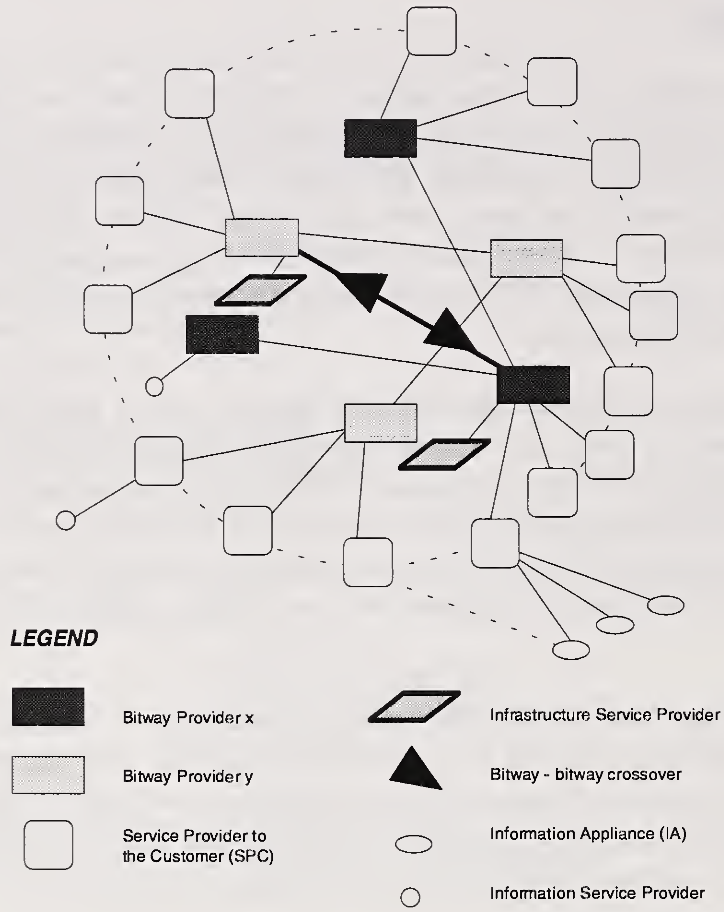

Figure ES-1. Emerging Relationships and Roles in the NII Environment

Several important points emerge through this model:

- There is the prospect of a broad competitive bitway industry providing the underpinnings of the NII.
- The SPC, by controlling the means by which services are delivered to the information appliance, to a large extent controls the evolution of the NII.
- The capability for creation of new competitive services from both within and outside the basic infrastructure is intrinsic to the scheme.

- The SPC need not be one of the conventional carriers. The classic demarcation of network and customer premises is blurring, as system integrators and outsourcing providers become local access providers that provide services even within the customer's premises.

Service Environment

Several existing service environments will influence the development of an NII service environment. Primary among these are Signaling Service 7 (SS7) and the Internet. Work is required to define the transition from these network/distributed environments to an architecture that encompasses the needs of the NII, grows from existing commercial offerings, and supports distributed computing models that evolve with the key enabling services discussed below. There is also a need for a large testbed for examining the various competitive technologies in a research environment. In this connection, scalability of the technologies will be a crucial factor.

NII Services Model

Earlier characterizations of the NII have represented its structure in three layers: applications, services, and bitways. Such a concept is a useful starting point, but is too general for characterizing specific areas of interest, and also tends to represent only an end-user view. The NII Services Model builds on a variation of the three-layer model—an Open Data Network (ODN) model with an hourglass shape. The constriction in the hourglass corresponds to a fourth layer, the ODN Bearer Service, which allows higher-level services transparency to the various network technologies below. The NII Services Model, depicted in Figure ES-2, advances the ODN view by defining the next level of detail in interfaces between bitways and services and between services and applications.

Two general classes of services can be defined—those associated with (or nearest) the bitways and those associated with (or nearest) the applications layer.

The services associated with the bitways are those services that are essential to the operation of the NII. These are called "core networking services" in this document. They consist of basic types of services, such as transport, rate adaption, and interworking between like and unlike types of information providers (e.g., between different telecom information providers and between telecom and computer information providers).

The services on the applications side are not defined as concretely because of the variety of applications envisioned for the NII. Here, rather than define very specific services, a set of "key enabling services" or "enablers" is defined. These enablers perform the relatively complex operations, such as collaboration and commercial transactions, required to develop many of the applications envisioned for the NII.

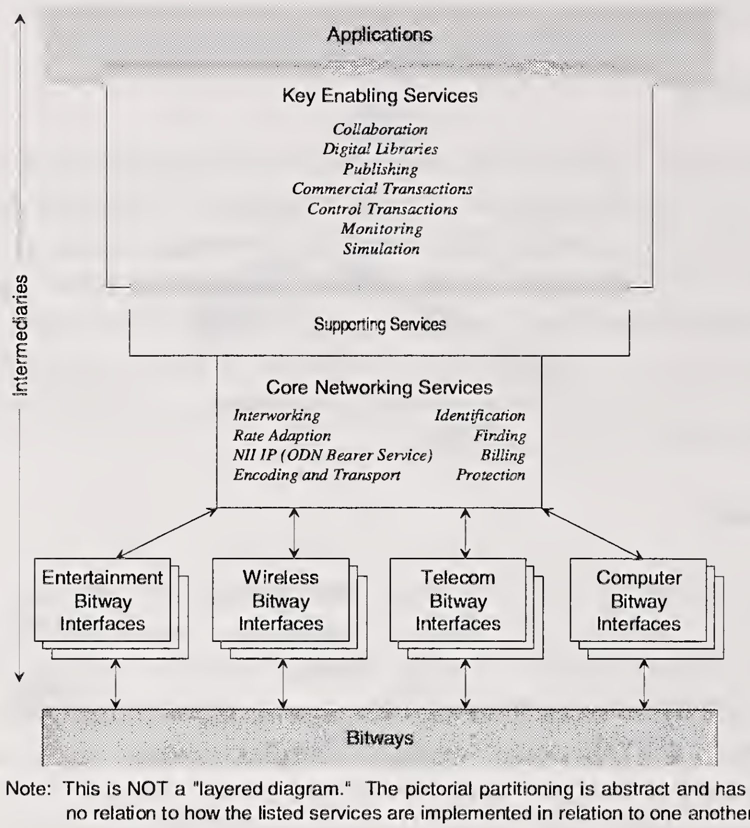

Figure ES-2. NII Services Model.

The key enabling services are complemented by an additional set of "supporting services" that may enhance core networking services or may provide additional capabilities that can be utilized in user applications.

Intermediaries may also be provided with different ranges of service. They may span the full distance between applications and bitways, or provide specialized services covering portions of this range.

An essential device not shown in Figure ES-2 is the information appliance. Many kinds of information appliances will exist, ranging in complexity from the set-top box to high-power workstations.

Additionally, in practice, a number of constraints arising from "environmental factors," internal and external to the data to be transferred, place restrictions on the attributes of the services that may be provided. For example, a video signal requires a minimum bandwidth, error rate, and information appliance capabilities to be usable for transfer and viewing; thus the video transfer service to be used must have specific attributes based on the type of bitway and information appliance that are to be used to view the video. A preliminary set of these environmental factors includes the type of data to be transferred, the type of bitway available for the data transfer, the type and capabilities of the information appliance, the type of storage available, and the management practices of the information provider. Attributes of the services that are required for a given set of these constraints include the content and format of the signal that must be used, the communications protocol required, the design of the intermediaries (if any are to be used), and the network basic management.

The next two sections describe in detail the above NII Services components.

KEY ENABLING AND SUPPORTING SERVICES

The goals of the NII include eliminating "stovepiping"[1] and ensuring that functions are performed in more efficient ways and make better use of technological advances, i.e., *not* carrying on business as usual. One approach to achieving these goals is to provide some small number of enabling technological capabilities that will span applications from entertainment, to business, to government, to individuals. The seven key enabling services shown on Figure ES-2 were selected for this purpose.

Initially, the enablers were identified based on the requirements needed to fulfill the national challenges; they were subsequently augmented to ensure as wide a usage as possible of the NII applications and capture the functionality that will have strong commercial interest. Although every effort has been made to ensure that the enablers selected form a sufficiently complete set, further review and discussions of the list with industry, academic institutions, and other government agencies are planned during the document review workshop.

The NII will provide the above enabling functionality through the definition and provision of certain common services, which may be utilized individually or in conjunction with other services in user applications. These services are built upon the NII core networking services

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[1]In stovepiping, the component functions of an application are tailor-made to work with that application only.

discussed below and may have intrinsic value of their own or add value to existing infrastructure services. The providers of these services may bundle existing services in novel ways; provide tools, aids, or graphical user interfaces to enhance usability; or provide some service essentially unrelated to the infrastructure except in using its services. Supporting service providers include government agencies, large corporations, nonprofit organizations, small businesses, and individuals in homes who might otherwise be classified as "users."

CORE NETWORKING AND OTHER SERVICES

Categories of Core Networking Services

The core networking services of the NII are essential for the common use or support of any application. Agreement on and implementation of such services among bitway and service providers will be essential if the NII is to fulfill its promise. The end use of a core networking service is optional, however, depending on the circumstances of an application. Core networking services are divided into two classes: (1) communication services (interworking/rate adaption, NII Interworking Protocol, encoding, and transport); and (2) basic management services (identification, finding, protection, and billing).

Intermediaries

An intermediary is a service that provides functions by which to interconnect, adapt, and facilitate services offered by other parties. For example, it is often desirable for services to be combined to allow construction of larger, more capable services. The intermediary can bring together the component services. In the evolution of services, it may happen that a proprietary or "uncommon" service becomes widely available, but its interface is not compatible to all potential users. An intermediary can then serve to provide the appearance of a common interface to the service without modifying either the service's interface or the applications that seek to use the service. Consequently, intermediaries also ameliorate some aspects of interoperability which might otherwise require an unattainable consensus to realize a formal standard. Well-known forms of intermediaries are brokers, agents, traders and mediators. A given intermediary implementation can serve concurrently in more than one of these forms, or roles. As in human society, it is expected that intermediary functions and technology will provide a highly competitive environment for entrepreneurs. An intermediary implemented by an automated process, particularly an agent, may have "intelligence" built into it; that is, it follows guidelines and has autonomy to react proactively to conditions it senses from its functional environment.

Service Attributes and Environmental Factors

As noted above, it is possible to identify environmental factors that dictate a set of constraints that in turn can be translated into a set of attributes to facilitate the subclassification of services. Table ES-1 shows the environmental factors and the service attributes they affect.

Table ES-1. Correlation of Environmental Factors to Service Attributes[2]

Environmental Factors / Service Attributes	Data Type	Bitways (Bearer Service Types)	Information Appliance	Data Storage	Information Provider (SPC)
Content/Format - Image Encoding - Video Encoding - Speech Encoding - Relational Objects Encoding	X	X	X	X	
Protocol (Communications) - Peer - Multipoint	X	X	X	X	
Basic Management - Billing - Protection - Finding - Identification			X	X	X
Distributed Control - Access - Replication - Migration - Concurrency	X				X
Intermediaries - Agents - Brokers - Traders	X		X	X	X

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[2] An X indicates high correlation between the environmental factor and the service attribute.

allow a smooth interconnection mechanism. The most notable of these issues include the following:

- The SS7 protocol and its interoperability and deployment are essential to the interworking between the emerging wireless industry and the traditional telecom carriers, recognizing as well the significance of such a fundamental transparent protocol to the exchange between various telecom carriers. In this context, the narrowband Integrated Services Digital Network (ISDN) interface is essential as well.

- The above incremental interface and protocol technology is not sufficient, however, to satisfy the competitive technology needs of the computer, entertainment, and telecom/wireless industries. The ATM mechanism as defined by some elements of the B-ISDN technology is a cross-industry enabler that is recommended for a standard backbone "glue." Interworking methods with regard to ATM for both bearer and even signaling services are essential.

- As the Internet expands, so does the number of host addresses; the latter are currently in short supply. This problem is currently under study. Similarly, the telephone companies are themselves running out of numbering plan addresses. It is logical that as these two components of the NII begin to converge, their addressing issues must be explored together.

- Different networking technologies use dissimilar techniques for transmitting and transforming their data streams. The timing of the transmissions (asynchronous and synchronous), the encoding schemes used to modulate signals, and whether or not rate adaption is used are essential bitway interworking methodologies that need to be addressed.

The Internet concept and philosophy will need to be examined in depth before large-scale bridging or scaling of that network with other heterogeneous infrastructures is carried out. The Internet brings to the table a variety of issues that need to be researched further before being applied to the NII. All the basic ideas that have made the Internet successful and usable will need to be rethought. It is imperative that further research and integration impact studies be done to assess these issues.

OPEN ISSUES

A number of issues identified during the course of this study remain to be addressed. The issues cited here are those the government can help resolve through law, regulation, or policy. Other service-related issues are omitted from this discussion because the authors believe that normal, competitive market forces will evolve effective problem resolutions. This collection of issues is a "starter set," to which additions suggested by outside reviewers are particularly welcome. The issues are listed below in order of importance, based on the immediacy of the need for resolution and the adverse consequences that might result from assuming an outcome that does not finally occur:

- **Universal Addressing.** We are about to exhaust Internet Protocol addresses as well as 10-digit telephone numbers. If we do not act soon on universal addressing, a rare opportunity will be lost. Electronic commerce may be slow to develop without universal addressing.

- **Anonymous Activity.** This is an area where strong emotions figure. If public outcry forces a legislative mandate to reverse course, retrofitting architectural features to protect or prevent anonymity could be costly.

- **Universal Security Policy.** The longer the wait, the more difficult it will be to implement a universal security policy. By waiting too long, the question is resolved in favor of no universal policy.

- **Standards of Proof for Resolving Commercial Disputes.** Electronic commerce for other than trivial transactions cannot achieve its potential until progress is made on this front, although other areas are not much impacted.

- **Registration and Licensing.** The formulations of particular approaches to registration or licensing depend on how the issue of security policy is resolved. It is another emotional issue, but it has less impact on technical protocols and service interfaces.

- **Information appliance Interfaces.** The marketplace may, if left unencumbered by policy, come up with one or a manageable few plug-and-socket conventions, but such an outcome is not certain. The economic impact of a heterogeneous outcome could be substantial, but would be dispersed across a large population. Failing to come to grips with this issue results in a year-for-year slip in achieving a standard solution.

- **Security Labeling.** Interoperability of protection services will entail overly complex intermediary services if there are no common concepts for labeling.

- **Sufficiency of Current Laws to Curtail Undesired Behavior.** Hostile action, fraud, negligence, invasion of privacy, and other undesired behaviors will never be totally eliminated. Continual reworking of laws is needed in the contest against "bad guys"—the inventive criminal and the negligent. Electronic commerce and certain life-critical services may be slow to develop if legal development lags.

1. INTRODUCTION

1.1 PURPOSE AND SCOPE

This document provides an initial description of a framework for National Information Infrastructure (NII) Services (hereafter referred to as the Services Framework), motivated by emerging information technologies. This framework is not intended to be prescriptive, but merely to emphasize any perceived obstructions to achieving the NII goals and objectives. It is presented at a high level of abstraction, relatively independent of implementation techniques and specific technologies; those details are left to product and service providers for their resolution.

The original goal of this document was to define an architecture for NII services. Instead, this document represents a less ambitious attempt to define a framework within which architectures of NII services can be discussed. The Services Framework as presented herein is intended to serve as a point of departure for discussing the definition, scope, and alignment of NII services. It should stimulate discussions among industry, academe, government, and other elements of the private sector. The widest possible audience needs to consider implementation of services, issues requiring legal resolution or governmental policy, the scope and responsibilities of service providers, and the refinement of NII goals and objectives regarding smooth interworking of the information infrastructure.

While representatives of Federal government agencies wrote this initial version of the Services Framework, it does not express definite government requirements,[3] nor does it dictate the development of NII services solely from a government perspective, although it applies equally to the government services sector. Contributions and comments from the private as well as other public sectors will help refine the Services Framework. It is hoped that this approach will lead to ultimate harmony among today's diverse views of NII services.

Industry will develop most of the NII through investments in wireless communications, broadcasting (cable and over the air), telecommunications, and computer technologies.

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[3]The mention of certain commercial products in this document does not imply government endorsement nor intent to purchase specific items. The purpose of such reference is for example only.

Industry, academe, and government need to collaborate in writing the next version of this document to reflect consensus positions. This effort will iterate to develop the Services Framework until a consensus NII Services Architecture evolves.

Finally, as with the development of any framework, many issues have arisen that are outside of the scope of the present effort, but can have significant impact on meeting the objectives set forth. While many of these issues concern policy matters, a large number relate to technology matters as well. Rather than attempt to develop a comprehensive list of such issues, this document addresses those that were salient in preparing the framework.

Moreover, this document does not fully address the important issues of data management, user interface services, and "stable" object management technologies. It is expected that these topics will be expanded upon during subsequent reviews by industry, academe, and government.

1.2 BACKGROUND

A three-layer concept is used to initiate the discussion of the NII in this document. The three layers are bitways,[4] services, and applications. It should be noted that while this layered concept is used to structure the discussion, the boundaries between bitways and services and between services and applications are in fact quite imprecise.

NII services include services associated with bitways and those associated with applications. The services associated with bitways, the bitway-service interface, can be more easily defined because it is evident that a limited set of core services is required for the NII to work at all; this set can then form the basis for the set of bitway interface services. The problem is much more complex on the other side, the application-service interface. There, the number and type of applications are essentially unlimited. Thus, rather than attempt to identify the elemental services and associated application programming interface (API) calls that would be required to build applications, a number of key applications—those on the national challenge list, as well as some others

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[4] The reader should note that the terms "network" and "bitway" are used synonymously throughout this document. These and other terms used in the document are defined in Appendix A.

considered important to the private sector—were used to define a set of broad services termed "key enabling services."

These enablers were deliberately kept at a high level to ensure that their number would be reasonable. In fact, they are combinations of lower-level services. Thus if these enablers are viewed from the perspective of their elemental components, they are highly interdependent, far from providing an orthogonal set to characterize the application space. However, if viewed as whole entities, they can be considered "quasi-orthogonal" since the functional capabilities of each are distinct: no one enabler can be replaced functionally by one or more of the other enablers. The reader is invited to question the selection of enablers and their completeness so the list can be enhanced to reflect the consensus of industry, academe, and government.

From a practical point of view, some forms of these enablers already exist; they are programming modules that are part of currently used applications. As part of the NII, they could be implemented as agents or brokers and perform the enabling functions described in this paper, or they could be broken down into lower-level, more basic functions and implemented as combinations of these functions.

An abstract model has been used to focus the discussion on impediments requiring immediate resolution, with an eye toward accelerated integration of existing infrastructure elements to provide key services in the near term. Three critical points have emerged in this regard:

- A small number of key enabling services, which can support a wide spectrum of applications, can be readily identified and must be made available to the information appliance (a device through which users access information services).

- A set of core networking services must be established as the baseline for creating a large market for NII information appliances, value-added services, and other related products.

- Common interfaces to and between bitways are a central and cohesive element of provisioning NII services and are needed to accelerate the rate at which services are introduced in the market. A preliminary review of cross-industry interconnection provides some specific recommendations for interfaces and protocols.

To enable greater understanding of how these critical points will affect the realization of the abstract model of NII services, several examples of NII applications are provided later in this document. These examples show the dependence of different types of applications on key enabling services and core networking services. Current problems in establishing interfaces to and between bitways are presented and discussed. The examples illustrate the need for concerted efforts to systematically identify areas where standards will need to be developed and where greater understanding is needed of how standards should be used. The examples also demonstrate how standards can be used to connect diverse bitways and allow NII services to be combined to provide unprecedented capabilities for the access to and exchange of information.

1.3 VISION OF THE NII

The vision of the NII that underlies this document encompasses services, capabilities and opportunities for applications, and the roles of users and service providers. To a degree, this vision builds on previous reports, such as that of the Computer Systems Policy Project [1] and other sources. In addition to nationwide services for education, health care, law enforcement, public safety, and manufacturing, this vision also addresses entertainment, home management, and even basic interpersonal communications. The NII must facilitate these services by providing the necessary communication modes for accessing and exchanging information.

The architectural framework for the NII results from identifying the functional requirements and applications needed to access information services, remote learning, commercial entertainment, and other interactive processes. But the legacy of existing services—developed in different industry segments according to different technical standards, laws, and service-level agreements—also constrains the framework. Although the NII must incorporate particular existing technologies, the vision is a technology-neutral approach, one of defining the NII in terms of capabilities.

Among the capabilities assumed in the vision of the NII are the following:

- **Connectivity**—The full capabilities of the network reach almost every home, school, library, business, and hospital, as well as other institutions.

- **Network Features**—Ultimately, the network that connects everyone will carry two-way video signals along with voice and data, and allow any user to connect to any other or many others. Initially, however, different forms (e.g., video, data) will be carried by different subnetworks interconnected with each other to form the "network."

- **Openness and Flexibility**—All users can affordably send information and specify the kind of information they want.

- **Interoperability**—A "network of networks" allows users of different networks to communicate easily.

- **Accessibility**—People can use the network cost-effectively regardless of disability, functional limitation, or remote location. A user can find desired information or entertainment easily through directories or by starting an "intelligent agent," an automated process that is on the lookout for information on services that can meet the person's needs.

- **Privacy, Security, and Assured Service**—The network has safeguards against illegal intrusion into people's homes or papers, including virtual homes and "papers" kept in computer storage. The network also protects intellectual property rights and prevents theft of services. The network resists threats to degradation or denial of service that can result from malicious attack, natural disaster, accident, or procedural error. The network is reliable enough to support life-critical services.

The NII will evolve from existing "infrastructure domains," including commercial computer networks, telephone networks, entertainment networks, wireless networks, and selected components of the Internet. The creative open environment fostered by the Internet must be balanced by the commercial network concerns of billing, security, scalability, legal liability (e.g., copyrights), and export control. Interworking is, therefore, a key enabler for the NII. Because it consists of interworking "domains," the NII introduces many degrees of freedom for specifying service bundling and provisioning. The convergence of technologies and the changes in the regulatory environment add to these degrees of freedom. Lines of demarcation among classical industry segments are becoming blurred.

The vision of the NII behind this document is one in which private industry provides almost all of the infrastructure. Issues involving development of a Government Information Infrastructure (GII) are being addressed by the committee for Government Information Technology Services (GITS). To ensure universal access, some government subsidies may be needed. There is an essential difference between subsidizing a service in general, which distorts markets and tends to drive out private investment, and subsidizing deserving users. The Services Framework establishes no requirements for particular service or user subsidies.

This vision is elaborated in subsequent sections of this document through a series of representative explicit cases that can be enabled.

1.4 ORGANIZATION OF THIS DOCUMENT

Section 2 presents an NII Services Model that defines the various components of the Services Architecture, including the key enabling services, core networking services, supporting services, and intermediaries. These components are then discussed in Sections 3 and 4. A key underlying technology for implementing the enabling services and promoting the applications is that of distributed systems and related object management techniques; this highly competitive area is not steady yet and is briefly discussed in Appendix B. Section 5 covers the interconnections among the different industries that will be the primary actors in the NII; such interconnection is deemed of primary importance to the orderly development of the NII. Section 6 presents examples of NII applications and discusses critical issues in the implementation of the NII Services Model. Finally, Section 7 identifies significant open issues that need to be addressed.

In addition, five appendices are included. Appendix A defines the acronyms and special terms used in this document. Appendix B covers the application environment, while Appendix C addresses data and knowledge management. Appendices D expands on the interconnection of bitways (Section 5) and Appendix E contains a discussion of the Open System Environment (OSE) and its role in the development of applications in the NII environment.

2. MODELING NII SERVICES

While the analogy of the NII as an information highway is a simple one, realization of the NII as a seamless open infrastructure, emerging from present-day products, services, and technologies, is inherently complex. A comprehensive analysis of relationships among applications, services, users, providers, devices, databases, and bitway technologies is a necessary precursor to development of an architecture for the NII. A meaningful Services Framework must simplify comprehension by abstracting away insignificant features, while retaining enough detail to be clear and informative.

A primary goal motivating the development of this Services Framework is to initiate a dialog with the appropriate industry, academic, and government representatives on how applications, both government and non-government, can be accommodated directly, with minimal difficulty, in the NII environment.

This section begins with a discussion of the NII environment and the roles of the service provider to the customer (SPC) and the information appliance in providing the services envisioned for the NII. Next is an overview of the existing and emerging service environments. This is followed by a brief review of some of the models proposed elsewhere for the NII. A detailed three-layer concept based on the Information Infrastructure Task Force (IITF) model is then presented as a basis for defining the various services required for the NII and the service components discussed in the sections that follow.

2.1 SERVICES ROLES AND RELATIONSHIPS

This view of the NII as "seen" by the information appliance highlights the emerging industry arrangements and relationships, especially from a business perspective. The services provided to the highly competitive appliance market can be seen in the context of this emerging business perspective, the SPC, and the user information appliance.

2.1.1 Emerging Business Perspective

Figure 2-1 shows a view of the NII depicting the roles involved in the provision and use of services. The approach represented by the figure is to view services in terms of how they will be provided to users, including the following:

- What is necessary, at a functional level, to access and coordinate access to these services.
- How the services relate to applications and to one another.
- Where competition opportunities and difficulties might lie.
- Where standards, or some forms of interoperability, are needed.
- What mechanisms can be used to integrate service access across the NII.
- Identification of some of the important roles and responsibilities (although without assignment, since that should be the result of policy and business decisions within and between the government and the industries contributing services and products for the NII).

A representation of the NII environment was developed in which services accessed through the NII would likely be realized. This representation takes into account the various means of attaching to the NII and the various industries and entities that would be providing services in this context. It is important to note that this view is not from the perspective of any particular industry segment or implementation, nor is it a physical representation of the NII (e.g., it does not show particular equipment or networks).

The component labeled "Bitway-Bitway Crossover" is intended to represent interworking between Bitway X and Bitway Y. Such crossovers will be necessary if seamless connectivity is to be realized across the NII. The crossovers will likely entail both technical and business interfaces between different bitways. Although some forms of crossover currently exist, these tend to be very special cases (e.g., between telephone local exchange carriers [LECs] and interexchange carriers [IECs]).

Crossovers are central to bitway integration.[5] The bitway provider can be an LEC, for example, to which the SPC is connected. Likewise, there is no technical reason preventing an LEC or IEC, for example, from in some cases offering access directly to information appliances and acting as an SPC, much as the LECs do today. It is possible for a system integrator, outsourcing provider, wireless vendor, value-added company, or

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[5]Technical aspects and issues of bitway integration are discussed in more detail in Section 5.

cable TV company to become an SPC. In addition, an information appliance may receive information from more than one SPC.

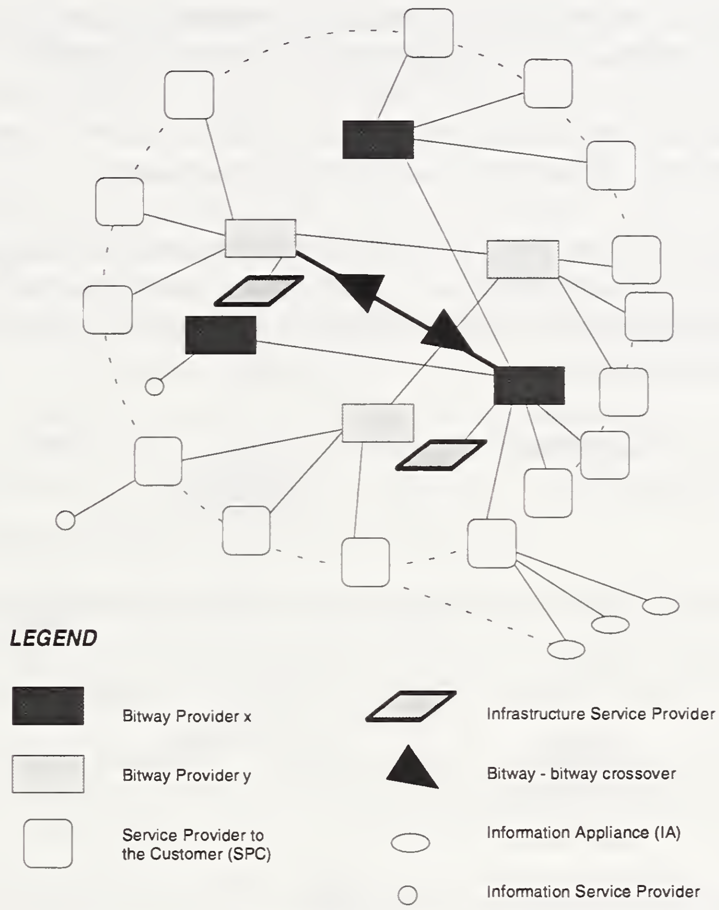

Figure 2-1. Emerging Relationships and Roles in the NII Environment.

Another element of Figure 2-1 deserves mentioning. It is designated "Information Service Provider." One is shown attached to an SPC, and another to a component of Bitway X. The first case is intended to represent an information provider such as a bulletin board operating out of an individual's home. The second case represents, for example, a yellow-pages service provided by a business different from the Bitway X provider. Thus, information providers can be viewed as being outside or within the NII scope.

Several important points emerge through this model:

- There is the prospect of a broad competitive bitway industry providing the underpinnings of the NII.
- The SPC, by controlling the means by which services are delivered to the information appliance, to a large extent controls the evolution of the NII.
- The capability for creation of new competitive services from both within and outside the basic infrastructure is intrinsic to the scheme.
- The SPC need not be one of the conventional carriers. The classic demarcation of network and customer premises is blurring, as system integrators and outsourcing providers become local access providers that provide services even within the customer's premises.

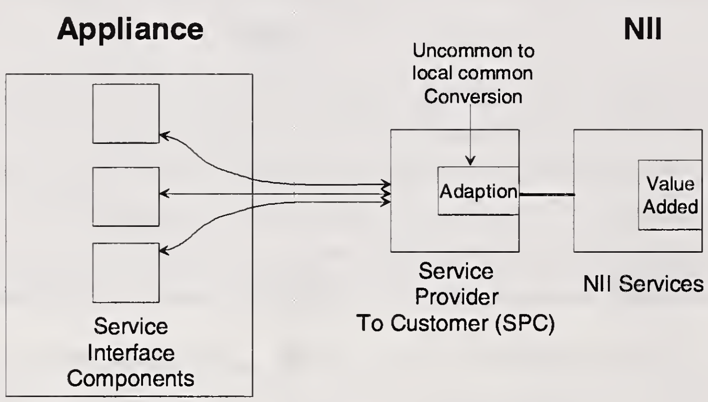

Figure 2-2. Relationship Between Information Appliances and Service Providers to the Customer.

2.1.2 Service Provider to the Customer

The SPC, an essential part of current and emerging networks, plays an even more important role in the NII. The SPC will manage the overall service environment as seen by its customers, and provide some form of integration and adaptation of the services offered elsewhere in the NII.[6] Here "customer" refers to users of the information appliance(s).[7] The relationship between appliances and SPC is illustrated in Figure 2-2.

The general functions of the SPC are as follows:

- **Provision of Service Interface Components.** The SPC will supply the customer, directly or indirectly, with the necessary service interface components, both hardware and software, that will enable the customer to access NII services through local networks. The service interface components may be isolated devices, such as converter boxes, or components for a generic device, such as hardware boards and software for a personal computer. Some components will be general-purpose, and others will be service-specific. A present-day example comes from service provision by commercial computer networks such as Mosaic and World Wide Web, both of which contain software components that provide service interfaces. A software package for a personal computer with Windows (or Macintosh computer) is provided along with the subscription to on-line services. This package is used to connect to the service, manage the user's session, and present the service on the information appliance. The network providers control the presentation of their services on the appliance.

- **Local Service Access.** The SPCs will specify the service interfaces to be used to access services on their local network. This will include the bitways, communications protocol, and content and format specifications for service access.

- **Local Common Adaption.** Through the local service access, the SPCs will define the service interfaces to be used in accessing both local provider services and more global NII services. The SPCs will provide for the adaptation of global services to local common protocols and content and format specifications. This will allow information appliances to be of simpler construction since only local common protocols and content and format specifications need be supported. It should also be possible to pass service access directly to the appliance without adaption to

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[6]In other words, the user's device, the information appliance, relies on an SPC to coordinate elements (services and bitways) of the NII and present them in a usable manner.

[7]The information appliance here may be an end-user's set-top box or a workstation; it may also be a large computer system on a business premise. That system may be a user of NII services, a provider of NII services, or both.

local common formats to allow the connection of more general/sophisticated appliances that may not comply with local common interfaces.

2.1.3 User Information Appliance

Many kinds of user information appliances will exist, ranging in complexity from expanded cable TV controllers to high-powered workstations. Two broad categories of appliances are likely:

- Low-cost devices that will fit into the general category of consumer electronics. These will be specifically tailored to accept services from a single or small group of SPCs. In an effort to establish market share, the service interfaces for these devices will likely be proprietary. This category is called the client appliance and is very cost-effective.

- General-purpose devices (descendants of today's PCs and workstations). These devices will generally cost more than those above, but will be able to perform many functions and will be capable of providing services to a broader range of SPCs. This category of devices will perform the function of server appliances, and must be scalable with regard to performance, design, and capability.

The information appliance, or more specifically, classes of information appliances, will play a major role in defining the public view of the NII. Technically, the interfaces defined for information appliances will be a controlling factor in the services accessible to an information appliance user. Within their relationship to the SPC, the information appliances' use of service interface components relates to many interfaces that exist in computers today, such as fax modems, Ethernet cards, Transmission Control Protocol/Internet Protocol (TCP/IP), and socket software. Many interface elements can be implemented in hardware/software combinations in computers, cable TV set-top boxes, and Integrated Services Digital Network (ISDN) video terminal adapters.

2.2 EXISTING AND EMERGING SERVICE ENVIRONMENTS

The mainstay of the current software market supports a machine-centric and local operating system-centric view of computing. In terms of supplied functionality, support for control of networked environments is less widespread, and support for the integration of diverse networked environments is even sparser.

Currently, there are several kinds of service environments from which one can draw examples that will influence the development of an NII service environment. Each solves a different problem, all of which are applicable to the challenges of the NII. Of these environments, Signaling System 7 (SS7) and the Internet are "standards"-based.

SS7 is used by telephone carriers as the basis for call control and setup in telephone networks. In the recent declaration of "Open SS7," local exchange and long distance carriers have opened their SS7 implementations, and have started offering integration facilities to software developers to encourage and facilitate the creation of a value-added service market coordinated via SS7.

The Internet, an example of a public network that was originally created to serve the needs of researchers around the world, is evolving toward offering commercial services. Businesses are beginning to consider its use in place of private wide area networks. Recent discussions of facilities for service billing and security indicate the Internet's movement toward supporting commercial needs. Facilities for creating services in the Internet are available as part of most commercial UNIX software environments, as well as other software platforms.

Many commercial offerings provide local area network technology. For example, Novell Netware has focused on network technology for local area networks, and is now expanding with product offerings for wide area networks and integration with SS7.

Several consortia are engaged in developing specifications and implementations of distributed systems technology (from which member companies develop and offer products). The Open Software Foundation (OSF) has developed their Distributed Computing Environment (DCE) and Distributed Management Environment (DME) to solve basic problems in distributed computing and management. The Object Management Group (OMG) is working on the Common Object Request Broker (CORBA), which details an object-based model for distributed computing; a broker architecture for linking/integrating object systems; and the Interface Definition Language (IDL), which is used to describe the interfaces between communicating objects. The use of an interface repository providing persistent storage of interface definitions is specified. These interface definitions are intended to be accessible during normal operation to enable dynamic binding of services based on their predefined interfaces.

Each of the above kinds of service environments will influence the development of a service environment for the NII. The degree of uniformity in the underlying infrastructure for SS7 and the Internet has led to their broad use, which raises certain questions. For example, as the market for technologies, such as those from OSF and OMG, expands, will it be filled with competing implementations of a single technology or with competing and incompatible technologies? The need for compatibility in these technology areas is critical to the creation of an infrastructure for distributed computing on the scale of the Internet.

Work must be done to define how we go from these network/distributed environments to produce an architecture that:

- Encompasses the needs of the NII.
- Grows from existing commercial offerings.
- Supports distributed computing models that evolve with the key enabling services.

There is also a need for a large testbed for examining the various competitive technologies in a research environment. This can occur in the public networks as an evolution of the current Internet or in the private networks, possibly as an extension of SS7. In either case, scalability of the technologies will be a crucial factor.

2.3 NII MODELS

There have been several basic characterizations of the NII. Most of these represent the structure in three layers: applications, services, and bitways, as shown in Figure 2-3. This characterization has been adopted by the IITF.

The three-layer concept effectively focuses attention on services, albeit in a roundabout way. Characteristics of the applications and bitways layers can be readily ascertained through review of present-day infrastructure elements. The top (applications) layer is represented by various information appliances, including computers, workstations, telephones, office equipment, and television sets. The bottom (bitways) layer is represented by existing networks, such as those provided by the telecommunications, computer, entertainment/cable, and wireless service providers. Unfortunately, the services layer is somewhat obscure, largely because of considerations such as the following:

- Whether entities considered to be in the applications layer can offer services.
- Whether bitways also offer services.
- Whether the activities of intermediaries (e.g., agents, brokers, or traders) constitute a service.

- The fact that distinctions between the terms "application" and "service" are difficult to articulate, and most definitions tend to reflect one particular viewpoint or another, depending on the specific industries involved.
- The fact that distinctions between the terms "user" and "provider" are also difficult to make since a provider of a service can also be a user of services from some other provider (e.g., telephone LEC).
- Whether the lines drawn between the layers of Figure 2-3 represent real interfaces.

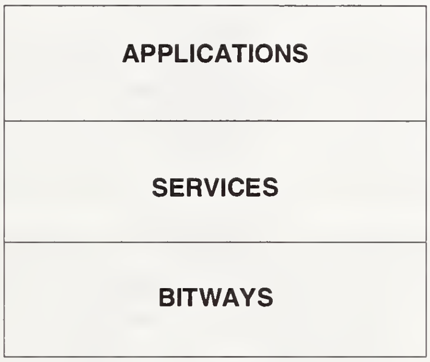


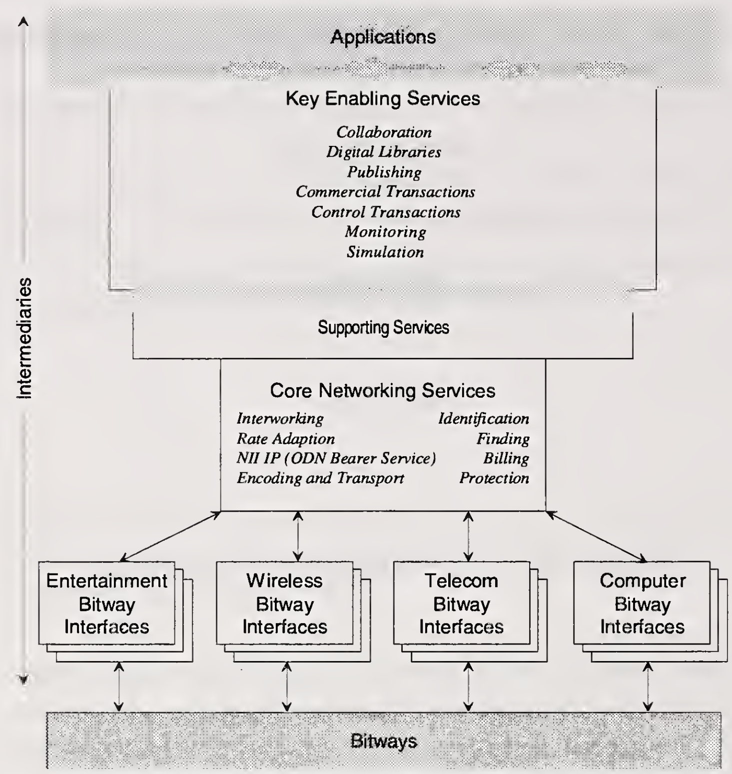
Figure 2-3. IITF Three-Layer Concept.

While the three-layer concept is a good starting point for identifying issues at a broad level, particularly with regard to policy, it begins to be less effective as implementation details are analyzed. The main limitation of the concept is that it is too general, causing difficulties in characterizing areas of interest.

Recently, a variation on the three-layer model was produced by the NRENaissance Committee of the National Research Council [2]. This model is an Open Data Network (ODN) model depicted as an hourglass. In this model, an ODN Bearer Service, an abstract bit-level forwarding service, is introduced in the services layer of the three-layer model and defined as an independent layer as well. Thus the model is called a four-layer model. The constriction in the hourglass corresponds to the ODN Bearer Service. The implication of the constriction in the hourglass is the need to allow higher-level services transparency to the various network technologies below. The ODN Bearer Service constriction offers an anchor for services above, abstracting out some of the details of the networks below without viewing network technologies as monolithic.

2.4 NII SERVICES MODEL

The ODN model has been adapted in this document, as shown in Figure 2-4, to define the next level of detail in interfaces between bitways and services and between services and applications. However, for purposes of clarity, the layered concept was abandoned in favor of a pictorial representation that conveys the interrelationships among the various services.



Note: This is NOT a "layered diagram." The pictorial partitioning is abstract and has no relation to how the listed services are implemented in relation to one another

Figure 2-4. NII Services Model.

Referring back to Figure 2-3, two general classes of services can be defined—those associated with (or nearest) the bitways and those associated with (or nearest) the applications layer. The principal difference between these two types of services is their complexity.

The services associated with the bitways are those services that are essential to the operation of the NII. These are called "core networking services" in this document. They consist of basic types of services, such as transport, rate adaption, and interworking between like and unlike types of information providers (e.g., between different telecom information providers and between telecom and computer information providers). The different interfaces provided to the bitways reflect the diversity in the forms of transmission that the NII will support.

The services on the applications side are not defined as concretely because of the variety of applications envisioned for the NII. Here, rather than define very specific services, a set of "key enabling services" or "enablers" is defined. These enablers perform the relatively complex operations, such as collaboration and commercial transactions, required to develop many of the applications envisioned for the NII.

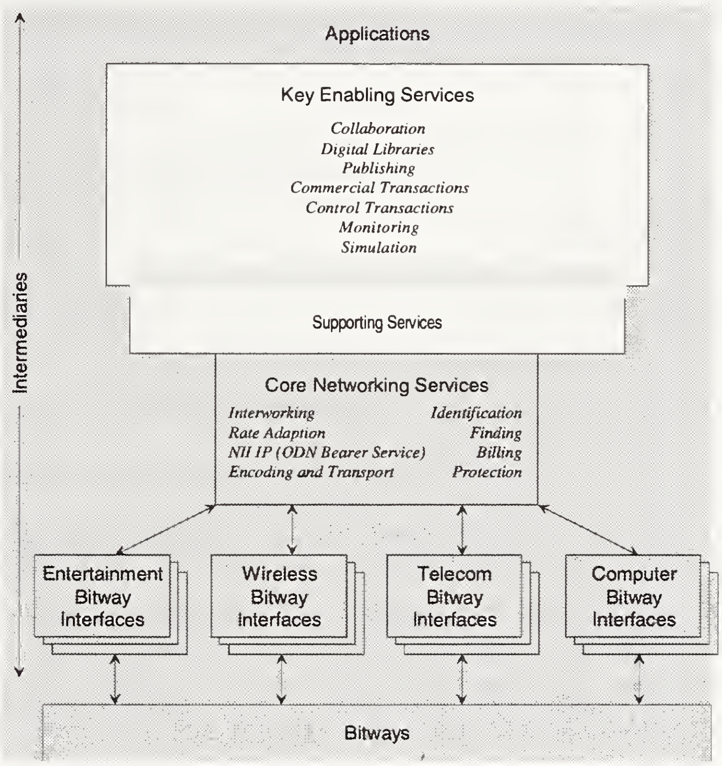
The key enabling services are complemented by an additional set of "supporting services." Intermediaries may also be provided with different ranges of service. They may span the full distance between applications and bitways, or provide specialized services covering portions of this range.

Additionally, in practice, a number of constraints arising from "environmental factors," internal and external to the data to be transferred, place restrictions on the attributes of the services that may be provided. For example, a video signal requires a minimum bandwidth, error rate, and information appliance capabilities to be usable for transfer and viewing; thus the video transfer service to be used must have specific attributes based on the type of bitway and information appliance that are to be used to view the video. A preliminary set of these environmental factors includes the type of data to be transferred, the type of bitway available for the data transfer, the type and capabilities of the information appliance, the type of storage available, and the management practices of the information provider. Attributes of the services that are required for a given set of these constraints include the content and format of the signal that must be used, the communications protocol required, the design of the intermediaries (if any are to be used), and the network basic management.

The next two sections describe in detail the above NII Services components.

3. KEY ENABLING AND SUPPORTING SERVICES

The goals of the NII include eliminating "stovepiping"[8] and ensuring that functions are performed in more efficient ways and make better use of technological advances, i.e., *not* carrying on business as usual. One approach to achieving these goals is to provide some small number of enabling technological capabilities that will span applications from entertainment, to business, to government, to individuals. A set of seven key enabling services, shown in Figure 3-1, was identified in this study and is discussed below. This is followed by a description of the supporting services, also shown in the figure.



Note: This is NOT a "layered diagram." The pictorial partitioning is abstract and has no relation to how the listed services are implemented in relation to one another

Figure 3-1. The Key Enabling Services.

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[8]In stovepiping, the component functions of an application are tailor-made to work with that application only.

It is expected that in the NII, applications will be based on individual, or possibly combinations of, key enabling services, supplemented with selected supporting services, and value-added core services. Where necessary, intermediaries will be used to integrate services in order to achieve interoperation at the application level. (Intermediaries are discussed in section 4.2). Examples of the use of enabling services, support services, and intermediaries are provided in section 6.

3.1 KEY ENABLING SERVICES

The key enabling services identified are as follows:

- Collaboration
- Digital libraries
- Publishing
- Commercial transactions
- Control transactions
- Monitoring
- Simulation

Initially, the enablers were identified based on the requirements needed to fulfill the national challenges; they were subsequently augmented to ensure as wide a usage as possible of the NII applications and capture the functionality that will have strong commercial interest. Although every effort has been made to ensure that the enablers selected form a sufficiently complete set, further review and discussions of the list with industry, academic institutions, and other government agencies are planned during the document review workshop.

3.1.1 Collaboration

Collaboration is the interaction among individuals or groups of individuals who may be remotely located with respect to one another, for cooperation on some specific application. Examples of collaboration include medical consultations between doctors in different parts of the country, technical reviews between professionals, and electronic meetings. In some cases, the collaboration may involve no more complexity than a telephone call. In many instances, it will involve the use of bidirectional, point-to-multipoint, or multipoint-to-multipoint interactions using voice, image, and video data, with information appliances communicating with several other appliances and multiple information servers simultaneously. These types of applications are several orders of magnitude more complex than today's point-to-point voice and data interactions. Use of intermediaries, except to establish the collaboration liaisons, is expected to depend upon the nature of the collaboration and the collaboration participants. The more complex applications will require high bandwidth to handle multimedia information. Acceptable error rates will depend on the application.

Applications requiring collaboration include the following:

- Telecommuting
- Virtual organizations
- Cooperative development and engineering
- Telemedicine
- Medical consultation
- Arts, music and literature authoring
- Entertainment creation and presentation
  - Interactive television
  - Games
  - Program authoring
- Information sharing
  - Bulletin boards
  - Net news groups
- Virtual factory
- Virtual department store

- Virtual classroom
- News gathering
- Interpersonal communications
  - Voice
  - Video
  - Fax
  - E-mail
- Scientific and technical research
- Government applications such as law enforcement and environmental regulations

3.1.2 Digital Libraries

The digital libraries enabler provides the ability to create information resources that allow access to electronic publications. Digital libraries function much as public libraries do in allowing access to collections of books and other materials. As such, the applications developed using the digital library enabler support access to collections of electronic books, periodicals, and other publications. The use of this enabler will make the location of the library transparent to the user. The information resource or resources in which these publications are located may be at a single site or may be distributed. This enabler is distinguishable from the publishing enabler: the digital libraries enabler is intended to provide public access to collection archival materials, while publishing is intended for timely distribution of materials for commercial purposes.

Access to publications in an application developed using the digital libraries enabler will be on a "read-only" basis, meaning that the users cannot change the content of any information accessed. Furthermore, the enabler will need to support procedures for authorizing access to and use of copyrighted material and for providing fair compensation to holders of intellectual property rights. While many of the items in a digital library can be used freely by the public, and are generally not intended for sale, fees may be charged for access to some materials.

The interactions between information appliances and the application systems built upon digital libraries will be somewhat asymmetric. Numerous, small, nearly synchronous messages embodying requests will emanate from the user's information appliance to the digital library. In response, the library will send asynchronous messages containing relatively large amounts of data. The information returned from a digital library application will probably require high transfer bandwidth to accommodate the multimedia documents. Requirements for privacy and transfer integrity will vary, depending on the nature of the information being accessed and the privacy requirements of the users. Because of the diversity of the information in digital libraries, extensive use of intermediaries is expected. Response times should be sufficient to support search and browsing of library materials without significant delays. Information stored in digital libraries will include the following:

- Books, journals, documents, and bibliographies
- Newspapers and various other documents providing public information
- Archival news
- Catalogs
- Science data
- Videos
- General information about such matters as:
  - Employment opportunities and availability
  - Health care
  - Social services
  - Homeless shelters
  - Religious resources

3.1.3 Publishing

The publishing enabler provides the ability to create and distribute publications. This includes creation and distribution of electronic books, periodicals, music, film, and other forms of art. These electronic publications can be distributed to many different types of destinations, including private homes, businesses, and government offices. They may also be sent to digital library systems where they can be accessed and retrieved by users.

The publishing enabler is intended for use in “for-profit” commercial activity. Therefore, it must also support mechanisms for limiting or regulating the usage or reception of certain kinds of published material. For example, periodicals may be provided to private homes or digital library systems at a price. Music, films, literature, and other works that are subject to copyright could be offered for sale. Other legal restrictions may be associated with access to and usage of such information. The publishing enabler must therefore provide facilities to ensure copyright protection of published material. This enabler may also support some means of revenue collection, possibly using remote pay-per-use facilities.

As noted above, this enabler is distinguishable from the digital library enabler described in the previous section. In addition to assuming the creation and organized distribution of publications that can involve profit-oriented commercial activity, publishing may also be associated with the notion of timeliness, the ability to produce items such as newspapers and magazines within a certain time period. Digital libraries focus on the creation and maintenance of archival information resources that contain many kinds of items (including those produced through electronic publishing). In this respect, the publishing enabler can be looked upon as a “producer” and “distributor” of electronic publications, while the digital libraries are “consumers” and “holders” of publications.

Generally response time will not be critical in electronic publishing. However, when there is a cost associated with the time interval over which a user accesses an information source, the enabler should support reasonable response times. Depending upon the amount of information to be transferred to the user, bandwidth requirements for distributing published material could be substantial.

The publishing enabler will combine lower-level NII services to support the following at the application level:

- Electronic advertising
- Publication and distribution of books, journals, literature, arts, music, and other documents
- Newspaper subscriptions
- Entertainment presentations

- Pay-per-view
- Movies-on-demand
- Virtual bookstores (created by combining the capabilities of the digital library enabler and the publishing enabler, supplemented by remote pay-per-use supporting services)

3.1.4 Commercial Transactions

The commercial transactions enabler supports traditional commerce activities, such as quotations; placement of orders; and exchange of money for goods and services, including information goods and services. These activities are closely analogous to classical transaction processing and often have critical response time requirements. Because of the critical economic nature of such transactions, privacy, security, and assurance of successful completion of the transactions are mandatory. Digital signatures for authentication and nonrepudiation, for example, are central features of this enabler. Bandwidth requirements should generally be low. Intermediaries may be involved if there are repetitive, standard functions to be performed, such as currency translation or transmission of Requests for Quotes (RFQs) to appropriate vendors. Users of this enabler include the following:

- Sales and marketing of goods and services
- Purchasing of goods and services
- Digital money
- Banking
- Stock market trading

3.1.5 Control Transactions

This enabler supports the reservation of resources or facilities, or scheduling and/or coordination processes among a group of participants. The principal difference between this enabler and the previous one is the differing time scales involved. Commercial transactions are generally complete within narrow time limits, usually a few seconds at most. Control transactions can vary in action time from less than a second to weeks. Critical response-time aspects do occur here, but are not typical. Bandwidth requirements can vary as well, depending upon the kinds of information to be transferred. Commitments may not reach closure immediately because some transactions may be outstanding for days or weeks following their initialization. Typical applications of this enabler involve the following:

- Resource management
- Collaboration scheduling
- Logistics
- Just-in-time production
- Inventory management
- Integration of point-of-sale and manufacturing activities
- Remote process control
- Travel and other reservations
- Concurrent engineering

3.1.6 Monitoring

Monitoring involves data transfer to and from sensors used to gather measurements particular to some purpose and presumed environment. Generally such data transfer provides status and/or statistical information for drawing inferences on behavior, analogous to telemetry or security monitoring. Monitoring consists of essentially unidirectional information flow, with each package of data having a relatively small, fixed size. Often the nature of the data is such that loss of a package is not critical, so that extensive protection against loss is unnecessary. Applications of this enabler include the following:

- Home security
- Fire protection
- Environmental regulation
- Home environment monitoring

- Hospital patient care
- Providing home medical services

3.1.7 Remote Process Simulation

Simulation involves the modeling of real, imagined, or theoretical environments using, in some cases, high-power processing platforms and sophisticated display units. Simulation contains an assumption of distribution of computation platforms and display units. Distribution may involve use of several processors that compute individual steps of the simulation in parallel, with intermediate results being sent to display sites. While simulation has some similarity to collaboration, the nature of the interactions is essentially different, with simulation involving relatively infrequent exchanges of information during distributed processing. However, there is a requirement for tight response times among processors, so that very high-speed transport protocols are necessary. Simulation may require transfer of text, image, and possibly sound data, and may also require very high effective transfer bandwidth with low error rates.

- Virtual reality
- Entertainment
  - Games
  - Interactive TV
  - Special effects
- Medical procedures
- Military training
- Engineering designs
- Scientific investigation
- Manufacturing
- Environmental modeling
- Education

3.2 SUPPORTING SERVICES

The functionality of the key enabling services will, in part, depend on making use of common supporting services. Services within the supporting category may be integrated into key enabling services or used in conjunction with enabling and core networking services to develop user applications. The providers of supporting services may bundle existing services in novel ways; they may enhance core services by providing tools, aids, or graphical user interfaces; they may also provide services that are specific to a particular industrial sector or government activity. In addition, supporting services could provide capabilities that go beyond mere enhancement of core services, including services that could not be provided by the NII Interworking Protocol (IP). Supporting service providers will include corporations, small businesses, government agencies, nonprofit organizations, educational institutions, and private individuals who might otherwise be classified as "users." Several preliminary categories of supporting services are offered below:

- **Specialized services for support of key enabling services.** These services could be integrated either into key enabling services or directly into application systems. They would provide important capabilities relating to the retrieval, manipulation, and storage of information (Appendix C provides further discussion of information management capabilities and their importance for all categories of NII services). Supporting services of this type would provide the following noteworthy capabilities:

  - **Knowledge-based query processing**—the ability to accept queries that may be imprecise or poorly defined, and to locate and retrieve information using basic core finding services augmented by knowledge-based methods for semantic analysis of query content and heuristic search. The use of such techniques would permit effective processing of very large amounts of information that would be computationally infeasible to process using traditional database query processing techniques.

  - **Knowledge discovery**—The ability to analyze information in large repositories in order to identify relationships within data and thereby produce new and useful information. This service may make use of automatic indexing, machine learning methods (such as neural network techniques), and statistical analysis methods.

- **Data translation and integration**—The ability to convert data from one data interchange format to another and to package it in a form acceptable to the receiver.

- **Knowledge-based language translation**—The automated translation of text from one language to another (e.g., Spanish to English) using artificial intelligence machine translation methods.[9]

- **Industry-specific supporting services.** Individual industries would define supporting services for their own specific uses. These services would be based on core services and other supporting services. For instance, providers of reference and bibliographic service for specific industries might wish to customize intelligent query processing services to analyze queries containing specific kinds of business or technical information. Other industry-specific services may be unique. The electronic commerce industry could develop services that support Electronic Data Interchange (EDI).

- **Public (government sector) services.** These include services developed for use by government in acquiring and distributing information. Public services will combine unique services developed specifically to satisfy government requirements, as well as build on core services, industry-specific services, and information management services.

- **Competitive versions of core networking services.** These include enhanced versions of existing core services or combinations of core networking services that offer additional functionality or performance over the core set. For instance, core networking services offer basic information search functions (discussed in Section 4.1.2.2). Enhanced competitive versions of this service, such as a "yellow pages" catalog or finding services that extend beyond a local area, might be offered through the SPC for a fee. Other examples might be enhanced protection services and supportive financial services.

- **Remote pay-per-use services.** These are services that could be integrated directly into applications to allow the applications to be offered as services for a fee. Using the remote/pay-per-use facility, end users could invoke the application system and

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[9] This supporting service category and the previous one may be implemented using intermediaries.

receive its services on a restricted basis. Payment could be provided using digital cash.

- **Service support mechanisms.** Other services may be provided for definition, development, maintenance, and management of core services, enabling services, and other supporting services.

To integrate services into applications more effectively, individual organizations will create frameworks and profiles. Frameworks will serve as reusable templates for application systems within which key enabling and supporting services can be selected, configured, and integrated with application code. (See Appendix B for further discussion of frameworks.) To facilitate integration of services and other software and hardware components, frameworks will utilize interface bindings based on common standards and specifications. These bindings will also be used by intermediary services to allow other services to interoperate.

3.3 STANDARDS FOR INTEGRATION OF SERVICES

The National Institute of Standards and Technology (NIST) Application Portability Profile (APP) [3] provides a classification of services offered strictly within a computing environment. The APP describes an Open Systems Environment (OSE), which establishes an architectural framework within which components from multiple vendors, possibly using dissimilar technology, can interoperate. This architectural framework identifies key interfaces and services exchanged at those interfaces.

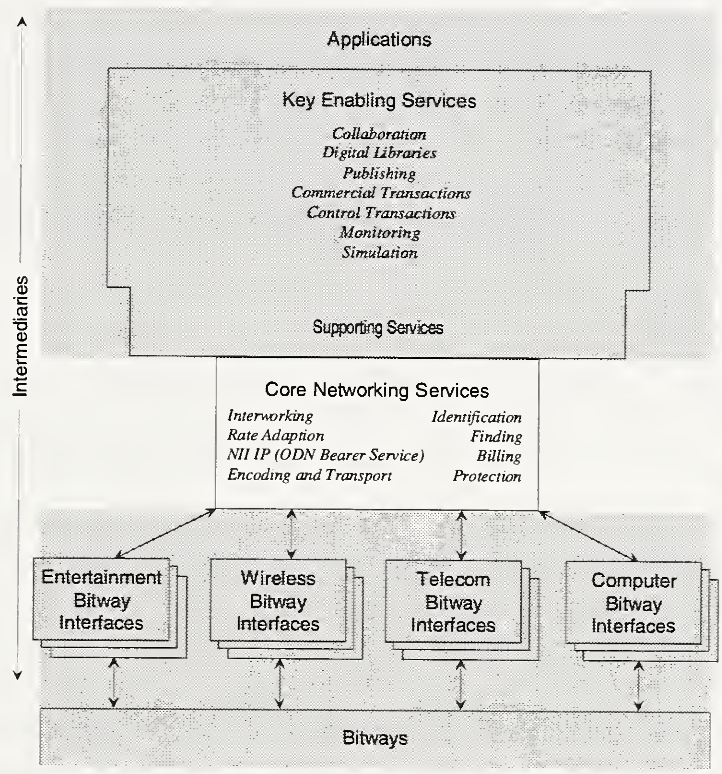
The APP/OSE utilizes a distributed system concept, which provides a context within which an organization can define a specific distributed system architecture tailored to its needs. The service and interface definitions are used as a template in selecting specific standards. They are also used to provide guidance to standards development where needed standards are not available.

The OSE concept used in the APP has evolved over the last decade through the collaboration of industry, government agencies, academe, and the standards community. It incorporates lessons learned from acquiring, building, and maintaining distributed information systems. A brief summary of the OSE concept is provided in Appendix E.

The Department of Defense (DoD) has taken a similar approach. The DoD Technical Architecture Framework for Information Management (TAFIM) provides guidance for the evolution of the Department's technical infrastructure. It does not provide a specific system architecture. Rather, it provides the services, standards, design concepts, components, and configurations that can be used to guide the development of technical architectures meeting specific mission (i.e., application domain) requirements. The TAFIM is independent of mission-specific applications and their associated data. It introduces and promotes interoperability, portability and scalability of DoD information systems.

4. CORE NETWORKING AND OTHER SERVICES

The core networking services and intermediaries, highlighted in Figure 4-1, are discussed in this section.



Note: This is NOT a "layered diagram." The pictorial partitioning is abstract and has no relation to how the listed services are implemented in relation to one another

Figure 4-1. Core Networking and Other Services.

4.1 CATEGORIES OF CORE NETWORKING SERVICES

The core networking services of the NII are essential for the common use or support of any application. Agreement on and implementation of such services among bitway and service providers will be essential if the NII is to fulfill its promise. The end use of a core networking service is optional, however, depending on the circumstances of an application.

Core networking services are divided into two classes:

- **Communication services.** These are layered services. They include the following:
  - Interworking/rate adaption
  - NII Interworking Protocol (IP)
  - Encoding and transport
- **Basic management services.** These services do not fit into layers, but are arranged functionally. They include the following:
  - Identification
  - Finding
  - Protection
  - Billing

4.1.1 Communication Services

These services provide communication between components of applications, infrastructure elements, key enabling services, etc. for request and response exchanges, and ensure correct interoperation. These services depend on the use of a common bitway access mechanisms, and include error detection and recovery features should the probability of undetected or uncorrected errors be too high on a particular bitway. For example, in data communications, communication services include specification of the packet size, compression technique, transfer rate, and error checking protocol. As discussed later, these characteristics are sensitive to the type of bitway used and the data type to be moved. Thus it is expected that several data transfer protocols will be defined for the NII. In addition, it is expected that data may traverse multiple bitways (e.g., cellular to wireline networks), and that this should be made transparent to higher-level services. This issue is discussed further in Section 5.

4.1.1.1 Interworking/Rate Adaption

The NII will be formed from a combination of multiple bitways offering a great variety of information transmission options spanning wireline, wireless, and satellite transfer technologies. Core networking services define access to bitway providers through a collection of individual industry interfaces. Bitways offer will vary widely in terms of data transfer rate, available quality of service, and synchronization capabilities. End-to-end connectivity, as viewed by an application, may involve a single provider or a mix of many providers, much the same as in the current Internet and telephony environments.

The various industry segment bitway interfaces shown at the bottom of Figure 4-1 are user-to-bitway protocols that span, at most, the lower three layers of the Open Systems Interconnection (OSI) reference model [3]. The signal transmitted to and from these interfaces to the external bitway environment is typically a bearer service channel with some form of framing and multiplexing. The interworking/adaption function is a signal translation process from one type of interface to another.

4.1.1.2 NII IP

The constriction in the ODN hourglass mentioned in Section 2, the ODN Bearer Service, corresponds to the core networking services in this model, a major component of which is the NII IP, a concept similar to the ODN Bearer Service.

For more than a decade, the discussion of layering in networks within traditional data communications has centered on the OSI reference model. Within that model, the network service is responsible for moving data between end-systems. A connectionless mode network service is provided by the Connectionless Network Protocol (CLNP), which provides passage across dissimilar interconnected networks. Within the Internet, a connectionless-mode network service is provided by the Internet Protocol. The need for a network service and a related protocol also exists in the NII. The NII IP offers transparency over the topology of the entire network and over the transmission media used in each segment or subnetwork.

The NII IP label is both intuitive and problematic. There is broad understanding within the data communications community of the function of the Internet Protocol and the way the Internet relies on it to enable the interconnection of networks. The same concepts apply to the NII. However, data communications is only a small part of the task defined by the NII, and neither CLNP nor the Internet Protocol has the functionality to provide all the necessary services. Still, the transparency issues are present in the definition of bitway coordination for the NII. This transparency implies the following general abstract services:

- A uniform system of addressing that makes all potential devices defined within the NII addressable. These devices include computers, other interactive (possibly mobile) communication and display devices, possibly passive display devices, and monitoring devices used in home or industrial applications.

- A routing function to direct flow through the networks. Routing depends on network topology and requirements for quality of service, synchronization, and multipoint capability.

- Establishment of quality-of-service parameters that will drive the possibly real-time choice of provider networks to be employed. Quality-of-service issues such as availability and reliability will be of paramount importance because of the diversity of network types (e.g., from the inherent channel error characteristics of wireless communications).

- Synchronization specifications to describe synchronization requirements between information flows.

- Multipoint capability to support communication between more than two NII IP terminations. This capability has implications for addressing, routing, quality of service, and synchronization.

The NII IP will consolidate bitways of a more diverse nature than those in the Internet or OSI environments. Given the overwhelming complexity of goals and implementation of those goals in the NII, it will be necessary to hide aspects of bitway-to-bitway integration beneath this single service interface.

4.1.1.3 Encoding and Transport

Transport mechanisms, such as reliable end-to-end protocols, will be needed to interconnect services via the available bitways. The infrastructure will support many types of data with appropriate definitions of reliability. The requirements vary significantly from computer data to voice to video, thus defining multiple classes of transport mechanisms and protocols. Encoding of data, voice, video, and computer information for transport involves many of the same issues. Encoding appropriate for each information type is needed. Many of these encoding schemes already exist or have well-established standards or current standards efforts. However, much information that is transported will contain multiple data types, and appropriate transport mechanisms and encodings remain as research issues.

4.1.2 Basic Management Services

A well-defined set of basic services can contribute to the quick establishment of a large market in which value-added services are used to differentiate among offerings. As is common in such cases, the distinction between basic and value-added services is sometimes blurred. Nevertheless, the concept helps focus attention on the more critical aspects needing resolution, some of which are discussed below.

4.1.2.1 Identification

This aspect provides identifiers for objects and resources that serve a wide variety of purposes, including protection (e.g., authentication), fault control, resource management, and locating and sharing of resources. In addition, the identities of users, information appliances, and other principals outside the NII require binding with distinct NII addresses. Identification is used to support the addressing function in the NII IP.

A name space is the set of identifiers used to equate with entities. Name spaces may be global (i.e., a one-to-one mapping between names and entities), contextual (i.e., one-to-many or many-to-one mapping, depending on context), or hierarchical (i.e., a global identifier composed of subidentifiers). The choice of identification affects the degree of management overhead, the perspective on resource and object access, relocation, replication, sharing, etc. Identifiers will exist at multiple levels of the NII architecture. The addressing portion of this functional area is part of the service definition of the NII IP.

4.1.2.2 Finding

As its name implies, finding includes the search, initial evaluation, selection, and linking of resources, users, applications, services, etc., including informational components, without prior configuration or specific knowledge by the requester. Finding, of course, requires the identification service. In order to perform the linking aspect of finding, it is critical that at the time of discovery of the desired resource, there be available information providing, in a consistent/standard manner, an accurate description of the resource. This description should include, but not be limited to, logical and physical structural characteristics of the resource, interface requirements, and references to applicable standards with which the resource is compliant. Finding will involve the use of extensive data and knowledge management capabilities, such as distributed transaction processing, query language processing support, and others. (See Appendix C for further discussion).

4.1.2.3 Protection

Many networks today operate with little or no protection for transactions, except that offered through the secrecy of the system (e.g., ownership, technical details), simple password schemes, and possibly the threat of legal action against malicious conduct. If the NII is to have commercial success, it will need to support a variety of individual and organizational security policies that address a diverse set of security requirements. This suggests that a comprehensive security policy is needed for the NII to ensure that a safety net of basic protection mechanisms is in place. While the many security services of the NII cannot be expected to meet more than the basic requirements, they should provide the foundation on which additional security services can be established.

To meet the basic needs of individuals and many businesses, several fundamental security services are proposed:

- **Authentication of the parties** (including identification) providing and using services

- **Authentication of the source** of information received on a bitway

- **Integrity of the information** conveyed by the bitway

Authentication of the parties can help ensure that the correct parties are in placed in contact for delivery of the intended service. It does not ensure that during delivery, the information has not in some way been tampered with. Source authentication ensures that once parties involved in a service have been authenticated, the information being provided comes only from those parties. Information integrity ensures that the information received is the same as that provided at the source.

Universal identification and authentication are essential for rendering all other security services uniformly over the NII. Therefore, it is desirable to institute a common authentication scheme from the outset, to avoid the establishment of noninteroperable enclaves. Common does not necessarily imply that a centralized authority is in charge, or that identical mechanisms are used NII-wide. Current technology suggests that such a scheme would entail the use of public key cryptography and an organization of certification authorities, and would require that each user and service provider dependent on security services register with the proper authority.

Ideally, the mechanisms used to provide the base security services would be identical. In practice, however, it is expected that a variety of competing mechanisms will prevail. Therefore, it is essential that mechanisms of comparable strength be used and, where necessary, the means to translate or otherwise employ the information used by one mechanism be provided to another.

Beyond the fundamental services, other security services are needed to protect information, prevent fraud and abuse, stop individuals with malicious intent, and ensure the privacy of individuals using the NII. Since the fundamental security services are limited, they must be supplemented with additional services to meet these needs. Such additional security services are regarded as value-added services, developed to meet the needs of a particular application area, and may require the upgrade or replacement of an information appliance. Value-added security services envisioned for the NII include access control, data confidentiality, nonrepudiation, and availability. Advanced services, including third-party notary services such as time-stamp services, are also expected. In addition, security management services, such as key management and audit, must be provided.

While the functionality provided by security services is important, the level of confidence one can place in those services is also of significance. For a user, this may be based simply on a written contract with the service provider, or it may require further evidence of compliance (i.e., assurance) from the service provider. Elements of assurance may be provided through evaluation of the services by an independent third party. Such an evaluation would include assessing the effectiveness of the system's mechanisms against the perceived operational threat and the correctness of their implementation within the system.

4.1.2.4 Billing

New abilities to pay for services will be needed to support the NII. There will be a need for digital cash that is reliable; offers reasonable protection against fraud and other misuse; and can be accepted by the user, vendor, and financial communities. Such digital cash, which would not require authentication of a user, would be used to pay for anonymous services such as printing of a publicly available document. It must be possible to store digital cash on a personal device (such as a smart card), transfer it to a vendor, and convert it into currency. At least some basic NII services must be available on such a cash-and-carry basis, without an established relationship with the banking/finance community. The digital cash must be practical to use to pay for small services, such as printing a document at a public kiosk or renting a movie for an hour, as well as large services.

Digital cash also forms the basis for more advanced electronic funds services that cannot be used anonymously. These services involve a financial third party beyond the buyer and seller already involved in a transaction. Financial services common in the current banking/finance industry will likely be extended to the electronic domain. Obviously, new forms may appear that can take advantage of the strengths of the information infrastructure. Electronic forms of credit services, debit services, checking, money orders, and other financial instruments are possible. Authentication and other security issues are paramount for protecting the user, the service supplier, and the financial service supplier.

4.2 INTERMEDIARIES

An intermediary is a service that provides functions by which to interconnect, adapt, and facilitate services offered by other parties. For example, it is often desirable for services to be combined to allow construction of larger, more capable services. The intermediary can bring together the component services. Intermediaries can be used to integrate a collection of supporting services and value-added core services in order to provide the capability of a key enabling service. Similarly, intermediaries could be used in the development of an application system to bind selected enabling supporting services using a framework (see Appendix B for further discussion).

In the evolution of services, it may happen that a proprietary or "uncommon" service becomes widely available, but its interface is not compatible to all potential users. In this instance, an intermediary can serve to provide the appearance of a common interface to the service without modifying either the service's interface or the applications that seek to use the service. Consequently, intermediaries also ameliorate some aspects of interoperability which might otherwise require an unattainable consensus to realize a formal standard. An example of the use of intermediaries to achieve interoperability is given in Section 6.1.

Well-known forms of intermediaries are brokers, agents, traders, and mediators (defined in Appendix A). A given intermediary implementation can serve concurrently in more than one of these forms or roles. As in human society, it is expected that intermediary functions and technology will provide a highly competitive environment for entrepreneurs. An intermediary implemented by an automated process, particularly an agent, may have "intelligence" built into it; that is, it follows guidelines and has autonomy to react proactively to conditions it senses from its functional environment.

4.3 SERVICE ATTRIBUTES AND ENVIRONMENTAL FACTORS

As discussed in Section 4.1.1.2, the NII IP is proposed to focus attention on managing the complexity resulting from the many types of bitways and the ways they are presented to services that are users of bitways. In that discussion, the NII IP is described as a set of general abstract services that would be provided by the bitways. As suggested in Section 2, it is possible to identify a set of environmental factors, based on the path, equipments, and SPC, that dictate a set of constraints which in turn can be translated into a set of attributes to facilitate the subclassification of services. Again, the reader is encouraged to comment on the adequacy and completeness of both the environmental factors and the service attributes.

4.3.1 Environmental Factors

The current set of environmental factors consists of:

- **The type of data to be transferred.** Although all binary, the data to be transferred vary in many respects and can be classified into different types, including text, binary, image and video, and sound, or a combination of types as would be the case for multimedia data. File sizes can range from a few hundred bytes for text data to terabytes for complete color sound movies.

- **The type of bitway available for the data transfer.** Bitway capacity and noise immunity vary with the physical type of bitway, i.e., whether it uses an unshielded twisted pair, a coaxial cable, or airways; the type of modulation and carrier frequency; and the number and noise figures of repeaters in the path (if any). Usable bandwidth can range from a few kilobytes per second to several megabytes per second.

- **The type and capabilities of the information appliance.** As discussed in Section 2, all information appliances vary in their capabilities.

- **The type of storage to be used.** A wide range of storage devices exist, with differing capacities, access speeds, and data transfer rates. Capacities range from hundreds of kilobytes (e.g., floppy disks) to multiterabytes (e.g., jukeboxes).

- **The management practices of the SPC.** The SPC may use specialized billing methods, or may have business agreements that limit its capabilities to provide service.

Once the above constraints have been defined for a given path, a decision can be made on whether a given signal can be transferred and what attributes the transferring service must have.

4.3.2 Service Attributes

The service attributes identified include the following:

- **Content and format.** This attribute covers encoding issues for text, graphics, images, video, voice, multimedia, etc., as well as coordinated combinations. Information encoding is an issue for both storage and transmission. Some forms of encoding are contained in the core networking services. Others are specific to individual industries; for example, the Motion Picture Experts Group (MPEG) 2 specification details the content encoding for video, and similar specifications exist in telephony for voice encoding. Information systems typically support detailed schema for describing the structure of information within a storage system or as encoded for transmission. Relational databases (Structured Query Language [SQL] accessible) and objects are common organization schemes. Specific attributes are needed to indicate the content area (e.g., image, video, audio, other information), along with detailed taxonomies for each area.

- **Communications protocol.** This attribute includes basic transport protocols, protocols between services such as mail agents, and custom protocols created by interface definition languages used to define distributed applications. Protocols are divided into two subgroups: peer and multipoint.

- **Basic management.** This attribute reflects the functions of identification, finding, protection, and billing, as discussed in Section 4.1.2.

- **Distributed control.** There are many forms and architectures for distributed control within the research community. There will likely be many competing forms of distributed control tailored to different services, applications, and industries. Typically, issues of replication, translation, migration, trading, concurrence, system functions, and access are considered elements of distributed control. This attribute will evolve to describe these service issues.

- **Intermediaries.** This attribute covers a set of issues that pertain to interconnecting, adapting, and facilitating services and interfaces (including the user interface), and providing for the implementation of technical policies established by conventions in distributed control. This attribute distinguishes specific architectures for intermediaries and issues within those architectures.

Table 4-1 illustrates which environmental factors affect the various service attributes. The definitions of some services will center on a single attribute; that attribute then can be used to categorize the service. The definitions of other services will cover a broad range of attributes; the implication is, then, that such a service is dependent upon multiple facets of the environment and is therefore more complex in its categorization.

Table 4-1. Correlation of Environmental Factors with Service Attributes[10]

Environmental Factors / Service Attributes	Data Type	Bitways (Bearer Service Types)	Information Appliance	Data Storage	Service Provider to Customer (SPC)
Content/Format - Image Encoding - Video Encoding - Speech Encoding - Relational Objects Encoding	X	X	X	X	
Protocol (Communications) - Peer - Multipoint	X	X	X	X	
Basic Management - Billing - Protection - Finding - Identification			X	X	X
Distributed Control - Access - Replication - Migration - Concurrency	X				X
Intermediaries - Agents - Brokers - Traders	X		X	X	X

Within the context of service attributes, the most basic form of a service is termed an *elemental* service. A first effort at defining elemental services focuses on services that fit

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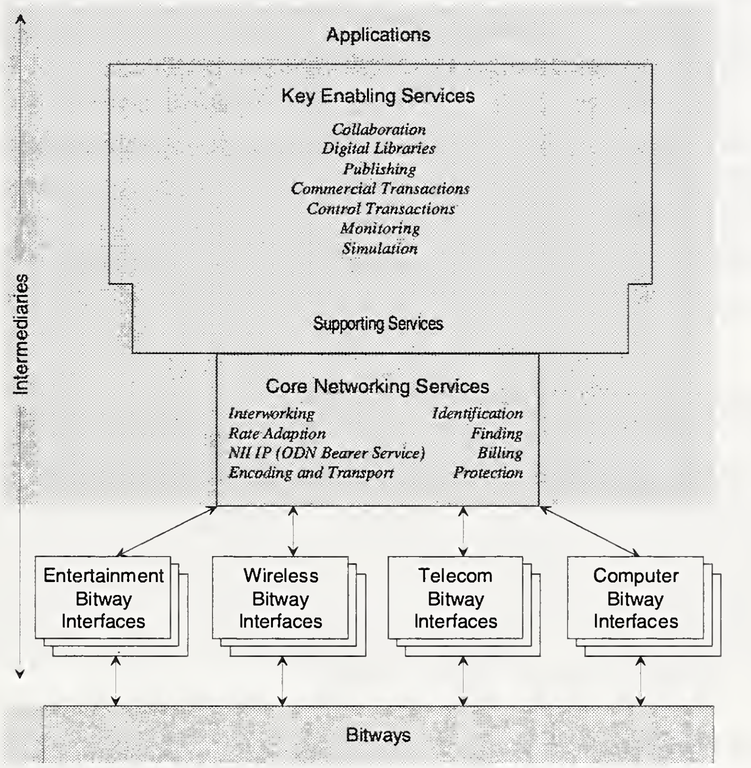
[10] An X indicates high correlation between the environmental factor and the service attribute.

into a single service attribute group. More complex services will involve multiple service attribute groups.

5. INTERCONNECTION OF BITWAYS IN THE NII

The efficient interconnection of the bitways of some specific industries is viewed as essential to the success of the NII. To facilitate this interconnection, the core networking services shown in Figure 5-1 are used.



Note: This is NOT a "layered diagram." The pictorial partitioning is abstract and has no relation to how the listed services are implemented in relation to one another

Figure 5-1. Interconnection of Bitways.

Although successful bitway interconnection strategies emphasize primarily the need for interworking and rate adaption services, other core networking services, such as encoding, transport, and a specific bearer service, are also required.

Bitways will form the rudimentary thoroughfare needed to move a variety of data types reliably, efficiently, and as expeditiously as possible. *Therefore, interconnection of dissimilar underlying networks will most likely be the focal point for accelerating the implementation of NII services.*

To accurately characterize the interfaces required to interconnect multiple industry bitway services, it is necessary to identify service elements encompassing specific bitway functionality. Services requiring various degrees of translation, demodulation, conversion, compression, and manipulation of data may be required to cross-connect these functions. Within today's analog and digital supply and distribution-based systems, there is a need to minimize this process. However, it is envisioned that for some time to come, a great deal of overhead associated with these interconnection activities will inevitably be introduced and require management. Integration and the subsequent distribution of services and information in different formats from multiple suppliers will also be required.

This section reviews the four key industries that must be interconnected, examines the issue of cross-industry interconnection, describes emerging industries providing bitway access services and related information flow, summarizes key interworking issues, and presents some preliminary recommendations related to bitway interconnection.

5.1 INDUSTRIES TO BE INTERCONNECTED

Interconnection of the industries selected in this study is essential to the success of the NII. To this end, available interface technology bridging several cross-industry networks must be explored. In fact, current cooperative alliances among some of these industries indicate a trend toward interconnection and convergence. This information technology and digital communications convergence is instrumental to the applicability of the NII services. The NII-related industries areas follows:

- **Computer industry.** Computers currently transmit data to individuals, as well as to other computers, principally to provide information for education, news, and business applications. Normally, digital data is transmitted; the file size can range from relatively small files to large, multimegabyte files. The computer industry includes all the major subindustry vendors, encompassing mainframes; PCs; workstations; and all protocol-based peripheral equipment produced solely to connect and access external services via networks, cable systems, and airwaves.

- **Telecommunications industry.** Telecommunications generally consists of two-way communications, e.g., telephone. The data handled is generally analog and relatively narrowband. Most commonly, many channels are multiplexed to exploit the relatively larger bandwidth of the bitways. The current trend in telecommunications is toward digital communications. The telecommunications industry consists of all the long-haul carriers, LECs, and other access providers; public and private data networks; and the associated equipment providers. These industries generally provide the backbone, local exchange, and signaling networks used to facilitate local and long distance connectivity. Higher-level services in the form of applications, intelligent agents, and network transport services will all use these providers.

- **Entertainment industry.** At present, the entertainment industry uses primarily one-way communications. The data is usually analog and relatively wideband. The transmission medium is also primarily analog, so that the term "bitway" is not yet applicable to the industry. Multiplexing of a number of channels is used in this case also, as the transmission medium used can carry a number of channels. The entertainment industry includes a wide variety of fee-for-service and over-the-air broadcast entities. The term "entertainment" is not meant to exclude news, educational, and alerting services that can be provided by cable or over-the-air broadcasts. Because of significant technical incompatibilities between the entertainment bitways and other bitways, full interworking may not be achievable initially.

- **Wireless communications industry.** Wireless communications can be either bidirectional, as with cellular telephone and two-way radio, or unidirectional, as with broadcasting. A large portion of the data is currently analog, although the trend here also is toward digital data. The bandwidth requirements range from low to relatively high. Geographically dispersed areas that are otherwise not cost-effective locations for laying cable can be served using the current radio-microwave and future wireless-based technology. Fleets of satellites in various orbits are to be launched in the next few years to carry various kinds of information. The global coverage of such satellites makes them contenders for providing widespread connectivity.

Other possible categories include the education industry and software vendors. In the area of education, televised courses have been offered by universities and other educational institutions for a number of years. Also common now are interactive telecasts in which students are located in classrooms that are physically distant from the teachers. With the advent of the NII, interactive capabilities will be extended to homes and offices, significantly increasing educational opportunities. Section 6.4 provides an example of how the NII could be used to provide unprecedented interactive educational opportunities. Software vendors are yet another industry category that could be included. The latter will be impacted by a significant number of interoperability issues involving network software, database systems, and other applications.

5.2 CROSS-INDUSTRY INTERCONNECTION PROFILE

Table 5-1. Skeleton of Cross-Industry Interconnection Profile Table

Industries → **↓**	**Computer**	**Telecom**	**Entertainment/ Cable**	**Wireless**
Computer	Bitways: Content/Format: Comm. Protocol: Core Net. Serv.: Intermediaries: Dist. Ctrl.:			
Telecom				
Entertainment/ Cable				
Wireless				

It is expected that the industry segments listed above will interconnect their networks within the NII. Thus, it is required not only that a computer (data communications) industry be capable of communicating with other industries of its own type, but also that it communicate with the other three types of NII-related industry (telecommunications, entertainment, and wireless communications). To illustrate the interconnections between the different industries, a cross-industry interconnection profile table, shown in Table 5-1, may be used. The column and row headers are the industries themselves, and at the intersections of the rows and columns are place holders for the network types and services:

- Bitways
- Content/format
- Communications protocol
- Core networking services

- Intermediaries
- Distributed control

A completed version of this table showing currently available interfaces would highlight areas of weakness and consensus, and identify areas needing increased cooperation and further research and development efforts.

5.3 EMERGING INDUSTRIES

Several industries are emerging to provide bitway access services and related information flow. These providers will need to interconnect, interoperate, and eventually cross each others' market boundaries in order to deliver their unique services to willing subscribers. They will comprise a major portion of the SPCs. Therefore, some form of harmonization of bitway providers will very likely occur.

Information carried within the NII will probably have to traverse multiple dissimilar backbones and physical media. It will go through various conversions and transformations before reaching its final destination. As time passes, convergence of the data formats and protocols used for these transformations to a smaller number of standard approaches should take place. Until such time, current technology based on existing interfaces and methodologies will be used to start the introduction of NII services.

Currently, the trend is for the major cable television (CATV) companies to combine their services with those of the telecommunications carriers. This will inevitably result in the combined CATV/telecommunications infrastructure becoming the keystone for an integrated communications, entertainment, and information services network. Many steps to this end have already begun with recent announcements concerning various video-on-demand (VOD) trials and ventures among the major players. Results from these integrated ventures are not likely to occur rapidly. Immediate and widespread technology deployment in these areas would be precluded by the variety of diverse backbone, signaling, and information payload carrying strategies currently used within the various industries.

5.4 KEY INTERWORKING ISSUES

A number of interworking issues were identified while researching the enabling services for the NII national challenges. Compilation of these issues represents a "ground-up" approach to defining the critical areas that will affect bitway interworking.

In many respects, the services offered by the bitways will encapsulate a normalized view of the complete set of bearer services provided by each participating interworking domain. Therefore, it is crucial that bearer services in the various "islands" communicate with the highest degree of compatibility, interoperability, and efficiency possible. The generic issues listed below require further definition, research and development, and discussion; consensus must be achieved on these issues to provide continuity to the service definition process:

- **Addressing and routing.** Unique names and consistent methods for routing entities around on the NII are needed.

- **Transport.** Transport protocols are outdated and cannot offer the kinds of services needed by the NII. Different applications can tolerate varying degrees of QOS requirements; if a specific protocol generalized for a particular class of service is used, some applications may suffer as a result. A new generation of transport protocols is needed.

- **Mobility.** Wireless computing will stress routing, addressing, billing, reliability, and security techniques.

- **Access methods.** The ability to provide so-called "last-mile" access will be required for successful NII usage. Cost-effective, efficient, easy-to-use equipment needs to be designed for bidirectional traffic, with a variety of information appliances in mind.

- **Quality of Service (QOS).** Network procedures and services are needed to guarantee that QOS requirements for an application will be met. Research is needed to understand how network components and interfaces can be designed to provide a wide range of QOS primitives.

- **Security.** Security will be required at all levels within the NII. The magnitude of the security issues may not be well known, especially for a distributed, multilevel architecture such as that of the NII. A comprehensive security policy will need to be developed that can be applied to the NII architecture.

- **Network management.** Management of heterogeneous networks and monitoring of traffic are necessary and will require more research.

5.5 PRELIMINARY RECOMMENDATIONS

As the above discussion suggests, national and, more importantly, international priority must be placed on interworking among the globally defined public switched networks, the Internet, the entertainment/cable networks, and the emerging wireless environments, especially personal communication service (PCS) networks. Such interworking will enable a ubiquitous and interactive digital capability that will span the United States, with an incremental growth toward higher bandwidth and scalable core networking services.

A preliminary analysis has been made of the key interfaces, related protocols, and associated service attributes necessary to promote inherent cross-industry competition. Essentially, a snapshot of bitway interconnection technology can be developed for several communications networks involving different information delivery media. Because of the various existing methods for information distribution, several important concerns must be addressed to allow a smooth interconnection mechanism. The most notable of these concerns include the following:

- The SS7 protocol and its interoperability and deployment are essential to the interworking between the emerging wireless industry and the traditional telecom carriers, recognizing as well the significance of such a fundamental transparent protocol to the exchange among various telecom carriers. In this connection, and with regard to expanding access to the Internet and promoting digital low-bandwidth connectivity to small businesses and homes, the narrowband Integrated Services Digital Network (ISDN) interface is essential. It is within this context that the evolution of the Plain Old Telephone Service (POTS) Universal Service paradigm can be articulated.

- The above incremental interface and protocol technology is not sufficient, however, to satisfy the competitive technology needs of the computer, entertainment, and telecom/wireless industries. The Asynchronous Transfer Mode (ATM) mechanism as defined by some elements of the broadband ISDN (B-ISDN) technology is a cross-industry enabler that is recommended for a standard backbone "glue." Interworking methods with regard to ATM for both bearer and even signaling services are essential.

- As the Internet expands, so does the number of host addresses; the latter are currently in short supply. This problem is currently under study. Similarly, the telephone companies are themselves running out of numbering plan addresses. It is logical that as these two components of the NII begin to converge, their addressing issues must be explored together.

- Different networking technologies use dissimilar techniques for transmitting and transforming their data streams. The timing of the transmissions (asynchronous and synchronous), the encoding schemes used to modulate signals, and whether or not rate adaption is used are essential bitway interworking methodologies that need to be addressed.

Finally, the Internet concept and philosophy will need to be examined in depth before large-scale bridging or scaling of that network with other heterogeneous infrastructures is carried out. The Internet brings to the table a variety of issues that need to be researched further before being applied to the NII. Some of these include current uses of the Internet Protocol, Internet's lack of signaling ability and call control, security, naming and addressing, QOS capabilities, reliability, vulnerability, usage chargeback, and access. Currently, system administration and maintenance are at best done using ad hoc coordination. All the basic ideas that have made the Internet successful and usable will need to be rethought. It is imperative that further research and integration impact studies be done to address these issues.

6. EXAMPLES OF SERVICES

This section presents service examples taken from many of the industries contributing to the information infrastructure. These examples illustrate some of the technology challenges and apply many of the elements of the NII Services Model (see Figure 2-4). Through these examples, an attempt is made to identify critical issues that must be resolved to both integrate services described in the Services Model and interconnect dissimilar bitway technologies. The examples focus on the use of service attributes in adapting services and bitway interfaces and achieving the interoperation necessary to make the NII a reality. The reader can see (1) the role played by enabling, supporting, and core services in providing advanced communications and information capabilities, and (2) the role of service attributes in integrating individual services and in interfacing information appliances and bitways. Issues involved in interfacing bitways, such as those illustrated in this section, will need to be resolved to create the NII IP.

6.1 ELECTRONIC PROCUREMENT

A small set of issues in electronic commerce is addressed by this example (see Figure 6-1), involving the provisioning of services to implement the process of carrying Requests for Quotations and quotations. This application is based on the use of a single key enabler, commercial transactions, supported by EDI services. In addition to the basic core communications services, value-added security services based on core management services are used to ensure confidentiality of transmission. The example also illustrates the use of intermediaries for adapting service interfaces. Service attributes are discussed in relation to issues of integration and evolution of services and applications.

Electronic commerce is a business application for the NII that links buyers and suppliers of goods through an electronic marketplace in which the basic procedures for commerce (i.e., Requests for Quotations, quotations, orders, and payment) take place over the electronic infrastructure. Within the participating organizations, this involves integration of financial services, accounting, product offering and description data, inventory records, and product and vendor histories. Several large testbed/pilot projects already under way utilize both value-added networks and the Internet. One of these projects involves a "procurement mediator" that defines the electronic commerce environment in terms of the following:

- Establishing business relationships with suppliers, banking, and customers

- Offering (or coordinating) the integrated technology for suppliers and customers to support the business relationships

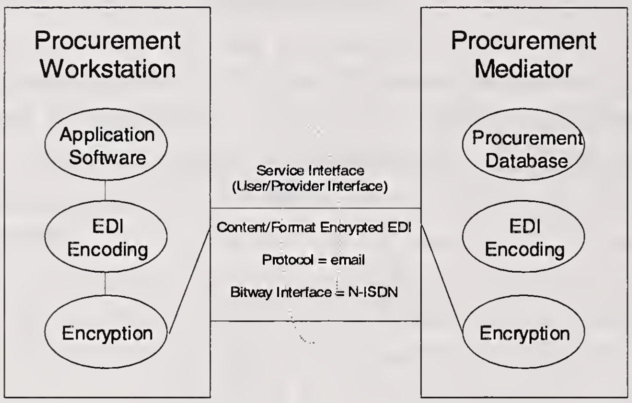


Figure 6-1. Electronic Commerce.

The procurement mediator maintains databases of the following:

- Vendors
- Products
- Outstanding quotations and orders
- Customer and vendor profiles
- Accounting information

The vendor and vendor product databases are maintained through business agreements with the vendors. The outstanding quotations and orders database contains records on quotations sent to potential customers and orders placed by customers. These are used to track orders through vendor handling, shipping, and customer feedback. Accounting information for billing and vendor and customer histories is necessary, along with links to digital money services.

To obtain membership in this particular electronic commerce community, a customer of the procurement mediator will have purchased a software package (supplied by the procurement mediator) for an existing machine and a narrowband ISDN line for the premises, permitting interaction with the procurement mediator.

The backbone of electronic commerce is the EDI standard, which provides for the electronic formatting of business transactions. Standardized EDI (X.12) messages and X.12 transactions sets offer combinations of requests and responses that have been established for many common business functions.

The first application function is the capability to request a price quotation on a product. The application software issues the X.12 transaction set RFQ, which is then encrypted. The procurement mediator requires that all RFQs and quotations be encrypted since confidentiality is required by many vendors to protect their competitive price bids. The encrypted RFQ is transferred via e-mail protocols to the procurement mediator's site. This begins an RFQ business cycle. Following review by one or more suppliers, a quotation is sent back to the customer as an X.12 transaction set Response to RFQ, ending this first phase of the business cycle.

Confidentiality is also a key motivator for maintaining control over distribution of information. Referring to Figure 6-1, in the absence of a general service interface such as the NII IP, a specific bitway interface, narrowband ISDN, was chosen for access to a 64 kilobits per second (Kb/s) bearer service. Since the application uses data communications-style packetized data, an Ethernet-compatible bridge was chosen to layer packet data on top of the 64 Kb/s circuit, creating a logically extended Ethernet. Packet filters on both bridges (one at each site) ensure that packets are exchanged only between the customer site workstation and the procurement mediator's server. To integrate the services needed to support this application, two key service attributes must be specified, which form the core of the interaction between the two distributed parties:

- **Protocol.** The time required for a vendor to compose a quotation in response to an RFQ can be lengthy. The process does not involve a "once and only once" requirement typical of transaction processing environments. It was therefore decided that e-mail was an adequate protocol for transferring the quotation information.

- **Content/Format.** EDI encoding is based on the X.12 standard. One of the strengths of electronic commerce as an emerging application is the acceptance of EDI for formatting business transactions, along with the effort to adopt a large set of EDI transactions to support typical business needs.

Beyond the focus of these two key service attributes, the required confidentiality is provided by a value-added security service that supplements basic protection core management services. In this example, encryption was chosen as the means to provide confidentiality of the information transfer across the e-mail links. As will be shown later in this example, each technology (EDI encoding and e-mail protocol) associated with a service attribute can be replaced by another technology choice (for example, a second customer using a different software package that offers a different set of integrated services). Each of the services can be adapted via intermediaries to conform to the needs of the procurement mediator. These choices will also apply to most of the examples that follow. However, confidentiality in the form of encryption must be enforced end-to-end to offer the necessary protection. Therefore, all participating parties must agree on a *common* form of encryption to be used. This does not mean that a single form of encryption must be used for all applications or by all parties. Common implies only that a form of encryption available to all parties to this transaction must exist. If a common form does not exist, then encryption serves to partition the infrastructure into two or more noninteroperating pieces or environments.

This example has focused on the use of services that each strongly align with a single key enabler. The result has been a clean description of the elements involved, making it easy to imagine replacing any component service with one that covers the same service attributes, but implements a different interface, protocol, or encoding. For this to be a reality, mechanisms for integration of services and other software components are necessary. Unfortunately, the lack of technology for "easy" integration has forced services and protocols down a different path. The elemental services used in this example are already being combined pair-wise to form new services that offer greater integration (and therefore are more usable), but possibly result in more complexity in the overall environment. Examples of such compound services are X.435 (integration of X.400 e-mail and EDI encoding) and privacy-enhanced mail (integration of confidentiality, authentication, and e-mail).

The anticipated explosion of services in the NII raises a serious question of how technology is to be integrated. Common integration mechanisms are needed as an alternative to custom integration. This is not intended to imply anything negative about the two compound services mentioned above, but to illustrate the larger issue of the services architecture and the need for solid technology to support integration of components in the NII as it grows. This issue of complexity is implicit in the many calls for an NII services taxonomy or "Dewey Decimal System" for NII services. There are broad implications regarding how to ensure the usability, scalability, and interoperability needed to meet the national challenge goals.

A second application example is a slight expansion of the first. It involves a second customer who is actually a distributor and owns an in-house-developed procurement management system. This system does not use EDI encoding for business transactions, but an internal format. Luckily, it does use e-mail as a protocol for delivering the transactions. This distributor has joined with the procurement mediator as a reseller. Interoperation of their systems is now a critical issue, although it was never considered before the contract that brought them together in this business arrangement. As part of the integration plan, the distributor has added an encryption service that is compatible with that of the procurement mediator. The EDI/non-EDI encoding is then the major hurdle. The technical solution is to employ a translator (an intermediary) to convert the e-mail-based internal formatting to EDI encoding on top of e-mail. Since the original internal (distributor) system did not apply encryption before packaging the message for e-mail (the encryption is to be done after EDI encoding and before e-mail packaging), the intermediary is implemented on a separate workstation at the distributor site that accepts e-mail messages from the internal system, reformats them into EDI encoding, encrypts, and transmits via e-mail to the procurement mediator.

This second application example has focused on adapting a legacy system to newer technology in an incremental manner. There is little established technical/architectural guidance available to resolve such issues in the evolution of technology. The complexity of evolution in this example could have been exacerbated if the in-house procurement system had already been based on a compound e-mail/confidentiality service that used a different form of encryption. The users already expect encryption to be end-to-end. However, because of changing business needs, the definition of the scope of the organization (i.e., what is end-to-end) has changed. How would new interfaces be inserted without changing much more of the technology central to the existing system or drastically changing the overall quality of service visible to the end user? Examining the integration in light of the service attributes emphasizes several long-term integration and evolution issues that must be addressed if information technology is to be allowed to evolve gracefully.

6.2 INTERACTIVE TV (GAME)

This example involves the use of the simulation enabler to realize a game played through interactive television. Each of the multiple, distributed players assumes a character role to be played in a game scenario (e.g., a Klingon in a Star Trek game[11]). A character has various characteristics (e.g., aggressiveness) and a set of equipment (e.g., weapons) that the players can use when their character encounters other characters in enacting the

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[11]Klingon and Star Trek are trademarks of Paramount Pictures.

scenario. Each player has a remote unit with which movements of the characters, equipment, etc. can be manipulated. Players are not necessarily aware of each other, and players and characters can enter or leave the game at any time. However, one of the objects of the game is for characters to encounter one another in the game scenario. Such encounters may be hostile or friendly, depending upon the nature of the characters.

The site at which the game simulation originates provides each player with an initial region or view of the scenario in which the game is being played. Encounters occur when the game characters move into other regions or views. Simulation is assumed to take place at a single site to avoid complexities in character coordination. Players pay to enter a game by means of remote pay-per-use supporting services, with actual payment transmitted using digital cash core management services. Optionally, competitive versions of basic core communications services can be provided to players to enhance the game. An example of this is the use of ISDN D-Channel Signaling to improve response times experienced by players. Since not all service providers may provide this capability, it must be offered to players at extra cost.

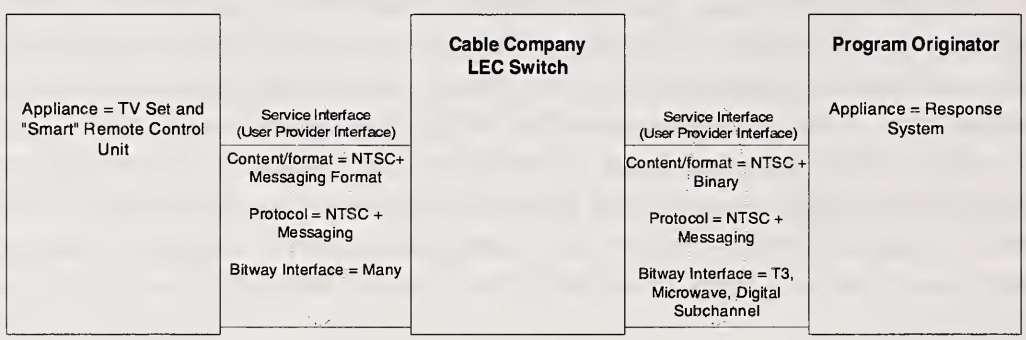

Figure 6-2. Interactive Game.

The information appliance is a television set, and includes a character control unit. Because of synchronization complexities and bandwidth limitations, it is assumed that this game will be played using wireline bitway technology. The complications from using non-wireline bitways are not technically insurmountable, but the added cost of doing so can bring into question the economic viability of the game. It is further assumed, again for economic viability reasons, that the game will be played using National Television Standard Code (NTSC) television rather than high-definition television (HDTV) or other digital television units; NTSC television is not likely to disappear from the scene until digital television becomes as inexpensive to own as the NTSC units are today. Thus, NTSC is the transmission format for the simulated scenes. To conserve bandwidth, the picture frames may be digitized and compressed for transmission, adding another attribute of content. Embedded in the signal may be messages to players indicating scores, equipment status, etc. This will require a different attribute for the message format. Similarly, character control messages will be sent from the players' control units back to the program origination site for integration into the game (see Figure 6-2).

The program originator could be remote from all players, e.g., a nationwide game, or it could be provided locally through, say, a local CATV company or telephone company. In either case, the SPC will be responsible for signal conversion to the information appliances to the extent that the information appliances themselves are incapable of such conversion. The character control units will represent significant areas of competition for game manufacturers such as Sega and Nintendo. Commonality of interfaces and formats will probably not be in their interest, and only market pressure from game players will have any influence in this regard.

6.3 VIDEO CONFERENCING

This example of collaboration involves a point-to-point videoconferencing system, capable of both video and data interaction, using ISDN as the principal transport mechanism (see Figure 6-3). The example highlights issues involved in interfacing information appliances and bitways so that the core NII transport service can be provided. On the left of the figure is the information appliance, in this case a desktop computer. The principal service interface component is an ISDN video terminal adapter that contains the following:

- An audio coder/decoder (codec)
- A video codec
- A data interface
- A multiplexer/demultiplexer
- ISDN interface (Basic Rate Interface [BRI])

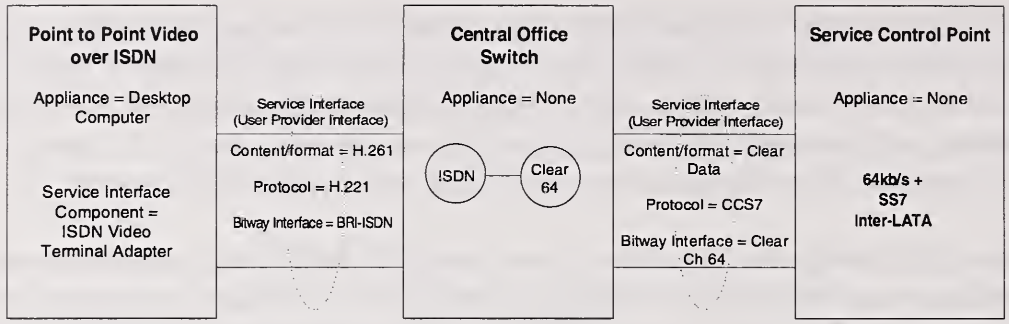

Figure 6-3. Point-to-Point Video Conferencing.

The multiplexer/demultiplexer takes (two or more of) the outputs from the data interface and the video and audio codecs and creates a single bit stream. The bitway connecting the ISDN interface to the SPC is the ISDN BRI in the local subscriber loop to a central office ISDN switch of a telephone LEC. Assuming that the video call is leaving the local access transport area (LATA) administered by this LEC, the video call is carried by an IEC via the long-distance network to reach a LATA and a central office of the (usually different) LEC on the other end of the call, and is then transmitted to the customer premises at the other end, where video equipment similar to that above exists.

Each of the ISDN video terminal adapter components cited above has a particular format, and in some cases a protocol, associated with it. There must be compatibility among these formats and protocols for the call to be completed and used. The International Telecommunications Union (ITU, formerly CCITT) has defined standards for each of these in Recommendation H.320:

- Audio codec: G.711, G.722, or G.728
- Video codec: H.261
- Data interface: H.221
- Mux/demux: H.221
- ISDN interface: I.400 (series)

Additionally, the video itself has two formats, Common Intermediate Format (CIF) and Quarter CIF, which are selected on a bandwidth availability and quality basis.

The H.261 video codec specifications provide a format for video compression, using a discrete cosine transform (DCT) procedure. However, a protocol associated with the specification permits negotiating to another compression procedure if desired. This would permit using a proprietary compression technique, most of which are clearly superior to the H.261 DCT procedure. How this negotiation takes place during an ISDN call establishment is not specified. There is also no specification as to how the two 64 Kb/s ISDN B-channels are to be used: whether to reserve one channel and use the other to carry the multiplexed data, video, and voice; to carry voice on one channel, and data and video multiplexed on the other; or to carry totally multiplexed information on both channels to obtain the higher 128 kb/s bandwidth. All of these choices are made by the manufacturer of the ISDN video terminal board. Thus, even with standards in use, interoperability is dictated by the particular business choices made by manufacturers for their implementations. Additionally, it must be noted that although these are standards for videoconferencing equipment, vendors are generally under no obligation to adopt them. They do so only as business choices, and usually in conjunction with their own proprietary approaches.

Data and display interactivity between end-users is carried out by protocols implemented in computer software in the users' desktop systems. Even here, some compatibility is dependent on the vendors' commercial choices and the users' purchase choices.

Although the ISDN standards and implementation agreements provide for a great deal of interface compatibility between the central office switch and the user equipment, a particular carrier may elect not to implement certain aspects of the service, or may restrict the capability, for commercial reasons. For example, if one LEC elects to implement a video dial tone and the other LEC does not, call establishment may be impaired.

The inter-LATA bitway for ISDN information uses SS7 protocols and clear channel 64 kb/s transport, for each B-channel used, from the LEC central offices to the IEC's service control points (SCPs) and between SCPs. The content of the information carried is transparent to the IEC's systems. (At present there are a few incompatibilities in these capabilities, due to commercial choices in switch vendor selection and to technical choices in implementing services from the standards.)

Finally, video conferencing capabilities could be enhanced by combining supporting services with the collaboration enabler. For example, in conferences that require a measure of privacy, value-added encryption services could be employed. Supporting services, in the form of competitive versions of core management services that employ ISDN D-Channel Signaling, could be used to enable the negotiation of compression algorithms and other features of transmission.

6.4 MULTI-BITWAY INTERCONNECTION EXAMPLE

An example of the value of and issues involved in cross-industry interconnection of bitways is shown in Figure 6-4. This hypothetical example illustrates an activity within the education national challenge application arena using the collaboration key enabler. More important, the example highlights the variety of necessary bitway providers involved in facilitating the flow of information. It depicts many problems in bitway interconnectivity that must be overcome to successfully deploy NII services such as collaboration. In addition to collaboration and multibitway provider issues, the example illustrates the interdependency among choices of information appliances made by users, choices of appliance configurations made by manufacturers and SPCs, and the characteristics of underlying bitways.

This scenario was chosen because it illustrates some of the issues involved in remote interactive technology. In this example, a field biologist in Alaska is to demonstrate a field exercise to a group of students. The mobile information appliance used by the biologist is interfaced into the information infrastructure through a low earth orbit (LEO) satellite system. The students are all in Chicago, Illinois; five are at home with either illness or immobilizing disability, while the remainder are in a classroom. The students at home are interfaced through CATV, while those at school are interfaced through a telephone company central office. Each student, as well as the teacher, has an individual information appliance through which interactions with the biologist can be supported. The teacher's information appliance is also able to monitor the students' activities. All of the information appliances are capable of video display. The biologist's camera is more sophisticated than those of the students and can acquire high-quality video that can be used to record field information and transmit it back to the laboratory at the University of Texas. The information appliances also permit data interaction among the participants. In addition, the biologist is able to move data from the laboratory in Texas to either her local information appliance or the appliances of the students. The Texas laboratory is tied in through a public data network.

The individual choices made by or for participants will be greatly influenced by the ability to realize this scenario. In particular, competitive marketplace considerations among products offered will determine questions of compatibility of equipment, as well as system procedures. Service dependencies, in terms of the attributes cited in Section 4, are discussed below to illustrate their impact:

- **Information appliance.** The choices of information appliances in this scenario have an effect on provision of the services. The wireless information appliance used by the biologist, for example, may constrain capability because of lower bandwidth and expectation of higher error rates on the local bitway than may be present in other parts of the system. The biologist's SPC in the field must provide the ability to handle the compression and error codes used in the biologist's information appliance and adapt these for use in the wider network contexts if communication is to take place at all. Similarly, if the students at home are using a low-cost information appliance with limited capabilities acquired principally for entertainment purposes, there may be some constraint on their interactive capabilities.

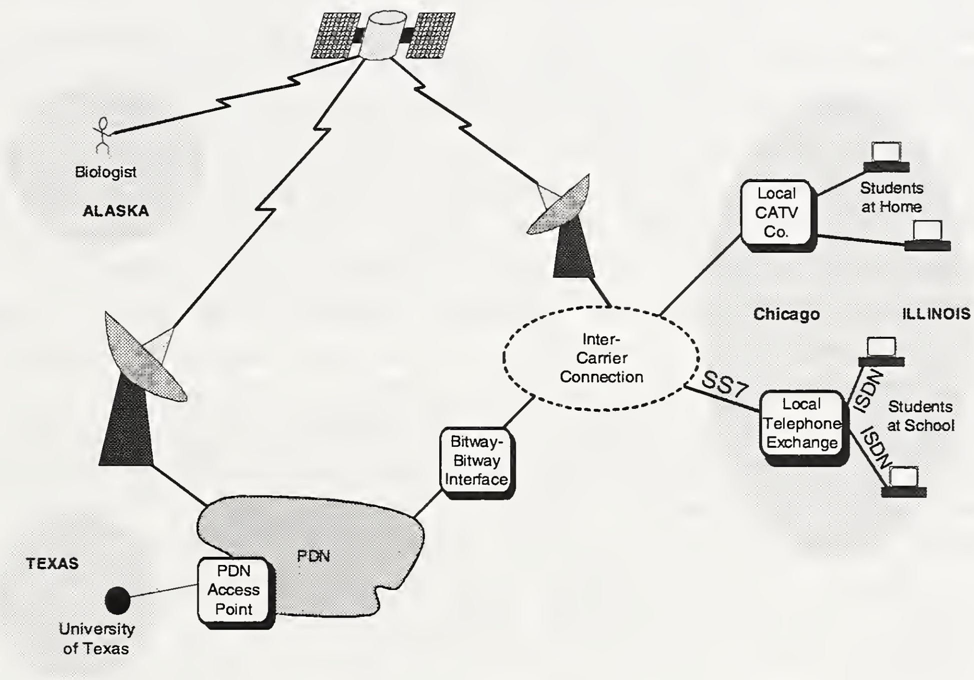

Figure 6-4. A Remote Interactive Education Example.

- **Content.** The SPC in Chicago will be expected to ensure that the format of the data matches the characteristics of the different information appliances used by the students. The point at which video format conversion takes place will have to be determined by these providers according to commercial arrangements.

- **Protocol.** The protocols for interaction among the participants offer other complications of choice. The mobile information appliance the biologist is using may employ separate protocols for data, video, and voice without multiplexing them, each on a separate satellite subchannel, because of commercial decisions of the information appliance's manufacturer. The students' information appliances at the school may all expect a protocol in which the data types are integrated, and may have software to do the demultiplexing. This situation reflects individual choices made by the biologist, the school board, the information appliance manufacturers, and the SPC. At another level, if the satellite network uses a different naming and addressing structure from that of the telephone network and the CATV network, there must be some way of resolving addresses to enable routing information to the appropriate recipient(s). In the NII, these problems would be addressed and resolved through the NII IP.

- **Bitways.** In addition to the above, the SPC must adapt the information appliances connected to the various bitways involved. In the example, the CATV network interconnects via an intercarrier satellite network with the public data network hosting the biologist's laboratory server. If the CATV company, usually a local company, does not normally do business with the satellite carrier, then a business liaison must be established. The SPC needs to make similar arrangements with the public data network. The CATV company may already have business arrangements with the local telephone company. It will then be necessary to negotiate adaptations of signaling, physical layer framing, link protocols, error characteristics, addressing and routing, tariffing, etc. These will be insurmountable problems if the various carriers' technical interface descriptions are not available. However, there is a question as to which party does the task of adaptation. If the adaptation is to be done by the CATV company, because of its size and local flavor, it may not be capable of the heavy-duty adaptation required. Is the adaptation then the responsibility of the selected intercarriers? Does the CATV company try to get the local telephone company to do the adaptation, under the assumption that it has the capability? Among the four SPCs and the intercarriers, it is not clear who is responsible for the end-to-end management of the collaboration. This end-to-end coordination is particularly significant when fault isolation and problem resolution become necessary.

The situations described above raise some serious questions regarding roles and policy. For example, in the case of the students at home, should there be a capability in the information appliance to meet educational needs? Who should provide such a capability, if it is lacking? Should *anyone* provide it if it is not available? Should SPCs be responsible for knowing and supporting all formats in common use, even if not in their business interest? Should they be responsible for finding out about them? If so, under what circumstances? Who would provide such information? What mechanisms would be available to enable scenarios similar to this (e.g., in terms of formats, interconnections, call management), and who would be responsible for providing such mechanisms? These questions will have to be addressed by appropriate groups within government, industry, and academe.

6.5 MOSAIC, A TOOL FOR INFORMATION DISCOVERY AND RETRIEVAL

In this example, we examine Mosaic, an interactive application for finding and retrieving information over the Internet. Developed at the National Center for Supercomputing Applications [5], Mosaic utilizes current technology and is available for use today. Mosaic integrates a collection of search and retrieval services offered on the Internet and enables the utilization of these services via a uniform interface. This integration of dissimilar local and remote services behind a common interface constitutes the underlying paradigm of Mosaic. Similar paradigms will also underlie future NII applications. The integration of Internet services in Mosaic requires resolving issues similar to those that must be resolved to implement NII applications. In this example, the discussion of integration issues is presented in terms of service attributes that are associated with present-day Internet services. The example also offers a view of future Mosaic-like, search and retrieval applications that use digital library enabling services and selected supporting services.

Mosaic integrates a variety of present-day Internet services such as the World Wide Web (WWW), Gopher, Archie, and remote file transfer (FTP) [6]. The integration of these services is transparent to the user who initiates various operations through Mosaic's hypertext interface. Mosaic provides access to remote directory services—such as Archie—to identify the location of information resources on the Internet. Selected resources may then be accessed using Internet facilities for remote access such as FTP. Using hypertext browsing and retrieval services, the user can retrieve multimedia items from servers, including text, sound, image, and video. Like most long-standing applications on the Internet, Mosaic treats information resources as files that can be transparently transferred using a variety of protocols such as remote file transfer (FTP) services or using a distributed file system. The software transparently invokes FTP services to retrieve selected files from a remote site. Mosaic also includes transparent access to programs that permit audio playback, image display, and movie viewing.

The notion of service attributes is useful in organizing the discussion of interoperability issues that had to be resolved to integrate the underlying Internet services used by Mosaic. For instance, to access and retrieve information from the World-Wide Web (WWW), which is a collection of interconnected information hypertext servers and repositories, Mosaic utilizes common protocols and processes data structured in standardized data and content formats. Therefore, the following service attributes are most important aspects of the Internet services used by Mosaic:

- **Protocol.** WWW clients such as Mosaic use a collection of protocols to access information "on the web." The Hypertext Transport Protocol (HTTP) is the main protocol used to retrieve WWW hypertext pages through a server. The HTTP protocol supports both search and retrieval (including index searches) and is faster than FTP for document retrieval (because HTTP does not require authentication). The File Transfer Protocol (FTP) is used for retrieving files from remote network nodes that support FTP but not HTTP.

- **Data and Content Format.** The mainstay of data in WWW are pages of hypertext defined in the Hypertext Markup Language (HTML), which is based on Standardized General Markup Language (SGML). A typical data structure accessed through WWW is a hypertext page that has links to other hypertext pages and sound, image, and video files.

To present the contents of a multimedia file to the user, Mosaic first determines the type of data in the file by examining either a file header describing the file content or the file extension. Mosaic then invokes the appropriate subsystem, such as an audio or video player, to process the file.

Mosaic's current capabilities can be viewed as an early version of what future applications based on NII services will one day provide. For example, to search for information located in federated systems of digital libraries, NII applications may employ selected aspects of digital library enabling services integrated with hypertext facilities, knowledge-based query processing support services and underlying directory service, remote access, and file transfer facilities. (It should be noted that Mosaic can now be used to access present-day digital libraries in the manner described in the paragraphs above.)

Using an information appliance that accepts voice input, a researcher could verbally request information about a particular topic, such as technical literature on a particular agricultural technique. A speech recognizer converts voice to an internal representation based on an extended SQL format. The application system could then employ knowledge-based query processing support services to analyze the query much in the way a librarian at a reference desk would. The original request would be checked for semantic consistency and reformulated if the conditions are too broad or narrow. To reformulate the query, production rules provided by the support service could be used that contain or use knowledge about the researcher's subject area. This knowledge includes taxonomies of agricultural terms, lists of libraries likely to contain agricultural information, and statistics on the amount of information likely to be yielded in searches on particular terms. These rules could be used to substitute, add, or delete conditions in the query or decompose the query into smaller queries. The reformulated query could then be targeted for libraries obtained from a directory service that are most likely to yield useful information. Similar industry-specific support services utilizing knowledge-based query processing methods could be developed for many subject areas and incorporated into applications.

Prior to actual access to libraries, the user will most likely be provided with an estimate of the cost of further use of services. If the user elects to proceed, supporting services based on digital cash would be employed to enable electronic payment. The application system could then proceed to link to selected libraries, using an underlying service based on a protocol that supports transmission of user queries. The query would be applied within each library. The user would be presented with a set of literature sources to examine, possibly with an evaluation of which sources are more likely to be useful. Digital library facilities could be used to access particular books or articles, and hypertext facilities would permit browsing the actual text itself. If a number of extensive text sources have been found and the user wishes to explore this collection, knowledge discovery support services could be invoked through the application interface to automatically browse the combined text from these sources. The discovery tools could further focus or expand the query or use statistical classification methods to find new, possible unanticipated data related to the original request.

As in Mosaic, the paradigm of integrated services hidden behind a uniform interface is a salient aspect of the underlying structure of this application. A standardized query language, such as extended SQL, would be used to query individual libraries, eliminating the necessity of conversion between query languages associated with particular library systems. To integrate the various supporting services discussed above, the digital library enabling services, and the underlying file transfer services, intermediaries would be employed where necessary to convert between different formats.

7. OPEN ISSUES

A number of issues identified during the course of this study remain to be addressed. The issues cited here are those the government can help resolve through law, regulation, or policy. Other service-related issues are omitted from this discussion because the authors believe that normal, competitive market forces will evolve effective resolutions. This discussion does not undertake to surface all possible legal and policy-related issues at once. Instead, it concentrates on a few key issues that will constrain the technical approaches to NII service interfaces and service implementation. This collection of issues is a "starter set," to which additions suggested by outside reviewers are particularly welcome.

Many issues arise from the multiple roles of government with respect to activities in the NII. These roles include provider of public services, protector of consumers, protector of the indigent and other disadvantaged persons, defender against hostile attack, codifier of standard commercial practices and legal standards of proof, investigator and prosecutor of criminals, protector of inventors and authors, educator of the citizenry, and sponsor of advanced research and development (R&D) for the NII.

In the discussion below, issues related to security, privacy, universal addressing, and anonymous use are first addressed, followed by other issues. The final subsection ranks the issues presented in order of importance.

7.1 SECURITY, PRIVACY, UNIVERSAL ADDRESSING, AND ANONYMOUS USE

7.1.1 General Discussion

Users are generally willing to assume a limited risk in order to use public networks. If they perceive the level of risk as too high, they avoid a network or restrict its use to low-valued, incidental activity. Risks can be avoided or mitigated by technical means, by "hedges" including insurance, and by civil and criminal penalties for various types of misuse. Technical means of protection include identification and authentication of users and service providers, controls to prevent unauthorized access to information or misdelivery of messages, use of cryptography to hide information content or avoid subsequent repudiation of documents and messages, safety inspections of information appliances connected to networks, and monitoring of network activity for suspicious patterns of use.

The desire for safety in using public networks must be counterbalanced against legal and cultural principles relating to privacy. Neither the government nor any commercial provider of core network services ought to inquire into the spiritual, political, or other noncommercial purposes for which users request services, as a condition for providing services. Sometimes these purposes are suggested in the content of information provided by the user and stored in persistent service objects. At other times, purposes for use can be inferred from data such as toll records, call setup information, and audit logs. Information indicative of the purposes for service requests that is kept as part of a service or for its orderly management should not be disclosed without the permission of the service requester, except in response to a subpoena, search warrant for probable cause, similar court order, or as authorized by law.

On the other hand, an inquiry into the spiritual, political, or other purposes for requesting a value-added service may be indispensable to providing the service. In such cases, users expect to be informed of the uses that will be made of such information before requesting a service.

Another principle is that neither the government nor commercial providers of infrastructure services can discriminate on any illegal basis in denying or delaying services. Service providers may, of course, deny service to users who are not current in payment of tolls, tariffs, or fees for services, or who do not comply with necessary legal restrictions in the use of NII services.

7.1.2 Issue: Universal Security Policy

To guarantee that risk does not exceed some acceptable maximum, a comprehensive security policy is needed. Such a policy would ensure that a safety net of basic protection mechanisms is in place from the outset, and supported by effective legislation. From this baseline, more sophisticated value-added supplementary services could be developed, implementing more rigorous policies. The core security policy could address identification, authentication, ownership, sensitivity and protection markings, maintenance of audit trails on disclosures, rights to challenge and correct recorded information, and protection of the information infrastructure from various threats (hostile forces and criminals, disasters, and mishaps).

The alternative to such a universal core policy is to allow different communities of interest to establish unique policies and associated security services. Subsequent standardization activities could pare the number of different services down to a manageable few. Intermediaries operating at the services layer could then negotiate pair-wise interactions between conceptually similar protection services that were willing to trust one another. Services implemented according to very dissimilar policies would probably not be trusted to interoperate.

7.1.3 Issue: Registration and Licensing

As a general principle, registration of ordinary users should be simple and nonrestrictive, so as not to interfere with the rights of free speech and peaceable assembly. Proof of identity will be needed to use billable services, at least until some form of "digital cash" can be implemented. Certain noncommercial transactions may also need to be restricted to known persons.

In some cases, the privilege of offering a service or connecting an information appliance might be licensed in the interest of overall security and privacy. The prerequisites for offering a service or connecting an information appliance might include the following:

- Demonstration of financial responsibility for any possible damages, e.g., proof of insurance or posting of bond.

- Inspection by a competent governmental body or licensed laboratory to determine that implementation of a service or information appliance accords with generally accepted safe practices.

Any restrictions on licensing of service providers must avoid censorship of information content under the guise of ensuring reputable business practices to protect the public.

Once a provider offers a service to the general public, particularly a core service, a condition for a license might be that the provider not withdraw the service without proper advance notice.

7.1.4 Issue: Anonymous Activity

There is a large realm of legitimately anonymous use of services, pseudonymous publication, and other activity subject to expectations of privacy. Possibilities for reconciling this need with the need to identify and authenticate users are as follows:

- Identify and authenticate users to a high level of trust, and provide by policy, law, or regulation that identification be "forgotten" for specified types of legitimately anonymous transactions.

- Identify and authenticate users to varying levels of trust that depend on the information appliances, the mechanisms and techniques being used at the information appliance access point, and the degree of disclosure agreed to by the user for a session. Particular services will either complete or deny requested transactions based upon the level of trust in identity.

Some users may wish to ignore messages from anonymous sources, publications by unidentified authors, and "offensive" material, whether or not published anonymously. To what extent must the nature, content, or authorship of messages and publications be accurately characterized in information transfer protocols and document indexes? Users may wish to filter out unsolicited commercial advertisements, religious tracts, pornographic materials, or other kinds of information. Possible approaches include the following:

- Require that "subject lines" and indexing entries contain codes characterizing information content and categories of authorship. This would necessitate precise legal definition of categories of potentially offensive information. Criminal or civil penalties could apply to omission or to deceptive labeling. Anonymous authorship of certain categories of potentially offensive information, such as commercial advertising, might be prohibited.

- Depend on the marketplace to offer "safe havens"—services guaranteed not to contain categories of potentially offensive information. If sufficient demand exists for advertising-free and G-rated services (for a price), the marketplace will deliver them.

7.1.5 Issue: Security Labeling

At service interfaces, it is technically possible to "mark" information to allow one service to tell another service, an application, or an information appliance about security requirements. Do such markings, when included, need to be standardized? One possibility is to "register" sensitivity markings defined by those communities having an interest in protecting their own information. The association of a sensitivity marking with requisite protection mechanisms would then have to be negotiated with the service provider.

An alternative is to agree on protection markings indicating the level and nature of technical protection that must be given to the information, for example, encryption strength, content and retention of audit trails, and access limitations. The reasons for requiring a particular strength of protection would not need to be standardized across interfaces.

For infrastructure services, will it be necessary to "mark" information to allow one service to tell another about security requirements and to interface with applications? If so, what will be the nature of this marking?

7.1.6 Issue: Universal Addressing

The NII will evolve from the public switched telephone network, the interconnection of various private computer networks, the Internet (possibly partitioned by "firewall" security processors), wireless networks, and entertainment cable networks. The convergence to bidirectional, interactive communications will proceed at a rate dictated by the protection of existing investments in information appliances, which serve, for example, a billion telephone users worldwide and include 20 million facsimile machines.

Effective use of the NII demands that it be easy to address information to any user at any information appliance in any location that is supported by the infrastructure.

In the absence of public policy on addressing, the heterogeneous networks forming the NII are most likely to have dissimilar addressing schemes. Whenever the pool of addresses in one scheme (e.g., 10-digit numbers for telephony, 32-bit addresses for the Internet Protocol) is exhausted or too difficult to administer, addressing will be extended in a manner similar to that previously used.

Should there be a public policy goal requiring or encouraging the heterogeneous constituent networks to adopt a common, universal addressing scheme? Many people will be reluctant to support such a goal on privacy grounds. If there is a universal address, will it be based upon identifying an individual user or organizational unit (wherever located and using whatever information appliance)? Or will the address be that of an access "port" (by whomever used with whatever appliance)? Or will the address be that of an instance of an appliance (by whomever and wherever used)? Whichever approach is taken, directory services and intermediaries can still make the three-way associations of user, appliance, and access point.

7.2 OTHER ISSUES

7.2.1 Sufficiency of Current Laws to Curtail Undesired Behavior

There is concern that segments of the population may be denied or limited access, but there is an opposing problem that those with access may be subject to new threats and liabilities. The following are examples of areas where existing laws on mail fraud, wire fraud, privacy, and reporting may not be easy to apply:

- **Fraud.** New forms of fraud are devised each day. The NII will undoubtedly be used as a mechanism for fraud in the future, especially if protection against masquerade is not provided.

- **Surveillance.** In the past, if a network switching element were compromised, this meant the potential for free service and transaction monitoring. In the future, it could mean the potential to monitor the activities of an entire household or business through a sophisticated information appliance. As consumer transactions become more automated, it also becomes easier to collect and aggregate the behavior and interests of individuals. Although this may be considered a useful service by some customers, others consider aggregation of even a little personal detail without prior consent of the individual to be intrusive. If the identity of persons can be inferred from addressing and routing information, wireless communications involving small cell sizes may divulge the private movements and whereabouts of a person even if the data content is encrypted.

- **Red-lining.** Quick and comprehensive access to a patient's medical records is an important aspect of health care delivery. Yet access to such information by insurers may limit an individual's ability to obtain or retain health, life, and other types of insurance. Other forms of insurance red-lining may be based on behavior inferred from commercial transactions.

- **Accident.** While ease of use is the goal of most software, it is seldom achieved. One can easily envision a consumer intending to purchase one item and instead ending up with another. It is also not clear how one returns a digital item or service.

7.2.2 Standards of Proof for Resolving Commercial Disputes

Technical standards ensuring nonrepudiation of messages and documents by "digital signature" and time stamping must be accepted by all courts at the various levels where commercial disputes are settled. Rules of evidence establishing the primacy of electronic copies with respect to paper copies of documents must be reasonably uniform among different courts. Without uniform treatment, electronic commerce will be seriously inhibited. Since case law is slow to evolve, statutory standardization seems necessary. The Uniform Commercial Code, appropriately modified, could be a vehicle to encourage the states to adopt compatible standards of proof.

7.2.3 Information Appliance Interfaces

Should all wired information appliances use a common physical connection (universal plug and socket)? Some possibilities are as follows:

- Define a common plug and socket, with the goal that all information appliances will eventually use it. One or more "wires" into a location will fan out into a number of identical sockets. "Plug and play" techniques will be needed to conduct a census of devices attached at a location, to install device-related software, and to make available the correct rendering and translation capabilities for services interacting with the information appliances.

- Use different types of plugs and sockets for different kinds of information appliances, as long as matching a plug to a socket is obvious through the use of distinctive shapes and matching icons, and it is physically impossible to insert a plug into a mismatched socket. One or more wires into a location will fan out to a heterogeneous set of sockets. More sockets will be needed, but interfacing techniques will be simpler.

- Since near-term solutions probably involve using relatively cheap plug adapters or black boxes, let evolution in the marketplace occur without early definition of any standards.

7.3 RANKING OF ISSUES PRESENTED

The eight issues presented above can be ranked in importance based on the immediacy of the need for their resolution and the potential adverse consequences of assuming an outcome that does not finally result. Comments by reviewers may result in a ranking different from the following:

1. **Universal Addressing (Section 7.1.6).** We are about to exhaust Internet Protocol addresses, as well as 10-digit telephone numbers. If we do not act soon on universal

addressing, a rare opportunity will be lost. Electronic commerce may be slow to develop without universal addressing. Government action will be instrumental in articulating this requirement.

2. **Anonymous Activity (Section 7.1.5).** This is an area where strong emotions figure. If public outcry forces a legislative mandate to reverse course, retrofitting of architectural features to protect or prevent anonymity could be costly.

3. **Universal Security Policy (Section 7.1.2).** The longer the wait, the more difficult it will be to implement a universal security policy. By waiting too long, the question is resolved in favor of no universal policy.

4. **Standards of Proof for Resolving Commercial Disputes (Section 7.2.2).** Electronic commerce for other than trivial transactions cannot achieve its potential until progress is made on this front, although other areas are not much impacted.

5. **Registration and Licensing (Section 7.1.3).** The formulations of particular approaches to registration or licensing depend on how the issue of security policy is resolved. This is another emotional issue, but has less impact on technical protocols and service interfaces.

6. **Information Appliance Interfaces (Section 7.2.3).** The marketplace may, if left unencumbered by policy, devise one or a manageable few plug-and-socket conventions, but such an outcome is not certain. The economic impact of a heterogeneous outcome could be substantial, but would be dispersed across a large population. Failing to come to grips with this issue would result in a year-for-year slip in achieving a standard solution.

7. **Security Labeling (Section 7.1.5).** Interoperability of protection services will entail overly complex intermediary services if there are no common concepts for labeling.

8. **Sufficiency of Current Laws to Curtail Undesired Behavior (Section 7.2.1).** Hostile action, fraud, negligence, invasion of privacy, and other undesired behaviors will never be totally eliminated. A substantial reexamination of current laws is needed to provide a solid legal basis that will be effective against "bad guys"—the inventive criminal and the negligent. Electronic commerce and certain life-critical services may be slow to develop if legal development lags.

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APPENDIX A

ACRONYMS AND DEFINITIONS

A. ACRONYMS AND DEFINITIONS

A.1 ACRONYMS

AAL	ATM Adaptation Layer
ADSL	Asymmetric Digital Subscriber Loop
AFS	Andrew File System
AM-VSB	Amplitude Modulation—Vestigial Side Band
API	Application Programming Interface
APP	Application Portability Profile
ASN.1	Abstract Syntax Notation 1
ATM	Asynchronous Transfer Mode
B-ISDN	Broadband ISDN
BRI	Basic Rate Interface
CATV	Cable Television
CCITT	see ITU
CIF	Common Intermediate Format
CLNP	Connectionless Network Protocol
CORBA	Common Object Request Broker
DCE	Distributed Computing Environment
DCT	Discrete Cosine Transform
DISA	Defense Information Systems Agency

DME	Distributed Management Environment
DoD	Department of Defense
EDI	Electronic Data Interchange
FCC	Federal Communications Commission
FCS	Fiber Channel Standard
FEC	Forward Error Correction
FTP	File Transfer Protocol
FTTC	Fiber to the Curb
HDTV	High-Definition Television
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
IDL	Interface Definition Language
IEC	Interexchange Carrier
IITF	Information Infrastructure Task Force
ISDN	Integrated Services Digital Network
ITU	International Telecommunications Union, formerly International Telephone and Telegraph Consultative Committee (CCITT)
JPEG	Joint Photographics Expert Group
LAN	Local Area Network
LATA	Local Access Transport Area
LEC	Local Exchange Carrier
LEO	Low Earth Orbit

MPEG	Motion Pictures Experts Group
N/B-ISDN	Narrowband/Broadband ISDN
N-ISDN	Narrowband ISDN
NFS	Network File System
NII	National Information Infrastructure
NII IP	National Information Infrastructure Interworking Protocol
NIST	National Institute of Standards and Technology
NNTP	Network News Transfer Protocol
NTSC	National Television Standard Code
OAM	Operations, Administration And Management
OC-X	Optical Carrier X (where X is a numeric)
ODN	Open Data Network
OMG	Object Management Group
OSF	Open Software Foundation
OSI	Open Systems Interconnection
PBX	Private Branch Exchange
PCS	Personal Communication System
POTS	Plain Old Telephone Service
QAM	Quadrature Amplitude Modulation
QOS	Quality of Service
QPSK	Quadrature Phase Shift Keying
R&D	Research and Development

RAID	Redundant Arrays of Inexpensive Disks
RBOC	Regional Bell Operating Company
RFQ	Request For Quotations
SCP	Service Control Point
SCSI	Small Computer System Interface
SDH	Synchronous Data Hierarchy
SGML	Standardized General Markup Language
SNA	Systems Network Architecture
SONET	Synchronous Optical Network
SPC	Service Provider to the Customer
SQL	Structured Query Language
SS7	Signaling System 7
TAFIM	Technical Architecture Framework for Information Management
TBD	To Be Determined
TCP/IP	Transmission Control Protocol/Internet Protocol
TMN	Telecommunications Management Network
UDP	User Datagram Protocol
UTP	Unshielded Twisted Pair
VDT	Video Dial Tone
VOD	Video on Demand
WAIS	Wide Area Information Server
WWW	World-Wide Web

A.2 DEFINITIONS

Agent. See Intermediary.

Application. A specified collection of activities or functions of an information appliance or set of appliances, i.e., a "binding" of one or more services on the user interface to the information appliance. An application may persist over time, in which case it is reusable, or it may exist for only one instance. An application may become a service if it is offered for use to users other than the owner through a standard interface with any fees prearranged. An application implementation (e.g., shrink-wrapped software) offered for sale does not make the application a service. NOTE: This is a definition that corresponds to definitions used by the computer and communications industries. The NII "applications" (i.e., national challenge application arenas), such as education, manufacturing, and health care, are collections of applications as defined here.

Bitway. The physical infrastructure and the access mechanisms, interfaces and transport mechanisms (often embodied in software) necessary for transmission, switching or routing, signaling, and related management of digital data, with or without format, across the physical pathways of the infrastructure. Current bitways are characterized by the transport medium (e.g., cable, air-link, fiber) and the business represented (e.g., entertainment, telephone, broadcast communications). A bitway can be as simple as a point-to-point private communications path (for transmission of bits only) or as complex as a public switched network with all its superset functions. The local bitway ("on ramp" to the information superhighway) is the physical bitway and associated services from the information appliance to the information appliance access point. The global bitway ("highway") is the collection of physical paths and bitway services that make up the interior of the NII, i.e., the collection of networks available for public usage.

Broker. See Intermediary.

Common Services. A service that tends to regularize some aspect of the service environment. Its use must result from a consensus by the parties. A service need not conform to a "standard" to be common. For example, in attaching an information appliance to the infrastructure through a service provider to the customer (SPC), certain interface and interaction rules will be followed, or no service access can result. Thus, the information appliance and the SPC should have a common view of the services and access interfaces provided to the appliance. The local access provider chooses, on the basis of business decisions, what interfaces and services will be offered. A user needs to find an information appliance that is compatible with what the local access provider supplies. Similarly, a common means of interacting must exist between the local access provider and other service providers elsewhere in the infrastructure. Sometimes this will imply the existence of an intermediary which provides the commonality of interaction by pair-wise translations. Ideally, common services should have public specifications of their interfaces and functions. Formal standards typically meet this ideal, and many de facto standards do as well. Examples of services with public specifications and their uses in computer-based information systems may be found in the Application Portability Profile (APP) from the National Institute of Standards and Technology (NIST) and the Technical Architecture Framework for Information Management (TAFIM) from the Defense Information Systems Agency (DISA). Such services are often said to provide the basis for "open systems." A service is "uncommon" if it tends to have specialized access; so that relatively few users can gain access to it. Uncommon services generally do not have public specifications and are often proprietary or private in nature, but not all proprietary services are necessarily uncommon: IBM's Systems Network Architecture (SNA) is in widespread use, and a substantial number of third-party providers, including competitors of IBM, produce products that can access SNA. Access to uncommon services may be mediated by intermediaries, provided there is sufficient interest to warrant the costs of offering an appropriate intermediary.

Core Networking Services. Services which are for the common use or support of any user or application. These services are unique in their functionality to NII operation, and because of their criticality, consensus in their definition, specification, and implementation will be highly desirable, if not mandatory, if the NII is to function as envisioned. The degree of commonality required in these services is a policy question, beyond the scope of this document.

Customer. That person, organization, or entity which receives services provided by the NII or its associated service providers. The conventional sense of customer usually entails payment for services, but the definition has been broadened here to include nonpaying consumers of service to avoid too complex a terminology. Generally, an information appliance is not itself a customer, but rather the extension of the human consumer who obtains service through the appliance.

Enabler. See Key Enabling Services

Information Appliance. An information appliance is any customer-controlled device through which a user accesses services (in particular, infrastructure services). This definition is as inclusive as possible for use in this document. It includes client appliances as purchased by individuals, as well as server appliances. Client appliances are very diverse and must be cost-effective, while server appliances need to be scalable. Information appliance refers, therefore, to such devices as television receivers, computers, telephones, facsimile machines, wireless personal digital assistants, and medical telemetry units. Sometimes the information appliance will require particular hardware or software, called service interface components, to enable service from an information appliance access point. A specified collection of activities of an information appliance or set of appliances is called an application.

Information Appliance Access Point. The place where an information appliance attaches to the NII to obtain services. Typically, this will be through some provider associated with the physical attachment, for "wired" information appliances, or with the "air link" for wireless information appliances. In general, there is no fixed way in which the access points will be implemented, since this depends upon the business of the implementor. For example, if the appliance is on a private network attached to the NII via a privately owned private branch exchange (PBX) tied to a satellite carrier, the PBX is considered to be a part of the access point along with the satellite company's ground station. Similarly, an ISDN local area network (LAN) bridge that connects a locally-managed, private LAN to ISDN provided, say, by a Regional Bell Operating Company (RBOC), so that remote users can get into the LAN, is considered to be part of the access point, along with the LAN system and the RBOC's central office.

Infrastructure. In the simplest case, an infrastructure is an electronic or optical network (bitway) intended to interconnect devices to support the passage or usage of information. In the more general case, an infrastructure is a set of bitways (coordinated and seamless, or not), with a set of basic services, information bases and tools, and aids to facilitate location and movement of information.

Infrastructure Services. See Core Networking Services.

Intelligent Agent. See Intermediary.

Interface Definition Language. A technique for specifying the interface to a service, used by an intermediary service, so that services using heterogeneous protocols and interfacing methods can be used together. The Interface Definition Language, or IDL, allows resolution of differences in data representation and service request methods. The service provider defines, through an application programming interface (API) or similar specification, the semantics and pragmatics for data and functions available through the interface. An API may be unique to a service implementation, may be used by several implementations sharing a common specification, or may be standardized. Simple intermediaries can broker services on the basis of IDL alone. Examples are the Open Systems Foundation (OSF) Distributed Computing Environment (DCE) and the Object Management Group (OMG) Common Request Broker Architecture (CORBA). More sophisticated intermediaries need higher-level knowledge of interfaces obtained from API's.

Intermediary. A service that provides functions by which to interconnect, adapt, and facilitate services offered by other parties. Common forms of intermediaries include the following:

> **Agent.** An agent acts on behalf of one of the interacting parties. The party the agent represents is legally responsible for actions of the agent. An agency agreement generally provides for a continuing relationship that extends longer than any one transaction handled by the agent. Note that a service user may have an agent, and the service provider may have an agent as well. In such a case, a mediator, as described below, may be necessary to conclude a contract. An "intelligent agent" is an automated process that operates on behalf of a user or service provider, frequently for another intermediary service offered by a broker or trader, according to rules established upon its invocation. Only infrequent human interaction is needed to control the process subsequently. An intelligent agent is sometimes referred to as a "daemon." It is capable of flexible, robust interaction with its environment in goal-directed behavior.
>
> **Broker.** The function of a broker relies upon the definition of specific roles for two other parties involved: a client who initiates a request and a target who provides service in response to a request. The client finds a service implementation for honoring the request, prepares the service interface to receive the request, and communicates the data making up the request. The broker is responsible only for bringing the parties together, has no legal responsibility for satisfactory completion of the contract between the client and service provider, but may receive compensation from either or both parties for services rendered. A broker's obligation usually extends only to the transaction at hand; the broker need not have a continuing responsibility to either party.
>
> **Mediator.** A mediator is an intermediary capable of negotiating aspects of the service to be provided (e.g., quality, delivery time, cost) impartially to meet goals of both a service requester and a service provider. The mediation function will often follow broker, trader, or agent functions.
>
> **Trader.** A trader acquires services from one or more providers for "resale" to a client. The trader insulates the client and service provider from having to conduct business directly with one another. The trader is responsible to the client requesting the service for all aspects of the service.

Key Enabling Services. A broad set of services that, taken together, provide significantly more capability over what is currently available toward realizing the NII national challenge applications (education, manufacturing, health care, etc.). An example is interpersonal communications, which ranges from person-to-person telephone calls to "virtual" enterprises wherein groups of users collaborate using multimedia information in a what-you-see-is-what-I-see conference.

Local Information Environment. The services, interfaces, formats and protocols supplied by an SPC to the customer as a business offering. That is, how the information appliance access point is implemented, including any value-added services the SPC offers.

Mediator. See Intermediary.

Repository. A collection of information that serves to identify, find, and characterize services, resources, and other information necessary or useful in the access to services and operation of the NII. Examples are directories, catalogs, and indexes.

Service. A persistent function or activity (i.e., one intended for reuse) offered as a capability for satisfying, in part, the goals of a user of an application. A service is often developed with the intent of collecting revenue for its usage according to pre-established fee schedules. Services are intended to serve more than one user. A technology-based service is a capability that can be implemented by equipage, processes, and procedures through a predefined, minimum set of interfaces that specify outcomes of service requests (rather than the behaviors of the service provider). These interfaces are either for direct service use or for management of the services. Non-technology-based services are not within the scope of this document.

Seamless. Describes a networking protocol intended to provide passage of information across diverse bitways transparently; analogous to, but with significantly more functionality than, the Internet Protocol or the Open Systems Interconnection (OSI) Connectionless Network Protocol (CLNP).

Service Environment. A collection of functions and services directed at specific kinds of usage and applications. In particular, a service environment consists of service definitions, service interfaces, core networking services required, and management and billing functions, plus intermediaries, tools, and repositories for the management of these components.

Service Interface Components. Hardware or software associated with an information appliance that is used to interact with the information appliance access point to obtain services. Examples are a set-top box for cable television; accessing software for computer services (Compuserve,™ Prodigy,™ America Online,™ etc.); or a terminal adapter for narrowband ISDN.

Service Provider to the Customer (SPC). The SPC is the implementor of an information appliance access point. An information appliance access point could be provided by a cable television company, a telephone local exchange carrier, a global satellite network company, a cellular or mobile telephone company, a commercial data network (e.g., ACCUNet), a telephone interexchange carrier, or a noncommercial organization (e.g., governments, Internet). When using a mobile information appliance, more than one of the access point providers could gain access for the user; i.e., access need not be constrained to a single provider. An important issue is the commonality of characteristics of the information appliance and the access characteristics the access provider offers at the particular access point. See also Application Access Point.

Trader. See Intermediary.

Value-added Service. A service available to users, usually at extra charge, as a supplementary capability to a conventional or standard offering of services.

APPENDIX B

ELEMENTS OF THE APPLICATION ENVIRONMENT

B. ELEMENTS OF THE APPLICATION ENVIRONMENT

To provide a more complete picture of the NII Services Framework, it is necessary to consider the applications environment, shown at the top of the NII Services Model (Figure 2.4). The interactions between application systems and the enabling services provided by the NII, as well as the NII services themselves, will be based on distributed systems technology, coupled with object-oriented computing.

B.1 DISTRIBUTED PROCESSING

The NII will use distributed systems technology to control processing and communications. Distributed systems are characterized by software components and databases that are physically distributed, and by heterogeneous interconnection characteristics and diverse mechanisms for cooperation. NII applications either will be parts of larger systems that engage in distributed computing or will themselves be using distributed capabilities. Each component of a distributed system will require support from underlying NII services to communicate with other components, to exchange data, and to coordinate distributed processing tasks. The required services include, at a minimum, all core communications services. They may also include core management services and supporting services.

B.2 MODELS OF DISTRIBUTION

Distributed processing within the NII will require coherent models of distributed computing. Many such models have been created in the research community over the last decade, some of which have been implemented in commercial products. Two prominent examples are distributed database management and the client-server computing model. These models, together with other models of distributed computing under development, will provide the basis for NII applications. Key enabling services used to develop application systems, such as collaboration, simulation, and digital libraries, will employ models of distribution. Use of underlying models of distribution will also provide part of a framework in which NII services can be linked to enable development of applications. These underlying models of distribution will need to be defined, standardized, and tested to ensure that application systems using them will be interoperable. Suppliers of NII services will then be able to develop specific services that can be integrated within appropriate models of distribution.

B.3 REALIZING OF MODELS OF DISTRIBUTION THROUGH FRAMEWORKS

There are two areas of focus for using models of distribution in the development of application systems for the NII: (1) achieving interoperability between dissimilar systems, and (2) using software development tools that are based on models of distributed processing. One important facet of achieving interoperability is satisfying constraints on the use of a particular service. These constraints are seen in the service interface by the user of the service (where the user can be a person, application system, or other service). For application developers, the attempt to integrate multiple services into an application, where each service imposes different constraints that may be incompatible, can present difficulties. To aid the application developer, reusable frameworks based on particular models of distribution will be provided. Frameworks are reusable templates that can be used as skeletons from which applications can be built. Frameworks provide a means to resolve potentially incompatible constraints. Applications will be constructed by adapting and customizing frameworks. For service interfaces that are not sufficiently constrained to achieve interoperability, frameworks may add necessary constraints. To help manage the complexity for the developer, software development support tools and environments will be enhanced to support such frameworks.

A popular example of a framework can be found in typical graphical user interface (GUI) programming environments. Such environments provide window definition primitives, window management capabilities, window manipulation capabilities, and other features. GUI frameworks may also contain buttons, edit boxes, and lists that can be modified and incorporated into applications. Specific software tools that support these capabilities can be integrated into a GUI framework and used to develop, deploy, and test application systems. At present, GUI frameworks are being developed which incorporate models of distribution that integrate distributed services for presentation on a particular workstation. Examples of this are the X-Windows system and OpenDoc, described below. Not only are frameworks such as these needed to support models of distribution, but it must be possible to link multiple such frameworks to create a single application.

B.4 THE ROLE OF OBJECT COMPUTING

A current trend in software development is to develop application systems that are based on object computing, also referred to as object-oriented technology, or object orientation. For the purposes of this discussion, objects are computational entities in which data and procedures are bundled together internally and hidden from external access and view. Communication with objects is accomplished by invoking specific object functions using a well-specified, public interface. In the object approach, abstract data types or classes are used to define object types having specific functions and behaviors that can be invoked through defined public interfaces. In a distributed computing environment, all communicating systems are defined as instances of particular object classes; all such objects communicate using public interfaces developed for objects of a particular class. The use of the object computing concepts to provide the conceptual underpinnings for communications in a distributed environment has given rise to the vision of distributed object computing in the NII.

In a distributed object computing environment for the NII, application systems would comprise objects, having public interfaces and private implementations hidden from external view. Uniform service interfaces would be established to allow communications between objects belonging to defined object classes, leading to the development of a distributed processing infrastructure for the NII. Object computing principles could be used to re-architect existing legacy systems for inclusion in the NII: filesystems become object repositories, databases become object databases, programming languages add support for defining and communicating with objects, and networks and distributed systems become distributed object systems. This does not imply that object technology will necessarily replace the existing technology. Instead, the object technology will be used to enhance and adapt current systems developed with pre-object technologies to allow them to operate in an object computing environment.

The object model of computing is general; many variants of the basic model have been conceived to provide underpinnings for programming languages and database systems, as well as distributed communications. Although arising from the same basic vision of computing, systems developed using different versions of the object model have proven to be incompatible.

B.5 STANDARDS FOR DISTRIBUTED OBJECT COMPUTING

Distributed object computing provides a basis for developing NII services that in turn can be used to develop applications. The enabling of distributed object computing will require the development of standards based on a common model of object computing that allows diverse systems to interoperate. One example of such an effort is provided by the Object Management Group (OMG). OMG was chosen as an example of an effort to foster the development of standards because it offers a relatively well-defined structure for developing applications based on object computing. Other possible examples, such as Open Distributed Processing (ODP) effort [7], also could be discussed but were omitted due to time and space constraints. OMG was organized to foster adoption of object technology through the development of appropriate standards to enable distributed computing. The standards developed by OMG are based on a common object model. These standards are intended to provide the ability to specify an infrastructure that supports definition and interoperation of distributed objects. This infrastructure then provides a basis for the development of services and application systems. In the case of OMG, a reference model has been defined, called the Object Management Architecture [8-10]. This architecture has four major parts:

- **Object Services** provide basic functions for defining, implementing, and using objects and object types. These services include persistence, security, concurrency control, data interchange, and others.

- **The Object Request Broker (ORB)** enables an object to be activated (moved from storage into memory and started), and provides the ability for objects to send and receive messages that invoke functions performed by the object. The ORB is based on a client-server model in which a client object conceptually requests services from a server object by sending a message that invokes a function on the server object. This client-server model for requesting services provided by an object has implications for the NII, as is discussed below.

- **Common Facilities** are special services that provide general-purpose capabilities useful for many applications, such as browsers, reusable interfaces, electronic mail, and others.

- **Application Objects** are defined by OMG as objects that are part of end-user applications. The role of application objects in the NII is discussed below.

To support application development, an infrastructure based on an architecture such as the one described here will have to be complemented by other components, such as interface definition languages and repositories. Interface definition languages, such as the IDL developed by OMG, are used to define public interfaces to objects. Interfaces defined using such a language are generic; they are language-independent specifications that can be translated into code used to build specific implementations. Repositories store interface definitions, developed using interface definition languages, together with object implementations. These repositories can be accessed by developers who retrieve and reuse appropriate items to develop their applications.

The OMG view of distributed object technology is language-neutral, location-transparent, operating system-independent, and machine-independent. At present, individual corporations are beginning to use the Object Management Architecture to create competitive distributed object management systems (DOMS). Using OMG specifications as a basis, DOMS offer solutions for integrating legacy applications and databases in heterogeneous distributed systems. To do this, DOMS provide an object management system capability that is layered on top of the legacy systems. DOMS also provide a technology substrate on which distributed applications can be constructed.

B.6 DEFINING OBJECTS THAT PROVIDE NII SERVICES

The example of the OMG view of object computing aligns well with the vision of an infrastructure needed to provide NII services. In this view, the Object Management Architecture or an equivalent would provide a basis for defining objects that can be invoked to provide NII services using public interfaces. In viewing objects as services, it is necessary to focus on interfaces. In the object model of computing, interfaces are the intersection points between objects. An interface specifies the following:

- The syntactic structure (or signature of the operations)
- Constraints applicable to these operations, such as timing, operation sequencing, and data integrity constraints
- A description of the function of the object

An object may have many interfaces. These interfaces may differ with respect to the amount of access that can be offered and the customization for particular environments.

B.7 SERVICE PROVIDERS TO THE CUSTOMER AND DISTRIBUTED OBJECT TECHNOLOGY

Objects and the supporting object technology create a logical infrastructure for providing access to NII services that can be fit into the physical environment defined by the service provider to the customer (SPC) and other service providers. An ORB defines a logical domain in which objects, and therefore services, reside. A service is offered via its local ORB by being registered in the server registry associated with the ORB. ORBs can be linked to make services from other domains available. Within a local computing environment, ORBs may be assigned per user, per computing platform, etc.

There are options for configuring ORBs in both the SPC and customer environments. Within the SPC environment, the SPC would provide an ORB that customers could use. A choice would be provided of having one ORB per customer connection or having one

ORB service for all SPC customers. All NII information services would be delivered to the customer through that ORB(s). The ORB would shield the customer from the location of services and the complexities of the rest of the NII.

Within the customer environment, configurations can be divided into two classifications. First are customers that use the SPC-provided ORB as their primary ORB; this would include low computing-power and single-use devices. Second are customers that supply their own ORB for local object/service management; this group includes, for example, organizations that support in-house local area networks (LANs) or private branch exchanges (PBXs) or individuals with workstations. This distribution of ORBs provides the underpinning for two approaches for delivering software: objects as commodities (buy a copy for local use) and objects as services on the network (remote access to a server). In both customer environments, these objects become part of the infrastructure. Applications, both commercial and in-house, will grow to depend on these objects/services. Issues of quality control, longevity, reliability, and liability will become paramount. Even though the technology can be distributed throughout the marketplace, responsibility to a customer must come through a single or a few providers.

B.8 ISSUES IN MANAGING DISTRIBUTED COMPUTING IN THE NII

This section addresses several important aspects of the management and organization of distributed computing in the NII, including federated forms of control, the use of traders to link objects providing services to users of those services, the integration of NII information services with multimedia, and presentation of an integrated view of services on a graphical user interface.

B.8.1 Federated Control

The NII will comprise a diverse set of components. No one single organization can manage the entire NII. Instead, a federated approach to management and control will be required. A federated approach to naming will be required to ensure that consistent names are used for the diversity of NII components. Interface types will be created by many organizations under many authorities for national and local markets and private use. Once created, an interface may have a long life and be referred to by many other elements of the environment. Identifiers for individual objects will be similar characteristics. Federated naming with local control over local functions is necessary to manage the diversity. A root authority for naming will have to be established for the entire NII.

Experience with the first generation of search and discovery tools available on the Internet [11] has demonstrated the congestion problems that occur when frequently referenced information bases are not replicated. Both interface repositories and implementation repositories will require replication.

As a commercial enterprise beyond the LAN, the facilities providing the commercial brokers, repositories, and objects (whose interfaces provide services) will require management, maintenance, and day-to-day support. Realistic management architectures, interfaces, and facilities must exist to support the day-to-day operation of the NII. Some early architecture efforts in this area are described in the Bellcore INA project [12-15]. The framework defined by this project is synergistic with the OMG efforts.

B.8.2 Traders

Trader objects/services [16] support the linking of clients and servers in a distributed system in which multiple service offerings are available to satisfy the service needs of a client. Specifically:

- A trader accepts service offers from service providers.
- A trader accepts service requests from clients of services.
- A service request is expressed as service requirements by the client.

A trader searches its service offer database to match the client request. The trader can select a single service offer that matches the request or can select all offers that match. The selected offers are returned to the client.

B.8.3 Multimedia

The OMG architecture and components offer a basis for the discussion of information services within the NII. But a large part of the NII discussion centers on the integration of information services with audio and video services. A separate organization, the Interactive Multimedia Association, has published a Multimedia System Services Request for Technology. One submission in response to the request for technology from Hewlett-Packard, International Business Machines, SunSoft, and others, offers insight into the integration of multimedia into the OMG architecture [17].

Some key concepts defined are as follows:

- **Stream.** A flow of media data through a device or across a connection.

- **Virtual Device.** Defines issues of resource management, stream position control, device abstraction, and media format abstraction.

- **Format.** Defines the format hierarchy, which includes various forms of digital audio and digital video.

- **Virtual Connection.** An abstract view of media transport between virtual devices.

- **Core Quality of Service Characteristics.** Characteristics for audio and video streams are defined.

Objects are identified for key control points and control parameters in the media data flow. These cooperating objects interact to provide a flow of control information separate from the media data flow. This framework is therefore analogous to the separate signaling and bearer channels that exist in telephony.

The Multimedia System Services encompass the following characteristics:

- Provision of an abstract interface for a medial processing node, extensible to support abstractions of real media processing hardware or software

- Provision of an abstract interface for the data flow path or the connection between media processing nodes, encapsulating low-level connection and transport semantics

- Grouping of multiple processing nodes and connections into a single unit for purposes of resource reservation and stream control

- Provision of a media dataflow abstraction, with support for a variety of position, time, and/or synchronization capabilities

- Separation of the media format abstractions from the dataflow abstraction

- Synchronous exceptions and asynchronous events; application visible characterization of object capabilities

- Registration of objects in a distributed environment by location and capabilities

- Retrieval of objects in a distributed environment by location and constraints

- Definition of a Media Stream Protocol to support media-independent transport and synchronization

- Use of OMG CORBA technology as the basis for supporting distributed objects

B.8.4 OpenDoc

The object model of computing, as evidenced in the ORB, facilitates integration of distributed NII services. A different set of integration issues must to be addressed to coordinate the presentation of services to a user on the information appliance. This obviously applies only to workstation class appliances, but these reflect a very important market segment.

Workstations imply the use of both local and remote software objects. Distant objects/services will be accessed via locally accessible brokers. Local services (local implying on the workstation) could be integrated via a broker. But brokers do not offer or control access to the user interface, nor do they take into account the types of integration necessary for the user interface: sharing of keyboard, display real estate, audio/video accessories etc. Technology focused on the integration and presentation of services on the appliance is therefore necessary. As a contribution to that niche, the OpenDoc [18] architecture, has been created by a joint effort on the part of Apple, WordPerfect, Novell, Borland, and IBM. OpenDoc targets the integration of services/software components for the appliance.

OpenDoc defines a compound document architecture. This is an open architecture based on a document metaphor for organizing graphical presentation that is designed to integrate software elements and enable sharing across multiple vendors and computer platforms. This architecture offers an object-based framework based on OMG CORBA object technology, specifically IBM's System Object Manager (SOM). Integration with OpenDoc on the appliance provides uniformity of the user interface and allows software to be structured into independent components.

There are two possible futures for this kind of technology. OpenDoc, or OpenDoc-like technology that offers desktop/appliance integration, will become part of the infrastructure since it affects the presentation of services, and therefore services will be constructed with such technology in mind. The other possibility is that the effects of this technology area will be restricted to the appliance, and control over the appliance will remain with the appliance vendor.

B.9 THE VIEW FROM THE APPLICATIONS ENVIRONMENT

Application development in this environment will be heavily influenced by the support technology in the form of NII services that will be available. Some key elements visible to the application developer will be the following:

- Large bodies of reusable code available in object/service implementation repositories. The source code will not be available. Interface definitions, functional definitions, operational constraints, attributes, and dependencies available from interface (and possibly design) repositories will be relied on for selection of reusable elements.

- More effort will be expended in searching for and examining components than creating new components. Search tools will have paramount importance.

- Distributed frameworks will offer basic integration of components targeted at typical tasks and problems. Selecting the proper framework for an application will be a key decision. Compatibility between frameworks and component objects/services will be a big concern for application developers.

- The code written by an application developer will direct the components.

Key issues for the application developer will be findability and reliability of components and frameworks to support the application.

APPENDIX C

DATA AND KNOWLEDGE MANAGEMENT SERVICES

C. DATA AND KNOWLEDGE MANAGEMENT SERVICES

This appendix represents an initial attempt to examine data and knowledge technologies and highlight the changes needed to apply database management system techniques to the NII.

There is currently a mental association in many people's minds between the term "database" and the commonly used database management system (DBMS) software products which are produced and sold by major DBMS kernel manufacturers. This association is valid, but it is also overly-restrictive. A database is any collection of data with a coherent structure that can be manipulated in some well-understood way using some primitive set of data-processing operations. Systems that manage routing tables for computer networks, electronic mail aliases, and even the information in electronic personal planners are also DBMSs, though they are frequently overlooked.

Data and knowledge management capabilities will be a critical component of the infrastructure of the NII. It can be anticipated that specific DBMS capabilities, such as distributed transaction management and self-description, will underlie key enabling services discussed in Section 3 as well as other services. Nearly all key enabling services and many supporting services will incorporate some form of data and knowledge management. However, it is still early, and concrete relationships cannot be defined yet. As efforts to advance the NII continue, a better understanding will be obtained of (1) how NII services will use data and knowledge management capabilities and (2) how DBMS technology will need to evolve to meet the needs of the NII.

C.1 THE IMPORTANCE OF DATA SELF-DESCRIPTION IN THE NII

Database management systems have always drawn a clear distinction between the description of a data set and the data set itself. This separation between meta-data and data has proven extremely useful as it allows us to query not only the currently stored information but also the structure of that information. In the NII, this self-descriptive property will become increasingly more critical. With the move to multimedia in the NII there will be an arbitrary collection of text, digitized sound, and binary images, as well as new data classes such as digital encodings of tactile information, all stored on disk according to their own peculiar characteristics. How will applications programs be able to sort out this almost random jumble of bits if the information storehouse cannot clearly and efficiently describe its own structure?

A parallel notion in database management is that of data independence. Most DBMSs provide two levels of data independence: logical and physical. New information will constantly be added to the NII and new and better ways to manage the physical layer where the data is stored will constantly be uncovered. The NII, then, must be flexible enough to easily extend its own self-description and improve its retrieval performance without disturbing the current set of users and programs which are interfacing with it.

Also important to databases are the notions of data abstraction and mnemonic naming. One would like to be able to directly request access to War and Peace instead of having to issue a large number of lower-level commands. In DBMS environments this is possible via data abstraction, a process that hides the details of how one stores, manipulates, and retrieves complex structures such as images, sound clips, or highly formatted documents, and similarly via a notion of a system catalog that hides the storage location of every object from the user, allowing him/her to access that data directly, by using its mnemonic name. Today these are very pleasant features; in the NII environment they will be requirements for success.

The NII extension of these notions will be the addition of a new level of abstraction which hides the mnemonic names of all objects related to some mental concept underneath the name of that concept. This feature will provide content-based addressing. An NII user will be able to ask for all information content on "Tolstoy's Novels" and directly retrieve War and Peace as well as Anna Karenina.

There are many problems to be solved here. First is a need to automatically extract the content from data objects of all types. Second is a need to create concepts over very large sections of the NII. There may be hundreds of thousands of references to a concept at tens of thousands of database storehouses, yet each of those relationships must be maintained.

C.2 SUPPORT FOR MULTIPLE VIEWS

Views take into account the fact that not all users want the same presentation of data. This disparity among users will only be exacerbated in the context of the NII. The database systems should present different views of the information for people with different levels of interest in the details of a topic, with different educational levels, with different background in the information being queried, with different abilities to see or hear or read, with different security clearances, and so forth. It may be useful to recall the past tight-coupling between database and artificial intelligence (AI) research. Many of these information screening and presentation issues may be better solved with AI techniques, such as the emerging personal electronic agent technologies, than with traditional DBMS select-project-join approaches.

C.3 THE HUMAN FACTOR IN THE DBMS EQUATION

Another change that the NII will force on the DBMS community will involve the people who are traditionally involved in a database project. In standard usage, there is a data administrator (DA), who is responsible for the information content and the policy decisions made in a data environment. Also, there is a collection of database administrators (DBA) who are responsible for deploying the information content and enforcing the policy decisions.

Certainly, in the context of the NII, these tasks will become intractable for human beings. Is it possible for a group of people, regardless of their number, to track every piece of information coming into every application running on the NII without introducing unnecessary delays, which the NII is targeted at eliminating? Can human beings create and adapt new information policies, or revise old ones, at the rate that such changes will be requested and required? In the opinion of many professionals, the answer to both of these questions is no.

In the NII there must be automatic means for acquiring new information, modifying the system's self-description, linking the new information to current concepts or creating new ones, developing an information policy for how this information can be used and by whom, and distributing all of these data and meta-data changes throughout the NII distributed system.

The same argument applies to systems analysts and applications developers, the individuals that examine information content and user needs to plan the development of immediately required, new applications and then build them. In the NII, the goal is to allow all users of any technical competency real-time access to all currently available information.[1] This implies that waiting extended periods of time for new applications to enable interaction with currently available but inaccessible information is not reasonable. Fortunately, planning is a developing field of study in AI and automatic code generation for databases is a well-understood and frequently solvable problem since databases are self-describing. The indication, then, is that these DBMS jobs can and must be automated as well.

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[1] Pursuant to established security policies, of course.

There is another major class of database technologists that should be mentioned here as well: those who actually develop and improve the DBMS kernels, interface tools, and utilities. Clearly the NII will require a tremendous growth in this field of database system and database interface research. As the NII grows and the amount of information stored scales ever upward, DBMS technologies must evolve at the same or faster rates of speed.

C.4 TRADITIONAL DATABASE GOALS IN THE CONTEXT OF THE NII

The NII will also require evolution in the methods used to meet standard DBMS goals such as: controlled redundancy, data sharing, restriction of access, provision for multiple interfaces, backup and recovery, standards enforcement, and retrieval of the most recent data that satisfies the request.

C.4.1 Controlled Redundancy And Data Sharing

In the NII, a major problem will be acquiring new data objects at some site and then propagating them quickly and efficiently to all places where they will be replicated. The new networking advancements which allow for dynamically maintained minimum spanning trees over a link-state routing algorithm network will be invaluable in this area. Other problems will be the sheer quantity of information being stored and transmitted, as well as the frequent fluctuations in user-access patterns. There simply will be too many load shifts, being created too quickly, and concerning too many pieces of information to allow for typical DBMS techniques such as replicating data objects close to the point(s) where they are most frequently accessed. What will be required is a way for the DBMSs of the NII to dynamically restructure the replication and allocation schemata, at machine speeds, as the number of requests for an object shifts.

The issue here is the classic database problem of how to afford a high degree of local autonomy without compromising the larger, global or NII system, objectives. Every NII node should be capable of acquiring new information, altering its own structure for performance or data content reasons, ensuring its own recoverability, protecting its own consistency, auditing its own performance, and scheduling and managing its own uptime and downtime. That sounds easy until one realizes that the NII global system also has data content, structure, recoverability, performance, and operational schedule requirements. Couple this fact with the distributed optimization proofs which demonstrate that one cannot achieve global optimality by optimizing the local components, and the difficulties to be faced become evident. These problems will be further complicated, of course, by the software, data, and meta-data versioning and configuration control issues.

Not only is it necessary to resolve the competition between autonomous versus global system goals and requirements, but also the NII must ensure that these solutions are not circumvented by incompatibility between distinct versions of NII software components. There is, of course, the parallel issue on the data side. The NII will support concurrent engineering which requires multiple versions of a product schematic to exist along with the capability to allow multiple users to modify the schematic simultaneously.

C.4.2 Restriction Of Access And Provision Of Multiple Interfaces

Another classic problem for DBMSs is trying to balance the need for flexibility in interfaces against the need for restricting access to information by certain users. Going back to the notion that not all users are created equal, it is clear that the NII should provide the ability for users to access the NII using graphical user interfaces, natural language interfaces, forms-based interfaces, standard query language interfaces, braille interfaces, and so forth. The problem, then, is largely one of security. Since it is desired that access to the NII be granted through any kind of interface, how is this to be made possible without having to publish too much information about the internals of the NII databases, information which increases the risk of a successful malicious attack on the NII system?

The answer, at present, is partially solved through the use of standards. The Remote Data Access (RDA) standard (ISO 9579) is a relational database command language which can be used to communicate with any vendor's RDBMS without bypassing the security and authorization mechanism by connecting as a DBMS application, which usually affords special privileges—or worse yet—by accessing the physical data directly. Standardized DBMS query languages allow for any kind of interface software to get the data in some canonical and safe way. Then the interface software can process it further to generate the special display characteristics required.

C.4.3 Backup And Recovery

The NII now contains data abstractions known as concepts which hide the mnemonic names of the underlying constituent elements, and this information must always be accessible to running NII DBMSs. Also, the NII databases that map mnemonic names ambiguously to the addresses of NII databases which contain the information must always have their information content available everywhere. That would imply that maybe the architecture should partition the NII nodes into three classes: one set being information-server databases, another being concept-server databases, and the third being name-server databases. That would permit performing the needed fragment replications so that the NII could always attempt to recover the information content of a lost NII database from running peers. Also, it should be possible to save redundancy of effort by not backing up all of the data objects at all of the nodes. Careful attention paid to the minimum spanning trees generated by the routing algorithm can certainly allow us to propagate backups through, some *k*, uptree neighbors. This means that instead of storing all of this information in backup storage at all *k*+1 nodes, the NII can store it only once and send it up the network subtree to the other *k* nodes if and when it is needed.

C.4.4 Standards For Distributed Database Systems

The NII will need standards as no distributed database system ever has before. The reasons are the intuitive ones surrounding the interoperability issue. Users must be able to access and update databases controlled by heterogeneous DBMSs. NII standards would also establish markets for conforming products, and that is with what the government as well as commercial developers will most likely be concerned.

C.5 NII QUERY LANGUAGES

What requires more elaboration is not so much the description of the query interfaces but the properties that NII queries, generated by any interface, should exhibit. The search space on the NII will be so incredibly large that queries must be forced to be painfully specific just to counter the combinatorial explosion of legal query responses. The problem is how will the interface know, before attempting to retrieve a practically intractable information set, that this set is indeed practically irretrievable. A shift in emphasis is required, from data management to knowledge management (including the management of knowledge about knowledge). Perhaps the concept-server notion could be useful here, as concepts could be arranged in hierarchies, and every node in the tree could contain a count specifying the current number of known references.

Query interfaces should also check NII queries for logical inconsistencies such as, "Show me all people who are not people," as these also would waste valuable NII resources performing useless operations. In fact, it should be possible with appropriate standards to allow the query interface software to optimize, decompose, compile, and distribute sub-queries to NII nodes in executable format. This would be highly desirable, as it would save the NII information-servers almost all of the overhead of query-processing.

C.6 DATABASE UTILITIES

The standard set of database utilities should definitely be extended and fully automated for use in the NII. The loader module should automatically import new information which has been legally sent to an NII storehouse. The system monitor should automatically adjust buffer sizes, transaction context areas, the block counts for multiblock reads, the number of available file handles, etc., to keep performance tuned under changing system load. The security and authorization subsystem should automatically approve new user accesses and select appropriate security privileges as the American public comes online.

On the side of new utilities, these examples come to mind. There will need to be a whole assortment of software modules to deal with the various communications and data protocols. The NII will need software subsystems to manage and access the concept and mnemonic name servers. Knowledge-based utility software will be required to analyze and classify all incoming data objects of every type. Specialized backup and recovery utilities will most likely be employed, and there should be some notion of a clerical-utility to track important events at every node, so that this information can later be rolled up to a central NII site for performance, access, failure, and other types of auditing.

C.7 CLASSIFICATION OF THE NII DBMS

One is tempted to go with a heterogeneous NII system that would allow every data object to be stored in a data model that is most appropriate at the cost of mapping between data models during the concept retrieval process. The federated database paradigm may be used here as well, in a slightly modified form, if it is possible to develop a way to carefully control replication so that most queries can be answered locally, as opposed to having to go through the more general NII network. Integration and translation issues are clearly very important.

C.8 TRANSACTION MANAGEMENT

Transaction management on the NII will become very much a synchronization problem of the most difficult type, which is synchronizing data delivery from multiple sources to multiple sinks. Another issue is availability of all pieces of a concept. Certainly the NII should not start sending the information if it is aware that network loads or downed nodes will prohibit it from completing the delivery in a timely fashion.

Recall as well, that the NII will have some very long duration transactions running within it. For instance, in concurrent engineering applications, there could be hundreds of people in hundreds of different locations working an entire day on a single design. There will be a need to tune transaction managers to deal with these longer and more complex transactions or logical operation sequences.

C.9 FILES AND INDEXES

In the NII environment, database files and indexing schemes will have to adopt totally new appearances. The NII now contains incredibly large collections of binary data, be it aural, visual, or tactile. In terms of indexing, in a multimedia setting the NII will need to move to feature-based indexing systems that look not at information headers and labels but inside the data, scanning its content.

C.10 DATABASE DESIGN

Database design typically progresses from the entities and relationships captured in an ER or EER diagram, through the implementation-level primitives of the chosen data model, down to the files and records of the physical layer. A critical issue is always the quality of the design being created. A good design will enable database use and future development work on top of the system. A poor design will definitely impede future progress.

The quality of a database design is normally established by comparing the intended data interrelationships to the explicit interrelationships in the system design. This, in practice, means that all logical functional dependencies (FDs) which exist in a data set should each be captured in a single primitive. This rule prevents the database designer from forcing the system to reconstruct connections or paths between primitives every time an update is effected and the FDs must be validated.

The logical question, then, is what does an FD look like in the NII environment? In a standard DBMS environment, an FD looks like *ssn* → *name* and indicates that any given ssn value functionally determines a name value. Certainly, these standard FDs will still exist in the NII context. However, there will also be new extensions of these FDs to capture content-based information. Examples might be *image* → *setting* or *song* → *mood*. Good designs will need to heed these new twists on the old notion of FDs. If this is ignored, the old problems of unnecessary NULL-space, spurious and dangling tuples, and insertion, deletion, and modification anomalies again will plague the NII's DBMSs. These FDs and the design process that uses them handle the problem of ambiguity that may be found in database modifications. For example, if the design is poor and employees are stored with links to images of project-logos and images of work-locations, then changing the project-logo that is linked to an employee leaves one guessing what should happen to the attached work-location image. If the work-location is the location of the project then it should change. If the work-location is the location of the employee's primary office then it should not.

Another database design notion, that of view integration, will also need adjustment to suit the NII. It is common practice to take a large set of diverse user data and functionality requirements and then stepwise synthesize them into a single coherent global picture. In the NII, the full set of data and function requirements will never exist. The NII's requirements will forever remain a dynamic property. The challenge, then, is to design dynamic view-integration techniques that allow for evolutionary data and function design. In addition to the aforementioned automatic loaders and application writers, there will need to be a notion of a global design watchdog that ensures that the "goodness" properties of the system structure are not unduly eroded by the processes of incremental change.

C.11 QUERY PROCESSING AND OPTIMIZATION

As mentioned in Section C.5, the more query processing activities that local query sites can do, the better for the NII. The biggest cost in NII query processing, however, will probably not be the standard ones of query decomposition, compilation, and reassembly. The biggest costs in NII query processing will be in the resource location and synchronization processes. There will be a requirement to bind concepts to mnemonic names and then ambiguously to physical site addresses. There will be a need to actually select one site address from the list of many, hopefully based on performance metrics, for each object. Then there will be the need to enforce multipoint to multipoint synchronization rules between all querying sites and all involved information sources. Also, access to some objects may require some small electronic payment to be rendered.

C.12 DATABASE CONSTRAINTS

Even database constraints will need to evolve to meet the NII challenge. Many of the restrictions that had previously fallen into the class of semantic constraints and were largely ignored will now need to be rigorously enforced. For example, requiring that the meaning of a picture (i.e., the objects captured in the image) be related to the database representations of all of those pictured objects and to no others will be critical. Enforcing sequence constraints over data objects, like the various images in a slide show, will be required.

In addition, all of the standard integrity constraints will necessarily require broadening. How is the uniqueness constraint defined over images? For example, are two pictures of the same thing with two different backdrops the same or different key values? How is entity integrity defined over music? Is a long pause for a number of measures considered to be a NULL value? How is referential integrity formally specified over tactile information? Is a successful reference achieved based on texture or weight or size?

Perhaps even more critically, is the NII going to permit integrity rules to move from the world of hard and fast rules to the universe of fuzzy logic? In the NII, it now seems to make some sense to have varying degrees of matches between objects and hence varying degrees of conformance to integrity constraints.

C.13 NEW DATA ENTITIES

In the NII environment, temporal and spatial data will become critical. For electronic commerce, temporal information attached to orders, bids, and contracts will be of eminent importance. For health care, spatial orientation of distant hospitals, doctors, and organs ready for transplant will be critical. Certainly these topics of spatial and temporal databases have been adequately researched. It is up to the NII to test and validate proposed approaches.

APPENDIX D

INTERWORKING OF BITWAYS

D. INTERWORKING OF BITWAYS

D.1 CROSS-INDUSTRY INTERCOMMUNICATIONS PROFILE TABLE

A completed version of the cross-industry profile table shown in Section 5 (Table 5-1) will illustrate how specific information industry suppliers currently interconnect and distribute information across their boundaries. It should be noted that in some instances, information flow between some industries will be based on speculation or on ongoing research activities. The table will provide invaluable "real-world" feedback into understanding such issues as the following:

- Defining relevant NII services from a practical "ground-up" perspective
- Mapping tangible interface technology with services
- Applying the services to various NII-specific domains and challenges

Gaps in the entries, or lightly addressed areas within each cell, may highlight the need for further research and development. Areas lacking standardization, consensus, or interoperable migration pathways may also need to be scrutinized for suitability to long-term NII technology deployment guidelines. Likewise, cells that incorporate a large variety of interface technologies should quite possibly be regarded as over-encumbered with interfaces, which may tend to propagate noninteroperable implementations.

Further discussions of the contents of the table with industry, academic institutions, and other government agencies are planned during the document review workshop. It is expected that these discussions will provide the information needed to populate the table, thereby permitting a common structuring of the key enabling services. Proper definition of the services, in combination with detailed interface and specification justifications, will then help coordinate future directions and resolve many of the open issues surfacing within the current definition of the Services Framework.

To illustrate how the cross-industry table may be completed, two specific examples are detailed here. The interfaces and services required for information to flow between the entertainment and telecommunications industries are discussed in detail in Section D.2.1. Section D.2.2 details more briefly the aspects of sending information from the wireless domain through several networking substrates or technologies. Several perspectives are highlighted to illustrate many of the key interworking issues that need to be addressed to achieve better bridging between the very large telecommunications industry and various public and private data networks—an issue that has not been addressed in detail by the NII community as a whole.

D.2 EXAMPLES OF BITWAY INTERCONNECTIONS

It is envisioned that the bitways will be engineered in such a way as to provide the functionality needed to support all higher-layer service sets envisaged within the NII Services Framework. This expansion should bring forth and highlight the key interfaces within the NII.

To provide the much-needed vertical connectivity among the various service entities throughout the framework, various emerging NII services need to be examined. One method of doing this involves examining several industry intersections within the cross-industry profile table. To begin populating the table, two examples that use multiple bitway interconnects were selected. The first example is based on existing technology and practice, while the second represents a hypothetical view of how such an interconnection may be implemented. In practice, other options may be used.

D.2.1 Interfaces Between the Entertainment and Telecommunications Industries

In this first example, to illustrate the interfaces between the entertainment and telecommunications industries, the emerging video on demand (VOD) service is examined. The VOD industry currently requires the use of advanced digital backbones and local exchange offices provided by the long-distance carriers and Regional Bell Operating Companies (RBOCs), respectively. The entertainment industry, through its use of the cable television (CATV) systems, will have to interface with these telecommunications carriers. How will this be accomplished? What are the required interfaces, services, protocols, and standards? To answer these questions it will be necessary to resolve legal and regulatory issues necessary to enable interoperation between the entertainment and telecommunications industries.

In general, the high-level services needed to provide the entertainment-to-telecommunications links consist of broadband communications and video-content oriented delivery services. These high-level services, in turn, must be developed using underlying services and core technology. The interfaces providing this connectivity are discussed below.

Experimental trials of VOD are currently being conducted. A set-top box much like a cable TV converter is used to allow the subscriber to request a movie from the service provider. A control system is used to signal the user's request to the service provider's video server system, where billing and initialization procedures take place. The movie is then delivered to the home of the requester and possibly to other locations simultaneously. To reduce up-front storage requirements and provide subsequent transmission efficiency of the movie, the information is stored in a Motion Pictures Experts Group (MPEG)-2 compressed format. Existing coaxial analog cabling plant is used in these experiments as an interim solution.

In the case of existing telephone copper cabling plants, advanced transmission systems based on state-of-the-art modulation techniques called asymmetric digital subscriber loop (ADSL) are used to transmit movies over the phone lines to the set-top device using a Narrowband Integrated Services Digital Network (N-ISDN) interface. Within the service provider's transmission backbone, the use of asynchronous transfer mode (ATM) technology has been the primary vehicle for distributing movies to subscribers. At some point, the underlying ATM-based transmission must be converted. Where this conversion process takes place is typically up to the service provider, allowing ATM termination at the video server or extended all the way to the curb if the fiber exists at that point.

Finally, different VOD architectures prescribe variants on where decompression of the video stream takes place. Some providers prefer to send MPEG-2 streams to the set-top device, while others limit the distribution point and use traditional analog methods to facilitate typical TV applications.

The above VOD example highlights many complex interactions, and along with the variety of technologies used as "jump-off" points, translates into numerous services and a variety of bitway technologies. These various services and interfaces represent the technology found at the intersection point between the entertainment and telecommunications industries. The network types and service attributes listed in Section 5.1 are used as partitioning tools to describe the interfaces and services required to facilitate the interconnection. These include the following:

- User information appliance
  - Devices:
    - Set-top devices

    - Other independent devices (ranging from low-end PC-based models to high-end graphics-based engines, also called subscriber terminals), televisions, computers, remote controls, and other related peripherals

  - Services:
    - User interface, presentation, and control
    - Line transceiver, demodulation, decompression
    - Back channel interface, remote functions
    - Video display driver capabilities
  - Interfaces:
    - RS-232X, coaxial cable, optical fiber
    - Windows-based PC, TV channels, remote control process

- Content/Format
    - Services: transport and encoded content for digital video streams
  - Interfaces:
    - MPEG 1
    - MPEG 2
    - Encoded digital audio/video streams

- Distributed control
  - Services:
    - MPEG 2 system layer control for transport stream
    - Video dial tone (VDT) gateway control
    - Maintenance of stream mapping table in VDT gateway
  - Interfaces:

    - MPEG II system layer control interface
    - Federal Communications Commission (FCC) mandated
    - Level 1/2 VDT gateway interfaces

- Core networking services
  - Services:
    - Signaling between subscriber terminals and VDT gateway
    - Stream management for the video server
    - Security and encryption services
    - Scrambling
    - Key encryption
    - Forward error correction (FEC), synchronization and jitter, procedural aspects of network interface, backbone signaling
    - Management of network, operations, and end-to-end control
    - Billing and accounting operations
    - Higher-level protocols, such as User Datagram Protocol/Internet Protocol (UDP/IP) are used in the VDT gateway for control
  - Interfaces:
    - Transmission Control Protocol/Internet Protocol (TCP/IP)
    - Upstream/downstream TV channels using offset quadrature phase shift keying (QPSK) modulation
    - Serialized firmware, encryption device interface, conditional access systems
    - Conforming interface standards for telecommunications management networks (TMN)

    - Mostly proprietary interfaces for most billing and accounting systems in the service operations centers

- Bitway
  - Services:
    - Transport of information via electrical, optical, and carrier wave devices
    - Transport streams for MPEG 2 stream layer
    - Physical-level framing
    - Flow control
    - Multiplexing
    - Adaptation of information stream
    - Signaling and control
  - Interfaces for backbone, community network, and switching office:
    - Fiber optic cable, wireless, video dial tone (VDT) network
    - CATV with analog modulation, CATV with digital modulation
    - Unshielded twisted pair (UTP), passive optical networks
    - Hybrid fiber and coax, hybrid fiber and twisted pair
    - Hybrid fiber and wireless
    - Asymmetric digital subscriber line (ADSL)
    - SONET, ATM, Signaling System 7 (SS7), and Narrowband/Broadband (N/B) ISDN. (The video stream is transported over a standard 6 megahertz TV channel using 64 quadrature amplitude modulation [QAM].)
    - OC-3 interface (155 Mb/s)
    - AM-VSB Signals in the 50 - 450 MHz signal band

D.2.2 Interfaces Between the Wireless and Various Telecommunications Industries

In the process of interconnecting different networks, a number of issues must be examined. The architecture of the network, services provided by the network, and the signaling used to control the network are important and highly interrelated. Current architectures consist of either a hierarchical or nonhierarchical numbering plan and synchronous (with timing) or asynchronous (without timing) transmission modes. Numerous services must be considered, and each needs to be examined individually when using different networks. Voice and raw data services are used here as examples to illustrate these relationships. The signaling is used to set up a communications path from point A to point B; then data is transferred along such a path.

In this second example, four different networks—a wireless, a digital telephone/ISDN, an ATM network, and the Internet—are used to illustrate the two example services.

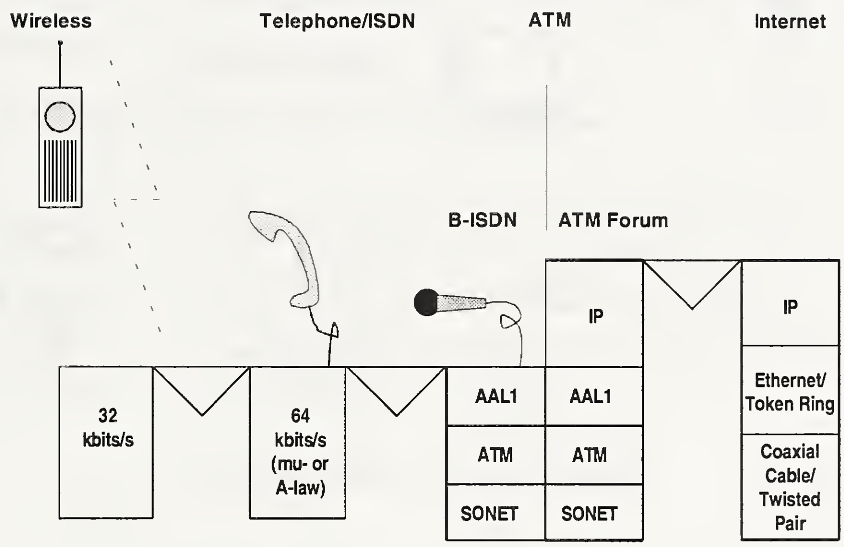

Figure D-1. Voice Service.

First the voice service is examined as it traverses different networking substrates and protocol stacks. The voice service is a continuous stream of analog data. In a digital telephone/ISDN network, the voice processing uses a sampling rate algorithm and a coding method for those samples in order to transform the continuous analog signal into a continuous digital bit stream. In today's networks, two encoding algorithms are used that interwork transparently: μ-law for the United States and A-law for others. In a wireless network where data rates are low, a different sampling rate and coding algorithm are used that generate low data rates and perhaps even partition the digitized voice signals into packets. Therefore, if a voice signal on a wireless network needs to reach a party on a telephone/ISDN network, an interworking function must exist to convert the sampling rate, as well as the coding of those samples. For an ATM network, voice data streams may be rate-adapted. To maintain timing within the voice stream, a specific ATM Adaptation Layer (AAL type 1) is used. In contrast, within the Internet, voice data is packetized, and therefore needs to be rate-adapted as well as decoded during interworking with other networks. In addition, it should be noted that encryption, particularly end-to-end encryption, adds further technical complexity to interface standards. See Figure D-1.

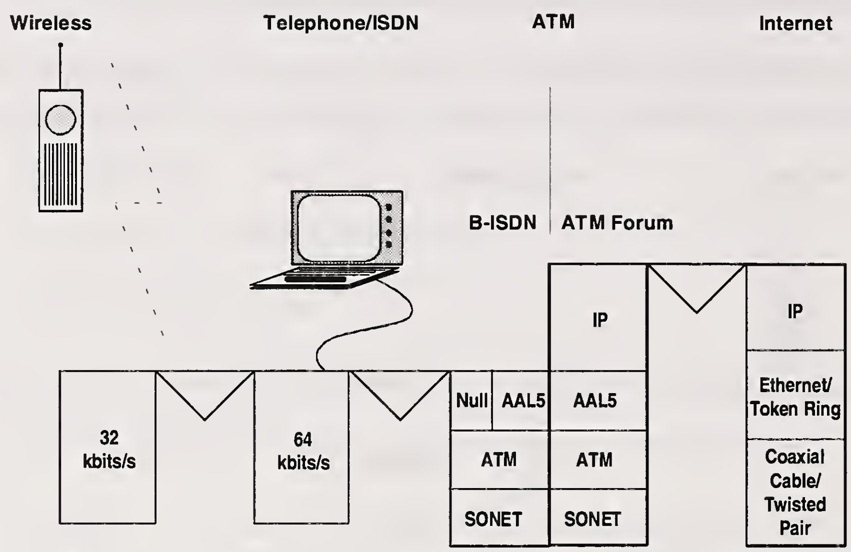

Figure D-2. Raw Data Service.

For a raw data service, the interworking functions are different from those for the voice service. In a digital telephone/ISDN network, raw data can be as simple as a digital bit stream from the computer into the network. In a wireless network, this digital bit stream would need to be rate-adapted for interworking with a faster network. In an ATM environment, a raw data stream may use the ATM cell payload directly, or it may use an AAL (AAL type 5) which was designed for data applications. The choice of which stack an ATM network uses will depend on whether there are any additional features required (e.g., error correction). Additionally, there may need to be rate adaptation between ATM networks and other networks. In the Internet, all data is sent in packets, and therefore must be reformatted for interworking with other networks. See Figure D-2.

Signaling plays a critical role in interworking of diverse networks and may perhaps be the most important item to ease interworking problems. In finding a path from point A to point B across diverse networks, signaling may undergo address conversion (e.g., telephone numbering plan to/from IP addresses), message conversion (e.g., ISDN connect to/from Open Systems Interconnection [OSI] connect), or routing conversion.

In ISDN, the signaling messages contain other valuable information to aid in the selection of interworking functions. For example, the bearer capability information element identifies a type of service being requested of the network. This information can be used by the network to select different paths or interworking functions. For example, if the bearer capability were coded as speech and μ-law, the ISDN would know that it could route, convert, and pass this call on to an attached telephone network because both networks support voice networks. However, if the bearer capability were coded as digital data, the ISDN would not be able to route, convert, or pass that call to the telephone network. In this case, the call would be rejected because a network in the path could not support the service.

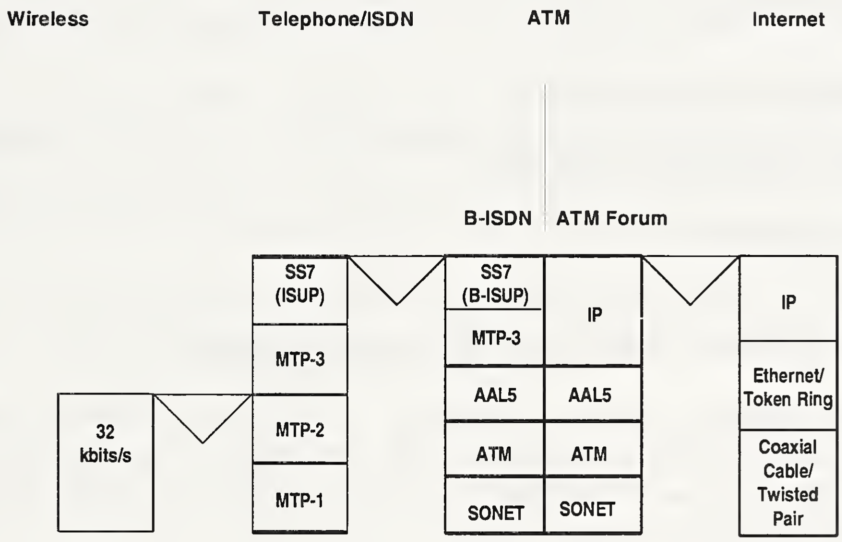

Figure D-3. Signaling Service.

A wireless network has a similar signaling method that is tailored to its architecture, as does the ATM network. The Internet, on the other hand, does not have this capability. Therefore, the networks to which the Internet connects must assume that it supports only a certain type of connection. Sometimes, the same technology (e.g., ATM) is used in different ways which require interworking functions. ATM as defined by the telephone companies is used differently than ATM as defined by the Internet community. The telephone companies use a different protocol stack and addressing scheme above ATM than that used by the Internet community. See Figure D-3.

The services and interfaces defined by the above examples fall within the general categories cited below. These categories implicitly describe the issues that affect this particular aspect of cross-industry participation; therefore, it is beneficial to the services definition process to partition interworking accordingly. Cross-industry intersections are constrained by the following:

- Information appliance data rates
- Modulation techniques
- Direction of communications
- Hybrid bitway interconnects
- Analog and digital distribution
- Broadband services availability
- Technology options for delivery
- Signaling issues

D.2.3 Technical Bitway Issues Derived from the Examples

The available technology options with respect to broadband communications and video delivery services also serve to summarize and define many of the specific areas required for further study. Section 5 highlights many of the higher-level generic issues within the bitway interworking problem space.

Looking at each service type area with respect to the intersection of industries also highlights very specific technical issues that form the basis of the recommendations in Section 5. These are key aspects of the technology environment that specifically address the high-level issues just outlined. Some of the more important issues uncovered while studying these specific types include the following:

- Harmonization is needed within the wireless community regarding finalization of the Common Air Interface Proposals. (This is a relatively fast-moving area, with many issues still pending.)

- Coordinated efforts to use the Common Channel Signaling protocol (SS7) within a common framework are required for interoperable interexchange carriers (IECs) and local exchange carriers (LECs), and guaranteed service availability. (This is an issue shown to exist even among similar SS7 implementations.)

- The asymmetric nature of the emerging ADSL interface technology will need to be addressed further for supporting higher-rate upstream traffic. (This issue will be determined by researching the ADSL scheme used to deliver digital information to an analog delivery medium such as the TV.)

- Noise levels associated with existing copper plant in the home will require further R&D prior to widespread installations of ADSL in the loop. (This issue will be determined by researching the ADSL scheme used to deliver digital information to an analog delivery medium such as the TV.)

- Fiber-to-the-Curb (FTTC) issues (or lack thereof) determine significantly what engineering constraints and capabilities must be factored into the network interfaces to support various bitway traffic patterns, and content. (This issue is shown currently by analog and digital solutions within the networks.)

- Open, common interfaces for maintaining security and integrity of data within the various industry sectors is a major concern and needs to be addressed in detail. (This issue is shown by the lack of interfaces.)

- Ubiquitous use of Synchronous Optical Network (SONET)/Synchronous Data Hierarchy (SDH) and ATM for basic transmission purposes is evident. (Common carriers are already putting these backbones in place, with the Optical Carrier (OC)-3 physical interface becoming the most widely accepted.)

- Operations, administration, and management (OAM), maintenance, directory services, and billing interfaces are currently highly proprietary. (This issue is shown by the lack of openly available interfaces.)

- Convergence of digital video streams to a few ubiquitous formats, such as MPEG and motion Joint Photographics Expert Group (JPEG), is necessary. Other encoding schemes for better quality levels can then be used if MPEG is used as the underlying encoding for the digital transmission. (This issue is shown by a large cross-section of MPEG interface usage.)

- The FCC ruling in 1991 allowing the VDT network services enables an “open level one gateway” and associated architecture to be put in place. Future coordination with FCC regulators may increase the long-term competitiveness of these industries.

- Analog and digital loops for transmission introduce many engineering problems, including increased overhead, higher equipment costs, and increased delivery processing, in contrast with digital delivery end-to-end using fiber-based technology.

- Use of MPEG compression with ATM is imminent; further R&D into this transport format is required.

- Harmonizing N/B ISDN interfaces with ATM transmission technologies will essentially provide ubiquitous access to integrated interface services.

- Bearer services will need to be defined in terms of abstract services such as quality of service (QOS) for bandwidth, delay, and loss.

APPENDIX E

OPEN SYSTEM ENVIRONMENT

E. OPEN SYSTEM ENVIRONMENT

From the perspective of users and technologists alike, an open system environment (OSE) consists of a computing support infrastructure which facilitates the acquisition of applications that:

- Execute on any vendor's platform.
- Use any vendor's operating system.
- Access any vendor's database.
- Communicate and interoperate over any vendor's networks.
- Are secure and manageable.
- Interact with users through a common human-computer interface.

In more technical terms, an OSE is a computing environment 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. These specifications are available to any user or vendor for use in building systems and products that meet OSE criteria.

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 between. The existence of greater or fewer computing resources on any platform will be apparent to users only in the context that they affect the application's speed of execution, for example, in how fast screens are refreshed or data is retrieved, or the capacity of each platform to process data (e.g., 16-bit data bus versus a 32- bit bus).

Applications interoperate by using standard communications 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: a plug-compatible technology or building-block approach for developing systems.

Unfortunately, not enough standards are in place to define an OSE completely. Standards organizations are working on this problem, but much effort is still needed. As technology changes, some standards will become obsolete, and other new ones will be required. Organizations can still accomplish a great deal in moving toward an OSE by selecting specifications that will provide greater openness over time.

E.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 is closely aligned with the Application Portability Profile (APP) and that provides a framework for describing open system concepts and defining a lexicon of terms that can be agreed upon generally by all interested parties. Figure E-1 illustrates the OSE/RM.

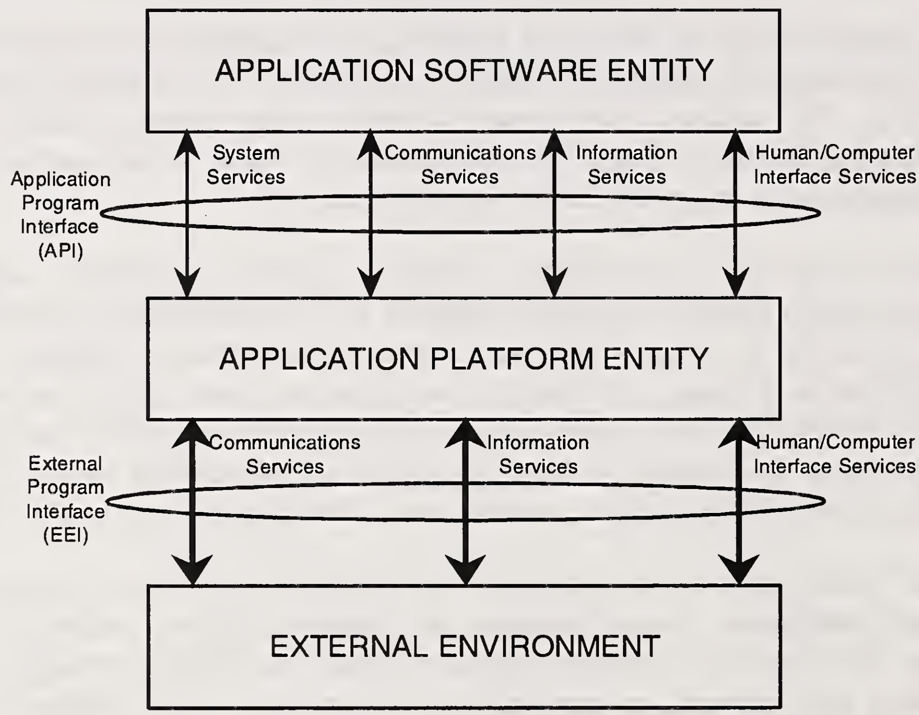

Figure E-1. Open System Environment Reference Model (OSE/RM)

Two types of elements are used in the model: entities, consisting of the application software, application platform, and platform external environment; and interfaces, including the application programming interface (API) and external environment interface.

The three classes of OSE/RM entities are described as follows:

- **Application Software.** Within the context of the OSE/RM, the application software includes data, documentation, and training, as well as programs.

- **Application Platform.** The application platform is composed of the collection of hardware and software components that provide the system services used by application software.

- **Platform External Environment.** 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).

There are two classes of interfaces in the OSE/RM, as described below:

- **Application Programming Interface (API).** The API is the interface between the application software and the application platform. Its primary function is to support portability of application software. An API is categorized according to the types of service accessible via that API. There are four types of API services in the OSE/RM:

  - Human-computer interface services
  - Information interchange services
  - Communications services
  - Internal system services

- **External Environment Interface (EEI).** The EEI is the interface that supports information transfer between the application platform and the external environment, and between applications executing on the same platform. Consisting chiefly of protocols and supporting data formats, the EEI supports interoperability to a large extent. An EEI is categorized according to the types of information transfer services provided. There are three types of information transfer services, to and from the following:

  - Human users

- External data stores
- Other application platforms

In its simplest form, the OSE/RM illustrates a straightforward user-supplier relationship: the application software is the user of services, and the application platform/external environment entities are the suppliers. The API and EEI define the services that are provided.

E.2 OSE PROFILE AND THE APP

A profile consists of a selected list of standards and other specifications that define a complement of services 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.

An OSE profile is composed of a selected list of open (public), consensus-based standards and specifications that define services in the OSE/RM. Restricting a profile to a specific domain or group of domains that are of interest to an individual organization results in the definition of an organizational profile. The APP 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. The individual standards and specifications in the APP define data formats, interfaces, protocols, or a mix of these elements.