

The Future of Information Networks and Distributed Applications

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Abstract

Information and telecommunications services are a critical and important component of the global economy; expertise in this domain gives a competitive advantage in the global marketplace. However, current R&D and commercial efforts are focused on credible market opportunities for each player involved, which necessarily lead to divergent interfaces, tools, and networks. Continued rapid growth of these markets depends on the convergence of these efforts to a common vision and plans for the evolution of the information infrastructure into a commercial information networks. Convergence is the process that integrates the previously vertical information businesses into "bit" producers, carriers, and users. This process is shaping the technology and business models for the computing, telecommunications, and entertainment/media industries.

The guiding vision for information networks is a system which enables users to access all the information they need, when they need it, and where they need it. For this vision to become reality and revolutionize the way we conduct our daily lives and business, network technology, user accessibility, and content handling tools must be developed in an integrated fashion. Operations and management functions must be developed and tested in order to achieve reliable operation of the infrastructure, manage the information appliances, and maintain quality of services along with the necessary privacy and security. Lack of a common user interface could turn the vision of an information services network into a catastrophic nightmare with users unable or unwilling to use new services and products. As a final point, it is clear that video will play a dominant role in most applications and will fuel the growth of a service market which includes entertainment, health care, education, commerce, and manufacturing.

1. Introduction

The Information Network consists of integrated components that provide client/server connectivity, heterogeneous database access, and distributed applications and services. This network is expected to open up new markets in information services and enable users to access all the information they need, when they need it, and where they need it. To open the service market, the infrastructure of the Information Network has to support strategic distributed large-scale applications, has to be interoperable and friendly with the users, and has to be easy to use. This infrastructure will be many orders of magnitude more powerful than existing facilities, such as the Internet. The creation of this future Information Network will require advances in many areas such as user access and network usability, operation and management of information networks, and the capability of supporting multimedia traffic, including digital video, and integrating it with other traffic as required by the applications.

The need for information services and advances in technology has caused the convergence of technologies and business models. A powerful Information Network is needed to support these new information services. In the first section of this paper, "convergence" will be discussed, along with business and technical drivers of the information marketplace. In the second section, the technical barriers, which have to be removed to accelerate the creation of the Information Network, will be discussed. Through this paper the Information Network will be presented in four functional areas as illustrated in Figure 1: applications, bitways, services, and operation and management.

The applications area is represented by various information appliances, including computers, workstations, telephones, office equipment, and television sets. The bitways area is represented by existing networks, such as those provided by the telecommunications, computer, entertainment/cable, and

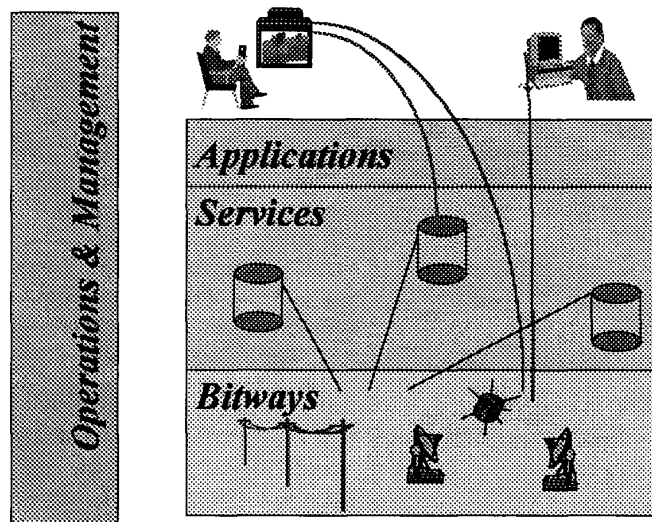


Figure 1. Information Network Components.

wireless service providers. The services area which lies between applications and bitways is somewhat more difficult to envision since it depends on whether the entities considered to be in the applications and in the bitways areas can offer "services". Lastly, the operation and management functions supply the capability of managing distributed heterogeneous systems across a wide geographical area, the ability to handle a rich mix of information services with a wide spectrum of quality of service requirements, fault management, performance management, security management, usage accounting and billing, and policy management. It also contains functions to enable applications such as routing, addressing, service mobility, load balancing, name transparency, and internetworking.

2. Convergence

A major socio-economic revolution is currently taking place that is firmly rooted in the creation, distribution, and use of information. The driving force for this phenomenon is termed "convergence". Simply defined, convergence is a process that is reshaping the technology and business models for the computing,

telecommunications, consumer electronics, and electronic media industries. In short, a new information-based computing paradigm is forming that will have significantly more impact than the PC revolution or client/server computing. A set of business and technical market forces are providing the energy for convergence. Examples of the business drivers are the deregulation of telecommunications, heightened global competition, and a dramatic increase in demand for information products:

- As a consequence of the deregulation of the telecommunications industry, many new entrants are competing for today's business. The competition is causing huge investments in upgrading the telecommunications infrastructure and in a drive toward improvements in service quality, increased responsiveness to customer needs, and overall reductions in service costs.
- Advances in global communications have led to heightened competition in global commerce, to forced improvements in product quality, and to general competitiveness. These advances have fueled a growing interest in electronic commerce to speed transaction execution, reduce transaction complexity,

increase accuracy, and support greater levels of customer service. As industry after industry embraces service as a major source of competitive differentiation, having a reliable and readily accessible information network that connects customers and suppliers is fast becoming a fundamental requirement for conducting business.

- The unbounded increase in the demand for information is another very significant business driver. An emerging set of applications should satisfy this demand by providing information on demand, be it documents, video, images, financial data, and so on.

The main technical drivers to the convergence phenomenon are the rapid evolution of the PC to an "information appliance", the mass digitization of data, and the critical mass of broadband networking.

- The applications are driving the innovation in the PC technology to satisfy special-interest computing requirements such as mobile computing. The evolution in the size of the PCs, such as the PDAs, and the innovation of user interfaces, such as voice, handwriting, and bar-code recognition, demonstrate the trend toward the development of PCs as end-user information appliances.
- The rapid shift to digital encoding of multimedia data, including audio, video, image, and text, is providing the feedstock to drive the information revolution. The availability of data in digital format makes accessing, indexing, combining, and transmitting information much less complex for computer applications. This availability is enabling the creation of multimedia applications that permit users to more easily understand and derive meaning from the data, thus providing the user with information rather than raw data.
- Finally, the new technologies of broadband networking such as ATM, the increased availability of broadband fiber optics cabling, and the growth of the cable infrastructure indicate that the broadband communication infrastructure is reaching a critical mass. This infrastructure will form the "bitway" of the information networks and enable the needed new multimedia applications.

Considering the business and technical drivers, the convergence is causing the creation of new industries and opening new service markets that focus on information-related products and services. The value chain of information services, shown in Figure 2, separates

creation, delivery, and consumption of information into activities labeled content, distribution, and users. The bi-directional arrows indicate that data flows in both directions.

Content is the source material for an information service which is supplied by one or more content providers. The distribution component consists of a network that connects users to the service, and a set of distribution systems. The distribution systems handle the capture, preparation, storage, retrieval, and delivery of information for the service. These systems must include a sophisticated operation and management system for the service. The last component is the users, who interact with the information services using PC-like devices (information appliances).

Although three areas of opportunity are illustrated in Figure 2 (content, distribution, and use), the information services model focuses on integrated products and services supplied to or by the three segments. These integrated information services are sets of distributed applications which will have the following major characteristics:

- **Industry specific.** An information service for medical records is expected to differ significantly from one operated by a shopping network. These differences include information content, customers, distribution mechanisms, applications, quality of service, and so on.
- **Large scale.** The information network has to handle a large number of users, tens of thousands and more. The databases are large, definitely distributed, and reside on heterogeneous servers.
- **Continuous operation.** Users of information services expect to pay for the service to run their business. Any prolonged disruptions in service will often result in non-recoverable revenue.
- **Complex system.** The information network will have many physical components such as disks, processors, and network equipment. The systems and software tend to be very complex compared to the known telecom network supplying transmission services only. It is important to mention that there are a number of integrated information services that exist today. Examples of such services include Mead Data Central, CompuServe, Westlaw, Dialog, and Dow Jones. All these current information services, however, are text-based. In the future, the information network will have to handle the emerging services which will provide multimedia-based information services.

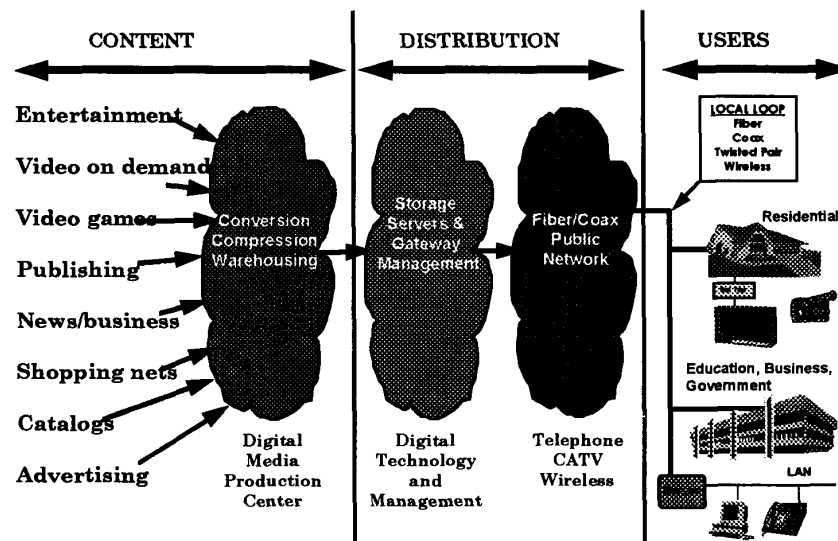


Figure 2. Information Services: Value Chain.

It is clear that the guiding vision for information networks is a system which enables users to access all the information they need, when they need it, and where they need it. For this vision to become reality and revolutionize the way we conduct our daily lives and business, network technology, user accessibility, and content-handling tools must be developed in an integrated fashion. The opportunity exists for the technology to impact the economy and accelerate the formation of the information service market. The following section focuses on the different technology needs of the Information Network.

3. Technical barriers

Technological progress in the following three areas has to be aggressively addressed to achieve the realization of an information network supporting the envisioned new services and applications. These three areas are operations and management, user access and usability, and digital video.

3.1 Operations and management of information networks

The large and often unrecognized barrier hindering the exploitation of information networks is the lack of cost effective solutions for operations and management (e.g., configuration management, fault management, performance management, security management, usage accounting and billing, and enabling services). In 1994, labor associated with the operation and management of private enterprise information networks is expected to cost the U.S. economy more than \$200 billion—a cost so large that it may prevent the mass deployment of new information products and services. Beyond costs, robust operations and management technologies, which are absent today, are required when deploying mission-critical applications, such as those related to electronic commerce, virtual enterprises, and other applications that may be a source of substantial growth in the information services.

The information infrastructure of the future involves a new paradigm different from conventional communication systems in the sense that the infrastructure will be capable of providing not only connectivity but also information services. Indeed, the

information infrastructure, satisfying the requirements of the future Information Network, will consist of information appliances and information service providers interconnected by a variety of concatenated communication networks, including terrestrial and satellite networks, cable television systems, wired and wireless telephone systems, and computer data networks with diverse characteristics and capabilities. It is irrelevant to users how many people are on the system or whether a particular network connects to any other one; the user only cares for the service quality and cost.

One of the major challenges for the computer industry, the telecommunications industry (wired and wireless), and the entertainment industry is to develop an information infrastructure with seamless interconnection of the individual networks capable of providing a variety of interoperable services. Operations and management functions must be developed and tested in order to achieve a reliable operation of the infrastructure, manage the information appliances, and maintain the quality of service along with the required privacy and security.

A paradigm shift will be necessary for the operation and management of the future information network. Concepts and approaches taken in network management in the past and present will no longer be sufficient, not only because there are heterogeneous networks and their interoperation to consider, but also that the actions and traffic from service and information providers and information appliances must be considered jointly with the network activities. One of the reasons for this is that the provider of service, directly to a customer, need not be one of the traditional service or network providers (e.g., telephone company). That provider may be, for example, a third party integrator who buys services from a network and resells them to customers, value-added. Another reason is that the nature of the interactions from the customer's appliance in general will be far more complex than in the past and likely will not have service profiles defined in a fixed manner that can be measured, managed or billed in a simple, one-size-fits-all manner. Most especially this will be the case when the appliance obtains information of various types from several different public and commercial providers across several different networks. Thus, operations and management activities cannot be separable from the components of the information system that lie "outside" the networks. Such activities must be present end-to-end, with differing responsibilities and cooperation among the participating providers.

3.2 User Access and Usability of Information Networks

Growth of the information services can be hampered by poorly organized or chaotic networks, badly designed interfaces, ambiguous protocols and procedures, and non-interoperable equipment and services. These problems create market entry barriers, limitations and inequities in access, and losses in potential improved productivity.

Rapid advances in computer and communications technologies could provide the opportunity today to realize a seamless web of communications networks, computers and databases that puts vast amounts of information at users' fingertips. This enables a whole range of new information services such as digital multimedia libraries of educational and cultural material; customized services such as specialized newsfeeds and business reports; information kiosks; travel information, maps, and travel agent services; video/music browsing for on-line rental; catalogs for electronic mail order and electronic shopping malls; and virtual enterprises.

Bottlenecks in user access and network usability could turn the vision of information networks into a catastrophic nightmare. New technologies must be developed and tested to achieve the overall goal of ensuring that a diverse range of information consumers, network operators and information service providers can exchange information and provide services rapidly, securely, conveniently and cost effectively. Some of the technical barriers are discussed below:

- **Intuitive user interfaces.** User interfaces must meet the highest standards of ease-of-use, so that users have easy access to information and services, in any language, at any time and anywhere. The interfaces should be adaptable both to many levels of user skill and to many types of applications.

There are significant challenges to be met in dealing with multimedia and in integrating multimedia search with text and data base queries. A widely accessible interface must improve on the current graphical user interfaces (GUI). These interfaces should also provide visual browsing capabilities and the use of spoken and written natural language for accessing information and services. They must be designed to explore all potential users' interface techniques including keyboard, mouse, voice and pen.

Speech recognition and human language translation and generation are likely to be key components in mass-market applications. The long-term technical

challenge in speech recognition is to build speech understanding systems that are easy to use; robust to background noise, telecommunications channel, and talkers; and work in virtually any language and with unconstrained syntax. In the next several years, realistic challenges include connected-word recognition with 99.5 percent accuracy, medium-sized vocabulary recognition with 95 percent accuracy, and robust rejection of extraneous speech and background sounds. Achieving these goals will enable many cost reductions and revenue-generating applications for telecommunications and information service providers.

- **Interoperable user interfaces.** End users should be able to access, simultaneously and transparently, multiple search servers. Widely differing interfaces must be able to use a common protocol to access information servers.
- **Intelligent agents.** The huge amount of information available at any one time will require the development of intelligent agents and filters to avoid overwhelming the end users. Technical challenges include developing information filters that learn user preferences and that deal with multimedia data including voice and video, and developing standard methods to capture, represent and communicate to agents the information they need to operate in heterogeneous environments.
- **Multimedia and scalable search and browse techniques.** Navigational aids, such as Gopher and WAIS, are currently aimed only at textual information in computer-based networks. No equivalent systems exist for the evolving multimedia information structures. Although the current textual search mechanisms are quite adequate, there are significant challenges to be met in dealing with multimedia searching and browsing. Work is needed in the retrieval of still images or video and the larger problem of combining results across multimedia. Indexes to be searched should be generated and updated automatically as data is added.
- **Fusion of information.** Advances are needed in search technologies to handle the fusion of results from query servers running different search engines against very large multimedia collections. Users should be able to access several search servers, simultaneously and transparently, and have the results combined in a meaningful way. Information providers should be allowed to register new servers easily and to provide attributes that describe their contents.

- **Information preparation.** Access to large-scale, high-quality, multimedia information requires generic tools for authoring, preparing information for efficient delivery through the network, and subsequently presenting multimedia information to the consumer. These tools should enable non-specialist users to handle information from a variety of sources, including live video calls, stored video, and stored interactive multimedia. Methods of dealing with knowledge representation need to be explored and tools are needed for automatic indexing of multimedia information.
- **Authentication and security.** Techniques for security and authentication need to be scalable and applicable to heterogeneous environments. Techniques for document authentication must be further developed and applied to multimedia objects, with copy protection schemes for high-value objects. Complete transactions between buyers and sellers must take place seamlessly. Using speaker verification techniques may provide additional security. All forms of payment, including subscriptions and pay-per-use, should be supported in a common framework.
- **Service portability and transparency.** The complexities of a heterogeneous, multi-supplier network must be hidden from the user to enable flexible, transparent access to information and services. Mechanisms should be developed so the end user can obtain services without concern for the details of the networking environment, the geographic location of the information sources, or other participants in a communications session.

3.3 Digital Video in Information Networks

Even though digital technology is well established, its application to video is not pervasive. Interoperable digital video capability across various information infrastructures does not exist to leverage the integration of video technology across computing, communication and consumer electronics environments. Creating an interoperable digital video infrastructure is by no means a routine or inexpensive process. A variety of R&D and deployment considerations must be made at each step along the way.

To make digital video a predominant service, the interoperability has to be real. In addition to providing connectability, interoperability in the wider definition means there are data models to store, retrieve, and edit the video; effective compression techniques to facilitate

video transmission over a variety of communication networks; and effective display mechanisms.

To meet the goal of an open, interoperable Information Network, data communication and video should fit within an interoperable system architecture which is flexible, extensible, simple, and enhances the ability of the services to work together. This overall interoperable design does not yet exist, but is essential to accelerating the implementation of information services and to be able to support the following requirements:

- Interactive and two-way exchange of video using simple information appliances over an information network that is as easy as two-way voice is on a telephone today.
- Widespread access to video via servers by consumers and professionals alike.
- Incorporation of video into computer-based applications for production, distribution and use.

Some of the technical barriers to achieving these requirements are discussed below.

Raising the information capacity of the Information Infrastructure. Interactive video transmission and distribution demand huge information capacity, including two-way capability. Lack of sufficient information capacity can significantly restrict the number of consumers of video information services. Improvements in bandwidth can be accomplished by improving the network hardware and network software protocols, and by effectively applying data/video compression techniques. Next generation video compression must be developed to meet a wide range of quality and compression level requirements. Some applications such as video production, medical diagnosis, and scientific analysis may require high resolution. Other applications such as desktop video conferencing or browsing a video library will require lower quality. System-level tradeoffs among picture quality, data rate, latency, data jitter, and cost to the service provider and the user must be balanced in an overall digital service system design on an application-specific basis.

Enable the design of interoperable system components and conversion equipment. There is a need for common hardware and software interfaces which allow interoperability between information providers, networks, and appliances. If properly specified, digital video can be easily repackaged, stored, and carried by a variety of distribution networks to a variety of receiving appliances. These interconnected distribution systems should involve a loose coupling of sources with destinations so that a

variety of sources can be connected to a variety of destinations via a variety of networks.

Protocols of the individual network elements can be subjected to the standards of each industry, but industry agreements are needed to define the interconnection points between the various sources, networks, and destinations. Development of these industry agreements is needed early in the process to avoid creating incompatible technologies or premature obsolescence of consumer equipment.

Definitions of these interfaces and the design of conversion equipment must be based on proven technology, otherwise there is a risk that the definitions will be ignored. The need is to promote research and development, based on technical feasibility studies of different approaches, to guide the creation and definition of these interconnection point faces and the design of conversion equipment.

There are 200 million television receivers in the United States and close to 100 million personal computers. Development of an infrastructure that ignores their use as information appliances will seriously delay acceptance of any new services. Developing a migration path to phase in new technology with old requires that the old technology interoperates with new services; the interoperability is an essential requirement to accelerate the growth of the service market. A migration path encourages technology that operates effectively in a hybrid world of old and new technology.

Create digital video tools and management capabilities. For video to become an effective part of the everyday computing environment, tools have to be developed for the construction and manipulation of the video databases, i.e., content organization, updating and editing, browsing, and retrieval. Measures must be developed for determining quality of service, and networks must be designed to guarantee levels of service quality. Data models for multimedia information are required, for example, before a multimedia database system can be developed. Such a multimedia server, that allows intuitive and easy access to variety of information content, will be the heart of any future integrated information services.

To succeed, the information infrastructure must provide for the delivery of motion picture and television programs to the home. This can only happen if the intellectual property rights of content providers are respected by the inclusion of access control mechanisms for payment and audit, and security of storage, transmission and display at all levels. Content providers have made it clear that failure to provide these tools will significantly inhibit the development of information-

providing services which are essential to the success of the network and its services.

4. Conclusion

Efforts should be made to increase the R&D investment directed toward solving the technical barriers facing the acceleration of developing a commercial information network. The first step should be the recognition, extraction, and prioritization of the barriers, followed by a commitment of the scientific community and information industry to work in partnerships to address these barriers. In addition, the three industry groups of the emerging and relentlessly growing information networks—the creators of information products such as movie houses, the distributors of information such as cable companies, and those who make appliances such as TVs with which users access the information—should recognize that they are at a particular decision point whose outcome will take them down very different paths. On one path, they can converge—work cooperatively toward building a seamless information framework based on the “interoperability” of the framework’s many components—a decision that will enable a more attractive and versatile portfolio of services. On another path, they could allow the swift momentum of information technology to sweep them forward (or away) individually without full regard for the rest of the framework. In the latter scenario, not only would the potential versatility of the emerging framework be clipped severely, but industry fears it would be virtually impossible to reverse.

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