Summary Report on the Workshop on Advanced Digital Video in the National Information Infrastructure

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The development of a National Information Infrastructure (NII) is a way of putting vast amounts of information at the fingertips of users in America and around the world. Digital video is likely to be the most technically demanding NII service. Recognizing this, several industrial and governmental organizations sponsored a recent workshop to define a vision of the role of digital video in the NII; identify the architectural, scaling, and performance issues in realizing this vision; and recommend the research, experiments, and other steps to be taken to resolve these issues. At the workshop, it was broadly agreed that the NII will be an amalgam of networks, information appliances, and services in which any company may provide any service to any user This heterogeneous system will necessarily be modular with an extensible architecture. The components of the NII will require publicly identified reference points and interfaces. The development of high-definition television (HDTV) will be a powerful force driving the development of NII applications. It was the sense of the participants in the workshop that the Grand Alliance proposal for HDTV is the best available alternative for terrestrial broadcast of HDTV in the U.S. Additional standards for advanced digital video will be required to meet the diverse needs of the NII.

A workshop was held May 10 to 11, 1994, in Washington, D.C., to highlight technical issues for industry and government decision makers with respect to advanced digital video (ADV) in the National Information Infrastructure (NII). The purpose of the workshop was to:

- Define a vision of the role of digital video within the NII.
- Identify the architectural, scaling, and performance issues in realizing this vision.
- Recommend the research, experiments, and steps to be taken to resolve these issues.

The workshop was sponsored by the following governmental agencies and industrial organizations:

- National Institute of Standards and Technology (MST)
- Technology Policy Working Group in the Committee on Applications and Technology of the Information Infrastructure Task Force (TPWG)
- Electronics Industries Association (EIA)
- Institute of Electronics and Electrical Engineers (IEEE-USA)
- Society of Motion Picture and Television Engineers (SMPTE)
- Advanced Television Systems Committee (ATSC)
- Cross-Industry Working Team (XIWT)

It was attended by approximately 180 people from industry, government, and academia, and consisted of talks and discussions by experts in information services, broadcasting, computing, consumer electronics, and government policy. The discussions were facilitated by participants forming four breakout groups to focus on architectural considerations, modular decomposition and interoperability; display performance; image capture and display requirements; and digital delivery services. This summary of the full report' presents the main ideas expressed by the speakers and the conclusions reached by the breakout groups. Six recommendations emerged from the plenary discussions, and the concluding section briefly describes the efforts of various organizations which are pursuing these recommendations in public forums.

A contribution received from Charles Fenimore, Chair, Program Committee of the Workshop on Advanced Digital Video in the National Information Infrastmcture; he is with NIST, Gaithersburg, MD 20899. Co-authors and committee members Bruce F. Field and Craig Van Degrift are also with NIST; Howard Frank is with ARPA/ESTO, Arlington, VA 2203.1714; Elden Georg is with Space Applications Corp., Arlington, VA 22203; Michael Papillo is with Houston Associates, Arlington, VA 22203; Glenn Reitmeier is with David Samoff Research Center, Princeton, NJ 08540-6449; and Will Stackhouse is a consultant in Redondo Beach, CA 90278-4039. An earlier version appeared in The *Report on the Workshop on Advanced Digital Video in the National Information Infrastructure, NISTIR 5457*, pub. July 1994, U.S. Dept. of Commerce.

Key Concepts

Definition of the National Information Infrastructure

"A system to deliver to all Americans the information they need when they want it and where they want it — at an affordable price."

— Michael Nelson, OSTP

The NII will be an amalgam of information networks, appliances, and services. It will consist of thousands of interconnected, interoperable communication networks, including terrestrial and satellite broadcasting, cable television networks, wired and wireless telephone systems, commercial computer network services, and the Internet and its successor.2 Computer systems, televisions, telephones, and other devices will all converge to serve as "information appliances" on the NII. Digital libraries, information services, and data bases will be needed to provide

the NII information content; users will buy content, not technology.

Content and useful applications will attract the usage necessary for NII success. The cultural industries, particularly motion pictures and television, can thus be seen as an essential part of the NII. It is critical that intellectual property rights associated with cultural items be protected by audit and control mechanisms at all service levels. Furthermore, the NII should be open to all information suppliers on an equitable basis.

NII applications will include distribution of entertainment programming, educational information, government data, manufacturing information, and access to health care. The production and distribution of entertainment programming today is a $37 billion information industry in the U.S. Digital program delivery over interactive networks will permit additional cost-effective services, such as video on demand and shopping at home. Electronic distribution of educational material will expose all students, even those in remote locations, to a high-quality education. Govemment, in part, is a vast information gathering and disbursing system. Electronic availability will facilitate access by business and the public to government reports, weather information, and other scientific data. Electronic "blueprints" and rapid communication between manufacturers and their suppliers are critical elements in improving manufacturing productivity. Health care may be improved by telemedicine and maintenance of on-line medical records. Telemedicine permits remote patient examination and diagnosis. Keeping appropriately protected medical records on line permits immediate medical review by specialists, allows simplified billing procedures, and provides more complete research material for population studies.3

The NII will be built, owned, and run by the private sector, with hundreds or thousands of companies providing services. The role of the government is to ensure that these systems and services are interconnected and interoperable in order to provide competition and choice for the customer.4 The goal is to have a fully competitive marketplace in which any company may provide any service to any customer.

System Requirements of the NII

Interoperable, extensible systems are required so that television and communications can evolve along the technology curve.

Communications and video standards should describe an architecture that is flexible, extensible, and simple. A flexible architecture allows loose coupling between the components while focusing on key interworking points. If the architecture is structured correctly, its performance can be optimized by improved engineering while still retaining maximal backward compatibility. System developers must plan for continuous deployment and renewal; system heterogeneity and migration will be the steady-state condition.

> *"The goal is to have a fully competitive marketplace in which any company may provide any service to any customer."*

In an NII environment of diverse heterogeneous networks, interconnected systems will need commonality among high-level functions such as addressing, device and environment description, service performance description, property-rights protection data, and transaction security. Lower level protocols of different individual network elements can be otherwise subjected to the standards of each industry, knowing that appropriate protocol conversions can be performed at network interconnect points. Two examples of these lower level protocols are the asynchronous transfer mode (ATM) protocol (an accepted world standard for telephony) and the MPEG systems layer (an accepted world standard for multiplexing video, audio, and data for digital television broadcasting).

Proposed technical approaches exist for efficiently mapping advanced digital video streams into ATM and handling the effect of "cell jitter" in applications where video and audio time synchronization are crucial, but industry agreements are still needed. Current video experiments are also being performed on the Internet to examine multicasting techniques and the use of multiple service classes to handle applications with different timing requirements. Further work remains to accommodate network diversity, to determine requirements for various applications of video, and to define network management policies that accommodate video requirements.

Efficient general-purpose networking involves a flexible, loose coupling of sources with destinations so that a variety of sources can be connected to a variety of destinations via a variety of transmission paths. This decoupling means, for example, that image timing and colorimetry information must be conveyed in a device-independent manner. Using digital converters between existing standards is likely to be more cost-effective than requiring uniform standards for all types of imagery in the system.

Despite many common characteristics, the NII information appliance may develop along two paths: task-oriented computer systems, and entertainment-oriented digital television. Entertainment systems require a bright, large-screen display for multiple viewers while computer systems usually have a geometrically accurate, small-screen display for a single viewer. This dual approach will provide NII services for different interests and needs, thus producing the quickest evolution of technology, services, and content. The architecture, however, must not force the technology along two paths, as applications may emerge to use the capabilities of both.

The Role of Video in the NII

An NII goal is to transmit images

and video as easily as a telephone transmits voice today.

Video applications will likely set the maximum bit-rate requirements of the NII. High-definition, "studio-quality" video will need to be sent point-to-point in real time between studios, editing facilities, and archive locations. This may set the maximum bit rate required by any individual transaction in NII. Similarly, compressed HDTV is likely to set the maximum bit-rate requirements of NII connections to the home.

The Grand Alliance HDTV System is an effective solution for delivering high-quality, high-definition pictures and sound over a wide service area by terrestrial broadcast. The FCC's mandate to simulcast HDTV within the existing frequency allocations for television service requires low interference with existing NTSC service. This provision forces difficult trade-offs among picture quality, sound quality, data rate, and HDTV coverage area, which must all be balanced in an overall HDTV system design.

Entertainment television service further requires strict synchronization of video, audio, and auxiliary data. The Grand Alliance system provides such capability and provides interoperability with other imaging media, e.g., motion-picture film, NTSC television, and still images. While the Grand Alliance HDTV system will be useful in many NII applications beyond entertainment, there will clearly be a need for other advanced video standards. Applications in video production, medical, industrial, space, scientific, and defense industries may require higher resolution, different frame rates, or a different level of compression to meet quality or data rate requirements.

Existing technologies, on which present compression techniques are based, will be satisfactory for many NII applications. However, additional engineering will be required to develop a family of compression techniques to meet a wider range of quality and compression level requirements. The MPEG-2 standard, adopted by the Grand Alliance, could be a starting point for such a family of standards. As technology evolves and new methods are developed, equipment upgrades will be needed and should be considered in information appliance design. Today, cost-sensitive applications (i.e., consumer electronics) use specialized hardware that is not easily modified. For future information appliances, careful consideration should be given to including capabilities and required protocols to enable the transparent upgrade of functions, such as decompression or display, by downloading new software.

Video standards on the NII should decouple programming, distribution, and appliances. Traditionally, each information supplier has had its own distribution system with appliances tailored to the medium. In the NII, digital video will be carried by a variety of distribution channels, and will be easily repackaged and stored. This permits video suppliers and users to use a common distribution infrastructure that provides competition across all markets. The distribution infrastructure must ride the technology curve, with continuous deployment and renewal. Video should be scalable and extensible, e.g., encoded in a multiresolution format that can be adapted to available resources. Achieving scalability without adversely affecting compression efficiency, however, represents an unsolved technical issue.

Compatibility and interconnectivity are of high priority in setting standards. Forcing premature obsolescence of consumer equipment should be avoided. Failure to do so may decrease the acceptability of the NII by consumers.

Breakout Group Summaries

Architectural Considerations, Modular Decomposition, and Interoperability

The architecture discussion focused on the identification of "key long-lived reference points" in the conceptualization of the network. The reference points identified were:

- Digital appliance reference points (physical point of attachment, logical point of attachment, status/remote-control management protocols).
- Channel/network reference points (channel end points, coding within channels, channel address space naming).
- Software/program object reference points (naming protocols for all items transmitted over the network, media-specific data formats).
- Reference points for third-party services supporting network management.

Rather than mandate a single standard at each reference point, industry should adopt a flexible architecture that assumes that the interfaces are constantly evolving and that most reference points will be realized by a variety of detailed standards. The principal requirement for NII interoperability is that a publicly documented interface be made available at each reference point. Market forces will then drive the implementation of converters and convergence of standards that facilitate the interoperability.

Display Performance

The Display Performance Group addressed a contentious issue: is it possible to reconcile the demands for interlaced image capture with the superiority of progressive scan for display? There was no consensus on this question. There was anxiety that interlaced scanning may corrupt the whole advanced digital video system. It was recognized that one way to lower this anxiety is to assure that all film-sourced material (initially 60 to 70% of HDTV prime-time material) be transmitted in progressive scan. (This approach is supported by the Grand Alliance.) An additional requirement is that all HDTV material be transmitted at the full resolution of its particular format; that is, any necessary filtering would be done at the-receiver. Adopting these requirements would smooth the transition to higher quality systems.

Display performance associated

with various technologies was felt to be properly handled by market competition. Government can accelerate the rate of innovation by facilitating interface standards, funding pilot programs using video in education and health care, and establishing regulations and policy in such areas as the protection of intellectual property rights.

Image Capture and Display Requirements

This breakout group focused on identifying image capture and display requirements for various ADV/NII applications, and the implications of decoupling capture and display devices from each other. Image capture devices were generally considered to be less of a gating technology for most applications than displays. The financial impact of conversions at the capture device is likely to be less significant than that at the receiving end.

Several video applications need display capabilities beyond that required for entertainment. Home shopping, medical imagery, and viewing of fine art require stringent color or detail fidelity. The decoupling of capture and display devices forces the use of a device-independent format for color information.

Point-to-point connectivity should allow video display devices and applications that use them to follow the technology curve. Nevertheless, the large installed base of standard NTSC television equipment must also be accommodated and will initially be the only video link to the NII for a large class of consumers.

Advanced Delivery of Digital Viieo Services

The Advanced Delivery of Digital Video Services breakout group addressed the requirements for delivering video services in the NII. The Internet was considered as a model for the delivery of NII services. It is ubiquitous in the U.S., has low barriers of entry for information users and providers, and is beginning to provide flexible search functionality. The Internet is not well suited as a channel for digital video, since it is bandwidth limited. It is also generally limited by an absence of network tools for traffic control, guaranteed delivery, privacy, security, and accountability.

Despite these limitations, the Internet serves as a model for the growth and evolution of digital services. It was suggested that government/industry cooperation can set goals for the NII, develop a minimal set of services now, and plan for the staged entry of added functionality.

> *"In the NII, digital video will be carried by a variety of distribution channels, and will be easily repackaged and stored. This permits video suppliers and users to use a common distribution infrastructure that provides competition across all markets."*

Government can also assist industry in developing network protocols. Government information services may catalyze the development of ADV-capable networks. Finally, the 1996 Olympic Games were identified as an opportunity for a demonstration project of HDTV and NII services that contain educational, health care, and entertainment elements, but copyright issues were cited as a serious barrier.

Panel Discussion

The Evolution of Standards: Is a New Approach Necessary?

The standards panel viewed de facto standards as contradictory to the goal of interoperability. De facto standards lead to market fragmentation, higher cost to the end user, and confusion in the industry. There can be a financial reward for the originators of de facto standards because the traditional standards process often lags too far behind technological innovation. Also, the traditional standards process is slowed by a tendency to overspecify, a lack of focus on issues crucial to interoperability, and by the proliferation of standards organizations. In addition, those working on standards are usually volunteers whose time is shared with other "higher priority" tasks.

For the process of generating NII standards to be successful, the traditional standards process must be improved. It must be tightly focused on the network itself and how to assure the interoperability of its applications and transmission links. Critical interfaces must be identified and the resulting architecture must be "open." Those working on the process must be able to give it their primary attention and must be accountable to an agreed upon schedule. Government regulation should be applied only when it is in the public interest, e.g., to guarantee universal access.

Recommendations

The following recommendations, while not the result of a formal decision process, nevertheless represent statements that were strongly supported in the plenary and breakout group discussions.

- The U.S. should move forward on HDTV as quickly as possible, as it can be a powerful driving force for the development of NII applications. The Grand Alliance Proposal for HDTV is the best available alternative and is superior to any system that involves digitizing NTSC signals. Digital NTSC systems would propagate interlaced transmission and continue the division between entertainment television and the computer/communications technologies.
- There will be continued controversy and disagreement over the desirability of an interlaced video format within the Grand Alliance System. Some believe that an all-progressive system is the only acceptable

choice. The anxiety level would be reduced if the major broadcasting networks commit to broadcasting film-sourced material in unfiltered, progressive format. This approach is supported by the Grand Alliance, and there is an informal understanding that at least four networks (ABC, NBC, CBS, and PBS) are planning to broadcast film in progressive formats.

- There is a need for a long-term program involving government and industry to facilitate interface standards; address intellectual property rights and information protection; fund research and development in interoperable systems; and establish pilot programs to apply advanced video technology in education, health care, and other areas of national importance.
- To serve the diverse needs of the NII, additional advanced digital video standards must be developed that complement the U.S. HDTV transmission standard. These should take into account and be interoperable with the U.S. HDTV standard.
- Standards should include both one- and two-way communications, provision for multicast video services, and internetworking cable, satellite, broadcast, common carrier, and packaged media. They should address the interconnection and interoperability of digital appliances and devices, digital networks and channels, software and programs, and third-party services. This will require identifying reference points (physical, management, and logical) and interfaces. Minimum service levels and staged criteria for interoperability and functionality should also be defined.
- Industry is encouraged to demonstrate a comprehensive "multimedia" event with integration of transport modes (e.g., ATM and broadcast), the use of multiple delivery networks (including the Internet), and the integration of text, graphics, and video. The Grand Alliance is encouraged to provide coverage, transmission, and display of both live and filmed programs so that both progressive and interlaced modes will be demonstrated.

Conclusion

The development of a National Information Infrastructure (NII) is a way of putting vast amounts of information at the fingertips of users in America and around the world. The NII will be an amalgam of networks, information appliances, and services, and there are many players involved in developing the standards and technology that will be needed to create an interoperable system. The following organizations have public, active efforts along these lines.

- The Information Infrastructure Task Force (IITF) has a Committee on Applications and Technology, within which the Technology Policy Working Group has focused on digital video issues. IITF documents are available on the World Wide Web at *http://iitf.doc.gov/.*
- NIST has several technical programs related to video technology, particularly to quality measurements for video systems, displays, and interfaces. The Advanced Technology Program has recently announced a focused program entitled "Digital Video in Information Networks." Detailed information is available by Internet at the Universal Resource Locator (URL), at *http://www.nist.gov/..**
- The SMPTE has a Digital Image Architecture Task Force, which is charged to define a digital video architecture. For information contact (Chair) Peter Symes by e-mail, at symes @ am.gvg.tek.com.
- The IEEE-USA Committee on Communications and Information Policy has sponsored a variety of information exchanges on digital video and on the NII. SMPTE President Stan Baron is a member of the Committee. He may be contacted at NBC, 30 Rockefeller Plaza, New York, NY 10112.
- The Grand Alliance proposal for digital, terrestrial broadcast of HDTV incorporates several features to achieve interoperablity with NII-type services. The evaluation of the proposal is being conducted by the Advisory Committee on Advanced Television Service of the FCC.
- The Cross-Industry Working Team is an industrial membership organization which is working with the IITF to develop technological and architectural approaches that bridge industry gaps in information technology while providing for interoperability and other NII needs. XIWT has a home page at *http://www.cnri.reston.va.us:3000/XIWT/public.html.**
- The American National Standards Institute has convened an Information Infrastructure Standards Panel to accelerate the development of standards required by the national information infrastructure. For information on the panel contact R. M. Hayden, e-mail chick.hayden@tl.org. Information is also available on the Internet at URL, *http://dsys.ncsl.nist.gov/pub/iisp/iisp.html.**

*This universal resource locator (URL) provides access to information on the World Wide Web, using an Internet browsing tool such as Mosaic.

References

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Interoperability Guidelines for the Home Information Infrastructure

Report of the Architecture Breakout Group, NIST Advanced Digital Television Workshop

By David L. Tennenhouse and David H. Staelin

In the first of its two meetings the breakout group had a wide-ranging discussion, during which a number of NII-related issues were identified. Broadly speaking, these issues could be classified under the following headings:

- NII vision
- Architecture
- User's perspective
- Digital video and the role of the Grand Alliance
- Integration
- Security and intellectual property issues
- Access modes
- Universal access

Experts on each issue were present, with a total attendance of about 40.

To start the second breakout session, the group conducted a thought experiment in which a hypothetical user purchased a new information appliance (such as a display), took it home and connected it to his home information infrastructure, used the appliance to exchange video information with other appliances within the home, used the appliance to find and view video-based information from external sources at both low and high data rates, and used the appliance to produce locally generated video information for onwards transmission over the NII.

Based on the results of the first two activities, the group identified a number of key NII-ATV Reference Points that were thought to be essential to NII interoperability. The remainder of this report presents: the context in which the reference points were identified; the individual reference points; and the group's recommendation as to how interoperability (at each reference point) should be achieved. These recommendations include the number of different standards believed to be appropriate for each of the reference points — one, a few, or many.

Reprinted from *The Report on the Workshop on Advanced Digital Video* in *the National* Information Infrastructure: *May 10-11, 1994, Georgetown University Conference Center, Washington, DC; NIS-TIR* 5457, published July 1994, U.S. Dept. of Commerce, NIST, Gaithersburg, MD 20899. David L. Tennenhouse is with the Laboratory for Computer Science, MIT, Cambridge, Mass.; David H. Staelin is with the Research Laboratory for Electronics, and Lincoln Laboratory, at MIT.

Reference Points for NII Interoperability

Figure 1 illustrates four broad classes of NII objects:

- Digital information appliances. The individual home and office devices that are purchased by individual users. These include any local networking equipment within the home or office.
- Digital information channels. The means of communication connecting homes and offices to each other, and to service providers that provide application-specific services and switching, such as television, telephony, etc.
- Third-party services. These include the primary information services themselves (e.g., sources of television programs, newspapers, stock tickers, etc.) and other services (such as authentication billing, etc.) that provide the glue that is essential to the smooth functioning of the NII.
- Software and programs. The information objects that flow over the channels and are executed at the service providers and at the customer-based appliances.

Within each of the "bubbles" of Fig. 1 a wide range of competitive solutions will emerge. Within some of the "bubbles" distinctive subarchitectures may be agreed upon by individual industries. For example, the television industry may develop one subarchitecture for digital broadcast channels, while the telecommunications and cable industries each develop and deploy their own competing architectures. One approach is to agree on a single architecture for the standardization of each class of components. However, given the rapid pace of evolution within the underlying technologies, such an architecture is likely to prove outdated long before it is deployed. Our approach is to allow each of the converging industries to continue to evolve at its own pace. NII interoperability is achieved by surrounding each class of objects with a set of NII reference points, as illustrated in Fig. 2.

NII reference points identify key interfaces that should be made public and interoperable. In a small number of cases a single standard for a reference point may be necessary. In other cases individual industries may agree on one or more standards that describe their interfaces at the reference point. Finally, there may be highly competitive reference points at which a large number of *de facto* interfaces are privately developed, but whose specifications are published to facilitate interoperability. Once these interfaces are made public two scenarios for interoperability at a given reference point emerge:

- Conversion. Converters can be developed to facilitate interoperation between objects implementing different interfaces.
- Convergence. Over time, it is likely that the industries involved will converge on a relatively small number of standardized interfaces that are realized at a given reference point.

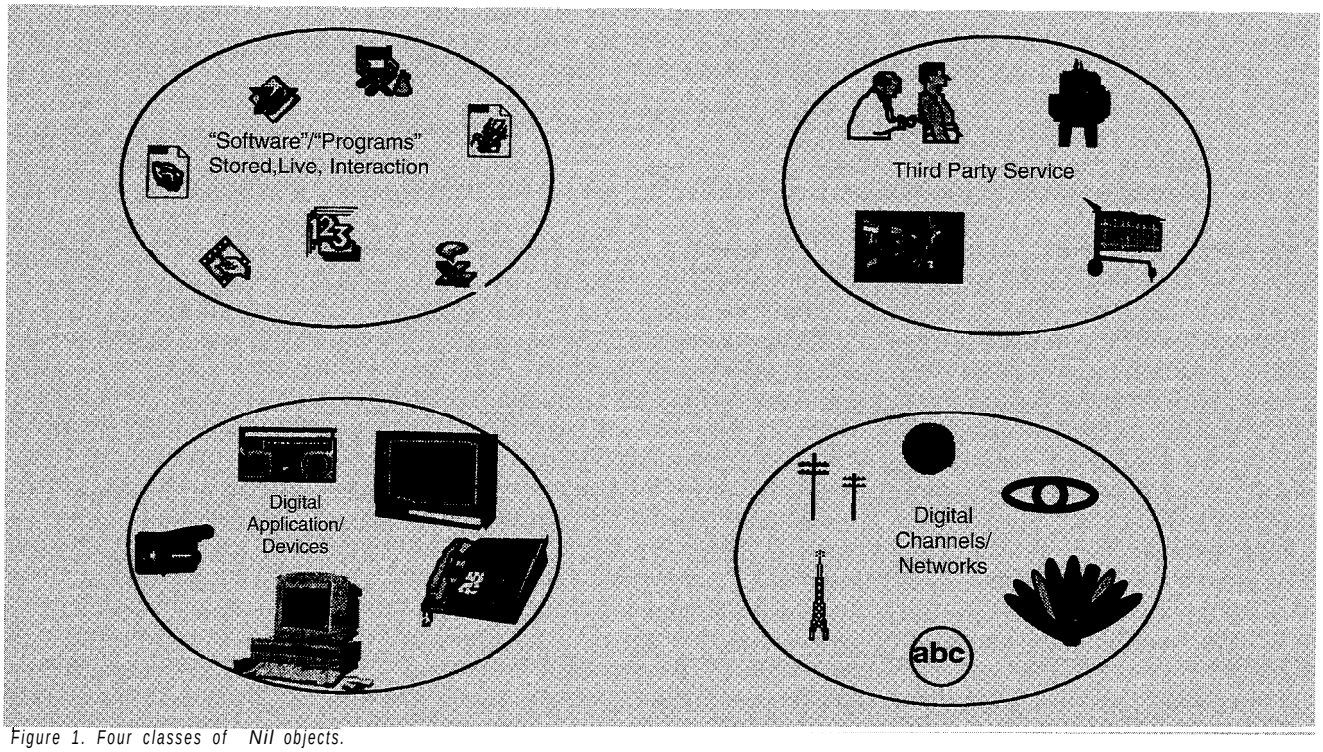

Figure 1. Four classes of NII objects.

NII reference points facilitate interoperability among different implementations of objects of the same class (i.e., different types of devices, different types of digital channels, etc.). They also facilitate interoperability between objects of different classes, i.e., between appliances and channels, or between appliances and programs. Once the reference points are in place a rich mesh of linkages can be developed to suit different NII requirements. For this reason the linkages shown in Fig. 2 are only illustrative — they are not meant to specify or constrain the relationships that might evolve in the future. For example, an information appliance that can be used witbin the home or office may also be used to manage digital channels or to support third-party services.

Summary

NII interoperability efforts should focus on the identification of key long-lived reference points. Rather than mandate a single standard at each reference point, the NII should adopt a flexible architecture that assumes the interfaces are constantly evolving and that most reference points will be realized by a variety of detailed standards. The principal requirement for NII interoperability is that a publicly documented interface be made available at each reference point. Market forces will then drive the implementation of the converters and/or convergence that facilitates interoperability.

For each class of NII object the group identified a number of reference points. A total of 13 reference points were identified at the meeting, and this set is likely to evolve as the NII emerges. The following sections discuss the reference points and the group's deliberations concerning them. For each reference point the group considered the following development scenarios:

- Many. At a *many* reference point each vendor develops its own interface and publishes its specification. The reference point serves to delineate the broad functionality common across the interfaces without much restriction as to detail. Interoperability is achieved through converters.
- Few. At a few reference point a relatively small number of documented interfaces emerge, either through a *de facto* (survival of the fittest) process, or due to the adoption of different standards by different industries (e.g., Cable vs. Telco).
- One. A *singular* reference point is a point at which there is a need for a single NII-wide standard.

For the *one* and few reference points the group considered whether the emerging standards should be developed through an industry process or through a government-initiated project (with industry involvement). The latter is exemplified by the cooperative manner in which the FCC and the television industry are developing an HDTV standard. Standards proposals are being developed and refined by the industry participants. The standard that finally emerges from this process will be blessed by the FCC.

Digital Appliance/Device Reference Points

Physical Point of Attachment (to the Home or Office Information Infrastructure, or HII)

This is the point at which undifferentiated bits are exchanged between the appliance and the HII. For tethered appliances it is likely to coincide

with a mechanical connector. A variety of digital coding techniques is likely to emerge.

It was the consensus of the group that a few standards should be defined at this reference point through an industry-driven process.

Management Reference Point

HI1 appliances should be self-describing and software manageable. Each device should include a management information base that describes the device, permits its status to be monitored, and provides for the remote control of its configuration. An example of a standard that supports this functionality is the Simple Network Management Protocol (SNMP). The information made available at the management interface describes the logical interface to the appliance. It may also describe optional or advanced features of the physical interface. A minimal standard for the physical reference point might only support the exchange of bits for management purposes — the detailed description of the physical interface would be discovered through examination of the management information base. The manufacturer, model number, and serial number should also be available at this reference point.

Although there is strong support for the definition of this reference point, the group was split as to whether there should be a single NZZ-wide standard or a few industry-driven standards.

Logical Point of Attachment

This is the point at which structured units of information are exchanged through the framing (i.e., packetization) of sequences of bits. The identification of the logical interface implemented by a specific device should be advertised at the management reference point.

The logical reference point will be fluid and competitive with many competing implementations.

Note: Conceptually the digital appliance reference points provide for interoperability among appliances and interoperability between appliances and digital channels. In many cases this level of interoperability may be supported through a home/office local area network (LAN). Although the HI1 architecture should provide this level of generality there is consensus that the engineering of individual products may compress the architecture.

Digital Channel/Network Reference Points

There are many classes of digital channels in the NII offering a range of services that support the exchange of bits. Examples of digital channels include ISDN, cable channels, digital broadcast (e.g., Grand Alliance HDTV), fiber to the home, digital satellite, digital cellular, etc.

Physical Point of Presence of the Digital Channel (at the Home/ Office Information Infrastructure)

Standards defined at this reference point describe the raw bit interface through which undifferentiated sequences of bits are exchanged at the channel end points.

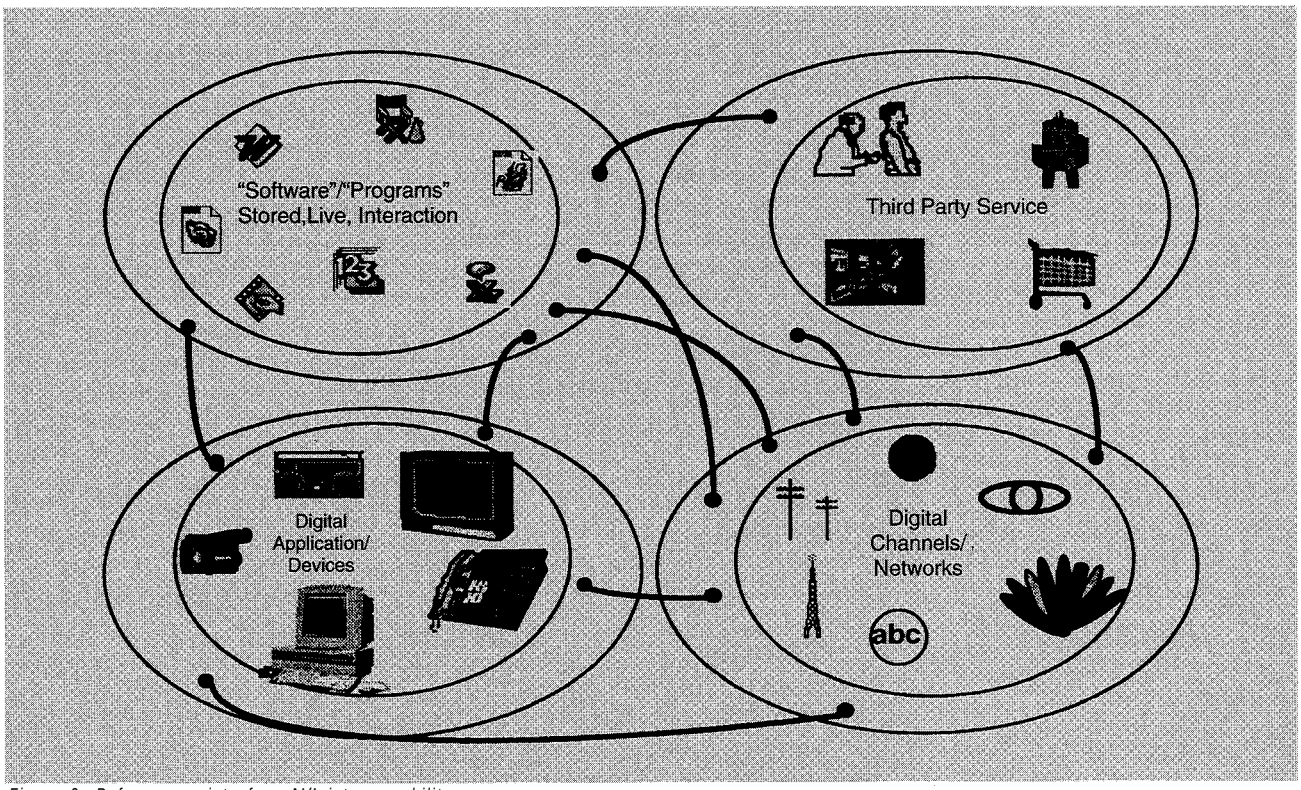

Figure 2. Reference points for N/I interoperability.

It was the consensus of the group that there should be one standard for each class of digital channel (i.e., each class of wide area network). The standard used by each class of channel should be defined through an industry-led process specific to that class of channel.

Physical Reference Point-Within the Digital Channel(s)

This reference point describes the coding of bits transmitted within the channel itself (rather than at the end points). Two distinct cases emerge: digital channels involving "enclosed" spectrum (twisted pair, cable, fiber, etc.); and "air" channels that use the shared free-space spectrum.

Enclosed Spectrum. The group was split by a vote of 13 to 9 in favor of a few standards versus a single NII-wide standard at this reference point. It was agreed *that the standard(s) should be arrived at through an industry-driven process.*

Free Space Spectrum. It was agreed that a single standard should be specified for each class (and band) of digital channel. The group was split as to whether these standards need to be "blessed" 14 in favor, 8 against) by some government agency.

Channel Address Space Identifier

It was generally agreed that each class of digital channel would have its own address space through which the end points of digital channels are named. It was further agreed that there should be an NII-wide address space identifier that could be used in conjunction with the class-specific addresses.

There should be a single NII-wide standard for digital channel address space identifiers. The standard should be approved and/or administered by some government agency.

Software/Program Object Reference Points

Movies, data files, application software packages, and live sportcasts are all examples of software/program objects.

Software Object Names

This is the point at which the object is assigned a name. The universal resource locators (URLs) used within the World Wide Web are examples of object names. Third-party services may be used to resolve object names into the names of related objects and/or the addresses of digital channel end points.

It was agreed that a few different standards would emerge at this reference point through an industry-driven process.

Sofware Object Name Space Identifiers

The software object name space identifier is analogous to the digital channel address space identifier. The group was split as to whether or not an NII-wide identifier is required. The contrary position is that the user or program resolving an object name would have prior knowledge as to the standard and registration authority associated with that name.

By a slim margin of 7 to 6 the group favored the establishment of a single NII-wide software object name space identifier.

Universal Label

The universal label allows each software object to be self-describing, i.e., it is analogous to the management information base of the digital appliances. The label has two parts. The header identifies the type of object and the format of the descriptor, which constitutes the second part of the label. The descriptor provides information concerning the object such as the copyright notice, conditions of use, instructions for payment of royalties, etc.

A consensus emerged that there should be a single NII-wide standard for universal label headers, and this standard should be "blessed" by an appropriate government agency. The group agreed that a few standards for descriptors are likely to emerge through an industry-led process.

Media-Specific Formats

Software objects incorporate and manipulate a range of media-specific forrnats, which can be composed in a number of ways. It was generally agreed that although a wide variety of "data" formats would emerge, a somewhat narrower variety of "audiovisual" formats should be specified. The latter would include both compressed and uncompressed encodings for still images, video, and audio information at a range of resolutions.

A consensus emerged that there should be relatively few standards for audiovisual media encodings and that these standards should be arrived at through an industry-driven process. The group was of the opinion that many different data encodings would emerge through a highly competitive process.

Reference Points for Third-Party Services

Third-party services may be provided by independent service providers or by a "primary" party, i.e., a digital channel provider. These services are identified by software object names.

Examples of these services are:

- Directories
- Navigation
- Payment/settlement
- Encryption key distribution
- Service integration/management
- Brokerage
- Trusted third-party services

Trusted third-party services include those provided by trustees, escrow agents, and authentication agents. It was noted that the operation of many third-party services would be dependent on authentication. Therefore the specification of the reference point for authentication agents may be a matter of some urgency.

It was generally agreed that there **would** *be at least a few, and possibly many, standards at each of the third-party reference points. These standards will be developed through an industry-driven process.*