8. THE CRITICAL TRENDS AND ISSUES

> *"A scientist is a man who can find out anything, and nobody in the world has any way of proving whether he found it out or not, and the more things he can think of that nobody can find out about, why the bigger the scientist he is."*
>
> *Will Rogers, 1930's*

This section summarizes major trends and issues faced by those working in the information age early in the 21st century. Section 8.1 begins with a series of quotations from various authors working in the field of telecommunications. Then in Section 8.2, some projections are added with a list of seven critical areas expected to impact the telecommunications infrastructure ten years from now. In making these projections, one feels somewhat like the scientist defined above by Will Rogers. At least the aim is to follow Lenz's Law which states "When predicting the future it is better to be approximately correct than precisely wrong!" See Vanston et al. (1989). Some projections are obvious, others are nebulous due to fast-changing needs and technologies. Still others depend on innovative research yet to reach completion. Finally, Section 8.3 provides a list of some remaining issues that still need to be resolved as the 21st century is approached.

8.1 Pertinent Quotes

This report has addressed emerging and evolving telecommunications technologies, and has attempted, where it seemed appropriate, to project their trends and outcomes. This is important to those who must try to plan for the future. Questions remain, however, as to the accuracy of the predictions. The quotations below are intended to give the perspectives of some others who write books and articles on this subject, and who are called on by corporations and Government agencies to help sort out the elements of the telecommunications explosion. A number of these individuals have already been referenced, but the quotes given here serve as a nice summary for the salient ideas.

Taylor (1992), on desktop computing:

> "The first key trend is the continuing shift in computing from host-centric to fully distributed networking. Equivalent to the shift from batch to interactive computing, this is only the second major evolution seen in this industry. This shift, fueled by the ready availability of high-performance low-cost workstations,

is moving more and more of this intelligence in the network to the desktop. Indeed it is not uncommon for the desktop processor today to have as much raw computing power as a fairly large time-shared mainframe had just 10 years ago."

"Future networks will need to handle very bursty, high-volume, high-speed traffic with essentially no delay because interactions occur less frequently but require instantaneous response time for entire file transactions."

Tamarin (1988), on the role of the user:

"One very significant result of the new technologies have been the user's ability, given sufficient resources, to bypass the public network and build private network facilities. This is a trend that will surely continue, to the detriment of the telecommunications infrastructure, if traditional service providers do not become more responsive to user needs. Consequently, regulatory organizations need to be active in seeking user involvement in order to avoid user abandonment of the public network."

Mushin (1991), on privacy and security issues:

"The privacy protection and information security issue has been called the problem of the human gold fish. The telecommunications business, whose mission is to store, process, and carry information, has a primary responsibility with respect to this issue. The protection of information ownership and privacy against third parties is necessary whether the third party is government, major institutions, political groups, or criminals. In this area, the development of business and private cryptographic methods and equipment is essential."

Mushin (1991), on globalization of telecommunications:

"Telecommunications technologies link people all over the world. Helping poor people around the globe is a moral imperative for the telecommunications business.

Economically, telecommunications companies should stimulate economic growth in the less developed countries through direct and/or indirect investment, purchase of their goods, and active cooperation with national/international organizations.

Socioculturally, they should respect cultural traditions of other peoples.

They should also realize that they are required to protect foreign peoples as well as their own people from destructive transborder information flow threatening national defense or violating fundamentally different values and cultures. "

Bonatti et al. (1989), on future network planning:

"Network planners must develop decision support systems needed for each of the stakeholding communications providers to assess the attractiveness of opportunities to adopt new telecommunications technology, and to commit plant expenditures, operations, and support systems necessary to accommodate new revenue-producing network services at forecasted levels of demands. As alternative services emerge, an increasing responsibility of the network planner will be to assist in decisions to withdraw from certain offerings and to abandon certain technologies in preference of newer opportunities. In summary, the dilemma of providing end-to-end service to increasingly sophisticated and demanding customers who are confronted by an array of options to serve their telecommunications needs, while recognizing that no individual provider can serve those needs without cooperative endeavors from partners, is likely to be the most important telecommunications challenge facing the industry in the 1990’s."

Ryan (1991), on integrating "circuit and packet switching:

"To successfully interface with all data communications equipment on the host or LAN side and to interconnect over ISDN with all other devices, next generation ISDN access equipment must provide comprehensive integrated protocol support.

Users increasingly demand integrated support of packet and circuit switching. The demand for integration is based on the trade-off between performance and cost. For an organization’s low-bandwidth applications, packet-switching services are substantially more cost effective. For high-throughput, response-critical applications, the dedicated line of a circuit-switched connection is necessary."

LaBlanc (1992), on future services:

"In the coming decade, the importance of communication for the economic well-being of businesses, individuals, and the country as a whole will continue to increase. To meet the demands of the marketplace, extensive and innovative changes will occur. Today’s vision of information superhighways and a national broadband network will become a reality.

Competition and technological innovation will increase the kinds of services available and the number of providers handling those services. Each of us may have our own personal communications number that will follow us to various locations, connecting us with our car phones, our offices, and our homes."

Brown (1985), on future services:

"Beyond ISDN, we can look forward to the day when customers, from the small family to the largest multi-national corporation, will have ready access to an array of information and communications services that once were dreamed of only by writers of science fiction.

At the same time, data, image, and video communications will eventually become as easy to use and as readily available as voice communication is today. For example, video or wideband channels available on demand for any purpose imaginable. Access to data bases around the globe -- perhaps accompanied by instantaneous translation of foreign languages into the customer’s own language. An unlimited assortment of software-based services, including services involving networks that can be set up immediately to the customer's specifications."

Herr (1986), on universal information services:

"While ISDN provides a powerful start, customers are going to demand more: more integration, more control, and more bandwidth to carry an increasing volume of traffic that will be in image and video formats. People communicate with each other through multimedia formats -- wideband voice and image combinations using the larynx, ears, and eyes as audio and visual ports. Therefore, communications networks that support integrated voice and image combinations have a greater potential to achieve information productivity than integrated voice and data combinations alone. What’s more, people need to be able to get information when they need it. It must be accessible rapidly. And since everyone has a range of communication needs that vary from time to time, the ability to provide services on demand becomes important to achieving information productivity.

...what we’re envisioning is nothing less than turning communications networks into giant, distributed computers, with all of their power available to customers at their fingertips and under their control. We want to universalize the Information Age."

Claus et al. (1991), on IN and UPT:

"With the application of the intelligent network (IN) architecture, information technology is introduced in the network by way of specific service centers. These service centers concentrate the intelligence which is necessary for the support of the services, and they are linked with the switching network via powerful signaling links based on Signaling System No. 7. With this concentration of intelligence at a limited number of locations, services can be implemented quickly, can be cost-efficient, and can easily be modified to meet new market demands. ... one such new telecommunication service, the Universal Personnel Telecommunication (UPT) service will provide network independent personal identification allowing the relationship between terminal identity and user identity to be changed and thus providing a complete mobility across multiple networks."

Jacobsen (1992), on OSS and AIN:

"Today’s operation support systems (OSS) are based on basic telephone service. Future OSSs must accommodate ISDN, SMDS, ATM, and the radical changes that will occur with AIN deployment. One of the goals of AIN is rapid service deployment, which is accomplished by placing general-purpose computers into the network that affect call processing and provide a switch-independent programming environment The deployment of AIN will change the way telcos do business, which will significantly affect current OSS's that simply cannot support the integrated environment AIN needs. ...future OSSs must provide timely, accurate and cost-effective support for all telco activities. Future systems will use imaging, expert systems and even artificial intelligence."

Carpenter et al. (1992), on ATM/SONET standards:

"In the future, long distance digital transmission up to 2.4 Gb/s will be based on the Synchronous Digital Hierarchy (SDH) recommendations from the CCITT, including the American SONET standards. Additionally, Asynchronous Transfer Mode (ATM) is being defined internationally by the CCITT. ... ATM allows the definition of virtual paths through the network, with multiple virtual circuits within each virtual path. For non-data services, the virtual circuits will behave in the same manner as SDH circuits, and the underlying ATM 53-byte cell structure will be hidden in silicon by the ATM adaption layer. Various technical issues remain open at this time (March 1992) in the definition of the ATM adaption layer for data services."

Modarressi and Skoog (1990), concerning B-ISDN:

"In the second half of this decade, Broadband ISDN (BISDN) capabilities are likely to emerge in the network. BISDN provides a cell-based network infrastructure with extremely high-speed switching and transmission capabilities. Although it is not clear what the penetration rate of BISDN-based services will be in the telecommunication market place, it is quite clear that broadband technologies will become commercially available and new services using these capabilities will be offered. Given that the BISDN network will be based on asynchronous transfer mode (ATM) switching/transmission principles, and implemented on a ubiquitous optical fiber facility infrastructure, use of enormous bandwidth on demand will become not only technologically possible, but also economically feasible. Truly integrated multimedia services involving voice, high-speed data, image, and video will emerge and penetrate the business and residential markets with a potential to profoundly impact and transform the very fabric of those markets and the nature of the work place."

Cerf (1990), on the INTERNET and NREN:

"Looking towards the end of the decade some of the networks may be mobile (digital, cellular). A variety of technologies may be used, including but not limited to FDDI, DQDB, B-ISDN using ATM switching fabrics as well as conventional token ring, Ethernet, and other IEEE 802.X technology. Narrowband ISDN and X.25 packet switching technology network services are also likely to play a role along with SMDS provided by telecommunication carriers. FTS-2000 might play in the system at least in support of national agency network facilities.

The protocol architecture of the system will continue to exhibit a layered structure although the layering may vary from present day Internet and OSI structures in some respects."

Lyles and Swinehart (1992), on broadband networking:

"Traditionally, the speed and capacity of data communications networks are increased incrementally in response to incremental increases in network traffic. We see this trend today in the introduction of such services as ISDN, frame relay, and SMDS to support applications (e.g., electronic mail and file transfers) that constitute the bulk of the current traffic. ...recently, several bold and compelling activities have been launched to counter this evolutionary approach with a revolutionary one, designed to support important new applications whose voracious bandwidth requirements and delay sensitivities cannot be supported by today's networks."

Gant (1990), on SONET penetration:

"One of the backbone technologies to be rolled out in the 1990's is SONET. If it follows the course of most technology substitutions, its period of most significant growth will be from 1995-2000." See Figure 8-1.

Carpenter et al. (1992), on gigabit networking:

"Gigabits/s networking is on the verge of realization. The hardware technology is in the laboratories or the test beds. The software technology is appearing, and applications, especially multi-media networking and long-distance visualization, are taking shape. Even before the technology is in the market, standardization efforts, especially ATM, FDDI follow-on, HIPPI (High Performance Parallel Interface) and FCS (Fiber Channel Standard) are under way. Technical challenges remain but the biggest barriers, particularly outside the United States, will be political and economic. The research community should take the lead in breaking their barriers."

Kleinrock (1992), on propagation delay in gigabit networking:

"The major conclusion of this paper is to recognize that gigabit networks have forced us to deal with the propagation delay due to the finite speed of light. Fifteen milliseconds to cross the United States is an eternity when we are talking about gigabit links and microsecond transmission times. As we saw earlier, the propagation delay across the USA is forty times smaller than the time required to transmit a 1-Mb file into a T1 link. At a gigabit, the situation is completely reversed, and now the propagation delay is 15 times larger than the time to transmit into the link. We have moved into a new domain in which the considerations are completely reversed. We must rethink a number of issues. For example, the user must pay attention to his file sizes and how latency will affect

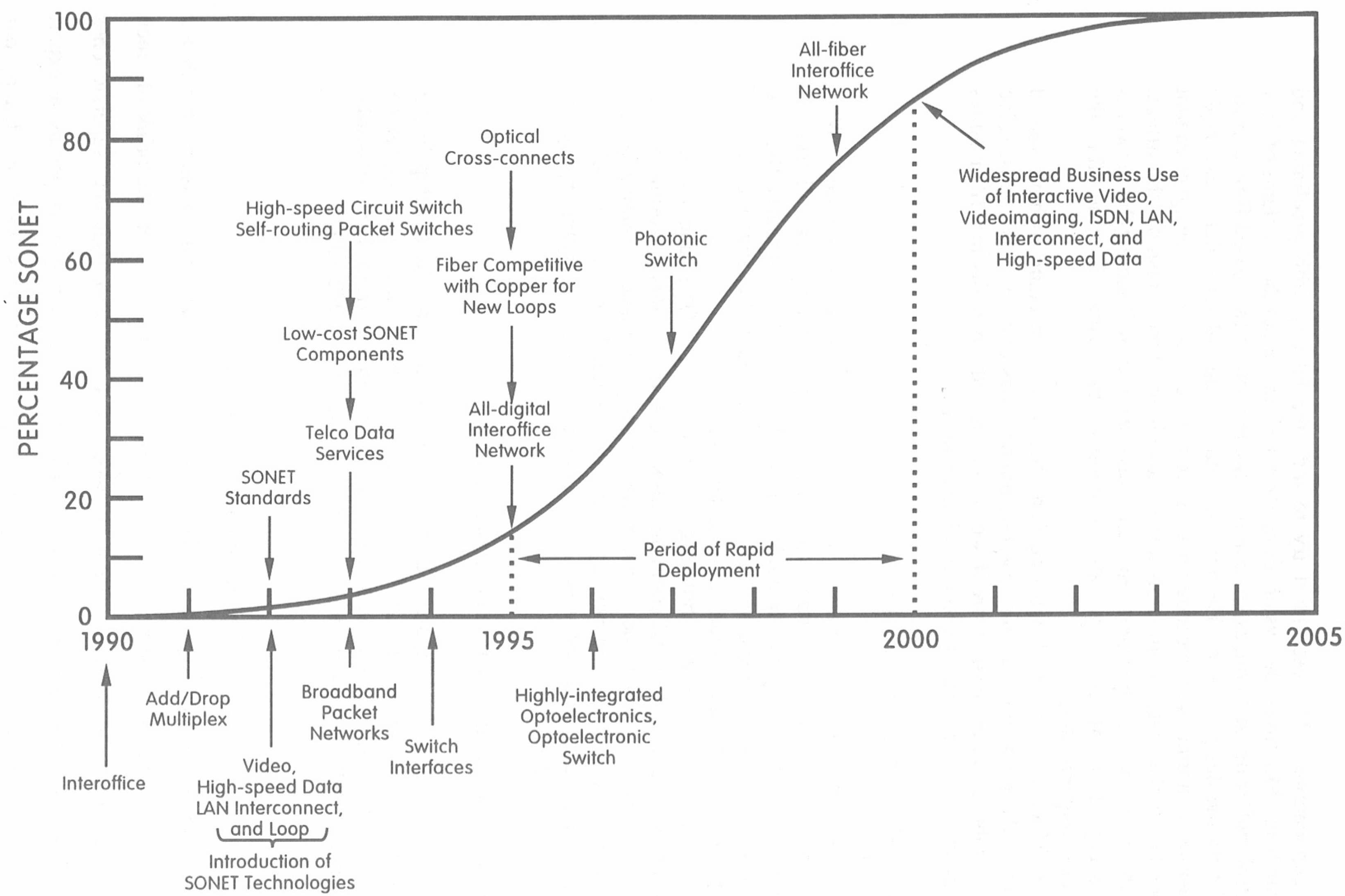

Figure 8-1. SONET penetration into the network (from Gant, 1990).

his applications. The user must try to hide the latency with pipelining and parallelism. Moreover, the system designer must think about the problems of flow control, buffering, and congestion control. Some form of rate-based flow control will help the designer here. He must also design algorithms which make rapid decisions if enormous buffer requirements are to be avoided. The designer cannot depend on global state information being available in a timely fashion; this affects his choice of control algorithms. In many ways, the user will see gigabit networks as being different from megabit networks; the same is true for the designer/implementer.

Much more research must be done before we can claim to have solved many of the problems that this new environment has exposed. We must solve these problems in the near future if we are to enjoy the benefits that fiber optics has given us in the form of enormous bandwidths."

Kung (1992), on gigabit LANs:

"Gigabit LANs will have a revolutionary impact on applications. With these networks many important applications (e.g., imaging and distributed computing) will no longer be limited by network speed. More importantly, new applications enabled by these networks will emerge, and will change the fields of computing and communications in a fundamental way.

Gigabit LANs provide both high-bandwidth (multi Gb/s) and low latency (tens of µs or less) end-to-end communication. LANs with this performance will pave the way for many next generation, high-performance computing and communication systems and new applications. Demands for gigabit LANs are widely recognized, and hardware component technology at gigabit speeds is basically available."

Timms (1989), on the broadband service schedule:

"The figure (our Figure 8-2) shows how broadband will develop in the period from 1980 to the year 2000. Integrated broadband access will appear on a substantial scale, starting with major business centers, from 1988 onwards. Switched broadband services will become available from 1992-1993."

8.2 Seven Ten Year Projections

As a result of the convergence of data processing and data transmission, distributed information networks now provide some new services, but are just now on the brink of much more. Ultimately, a worldwide digital network with megacell/second superswitches interconnected with a gigabit/second optical fiber backbone and managed by pervasive expert systems or artificial intelligence machines will provide more of the services needed by our

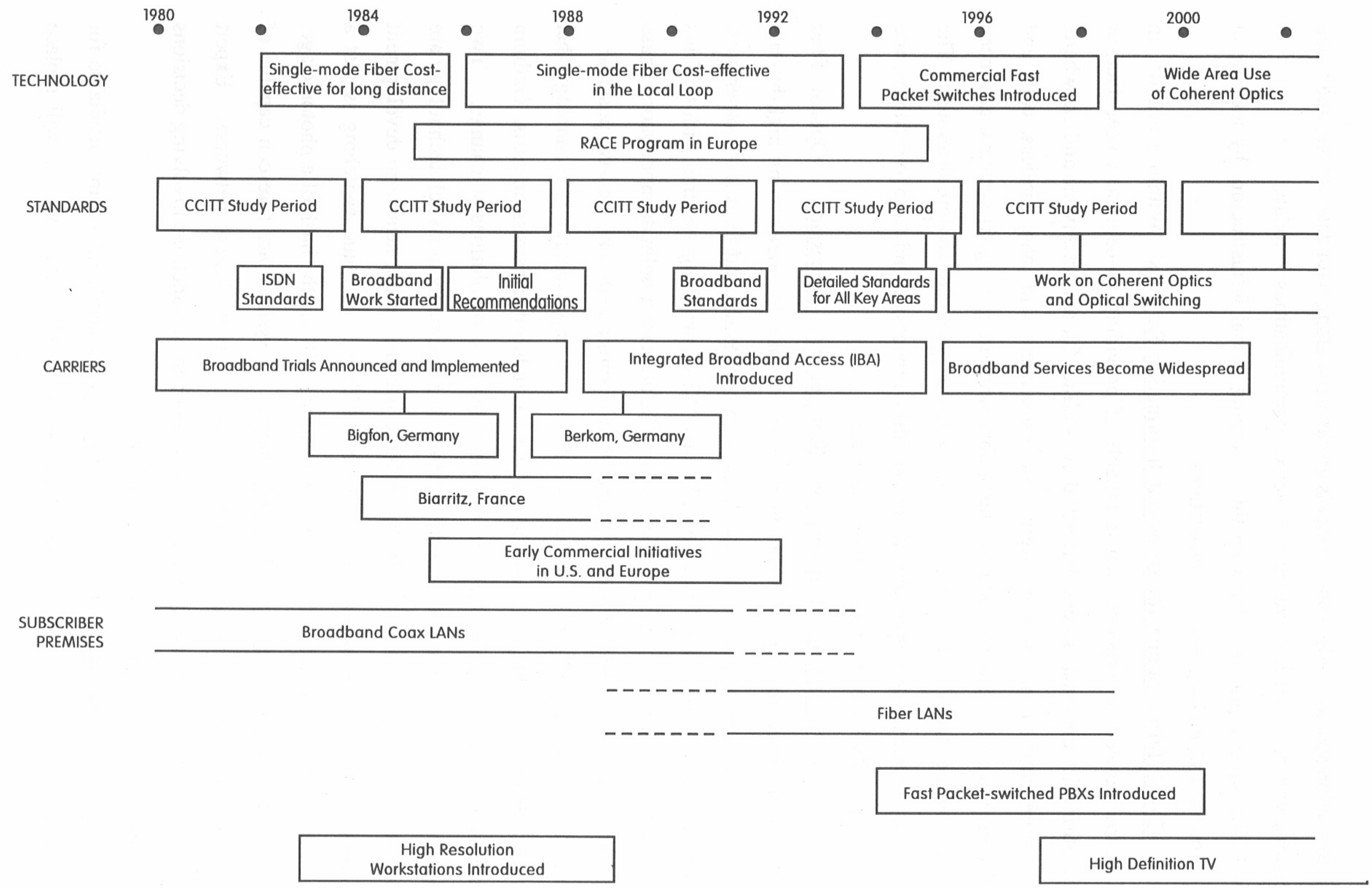

Figure 8-2. The development timetable for broadband (from Timms, 1989).

emerging information society. Wideband channels on-demand, along with data, image, and video communications will be as readily available as voice communications is today.

The following paragraphs expand on this emerging global infrastructure by looking at some key elements and making ten-year projections.

(1) Global Infrastructure for Universal Information Services. Within a decade, an intelligent, global network is expected that is capable of providing on-demand voice, data, or video information with universal access (terrestrial or satellite) for almost anyone and anywhere. The infrastructure environment will be digital and packetized, wire and wireless, cells and cellular. The essential elements required for this global structure are digital systems, advanced intelligent networking (AIN), and some form of wireless personal communications. The infrastructure may include both public and private facilities, processing and storage facilities, and a global interoperability based on international standards.

(2) Photonic Switching, Transmission, Storage, and Processing. Optical fiber transmission systems have already proven to be an ideal medium for transporting high-bit-rate information. As such, it relieves the radio spectrum from congestion and frees it for other uses. Optical integrated circuits are on the horizon. Photonic ATM switching systems with terabit/s capacities are under development. Integrated optical applications for amplitude modulators, phase modulators, demodulators, switching matrices, and beam forming networks are also possible.

According to Kleinrock (1991), there is no near-term improvement in technology that would dramatically drop switching costs, as fiber optics has reduced transmission costs. Gallium arsenide components would help, but are not considered a revolutionary change. Two technologies on the horizon that could provide dramatic improvements in switch technology are warm superconductivity and photonics. Neither of these is considered a near-term development but either could have a major impact in the future. Although photonic switching is just a laboratory experiment, it is entirely possible the 21st century will see the birth of a photonic age.

(3) Artificial Intelligence and Expert Systems. AI systems are foreseen capable of continuous speech recognition, signal compression, and more intelligent networks. Expert systems will provide most of the network management and control functions involving decisions based on networking information retrieval and analysis.

(4) Accessing Technology using ATM and SDH. Today's LANs are unsuitable for supporting interactive multimedia traffic; therefore, ATM or ATM-like switches will replace

LANs, and ATM technology will permeate future customer premises. This is because ATM is a parallel switching system that supports multiple users transmitting simultaneously. LAN users, in contrast, share the transport medium one at a time. Like today's PABXs, small ATM switches on the business premises, connected by high-speed trunks to public backbone networks, will serve all of the business needs. Frame relay, SMDS, and FDDI will be fading from the scene.

The synchronous digital hierarchy standard for high-speed transmission will dominate the global infrastructure in ten years.

(5) Wireless Systems. Wireless systems include mobile systems such as cellular systems, PCNs, cordless phones, paging, and wireless LANs. Media include terrestrial radio and satellite. In the next ten years, the industry expects many new wireless services to emerge as more and more people are on the move. Wireless LANs are just appearing now. Wide-area wireless private networks can be implemented with central transceivers and mobile equipments. Standards are currently being developed for the next-generation public cellular systems. This includes a possible all-digital cellular system based on spread spectrum technology (Krechner, 1991).

Cellular, satellite, and microwave systems to expected to continue to evolve, but each in its own specialty area of application.

For personal communications, a PCN will evolve and compact, fully-featured terminals will provide complete access to services anytime anywhere.

(6) Multimedia Workstations and Communications. The organization, storage, manipulation, and distribution of information are all functions critical to the success of most businesses. As long as the importance of the content, not the conduit, is recognized, these workstations will have beneficial applications, including interactive education, multimedia conferencing, medical, and a host of others.

Already, PCs offering advanced capabilities such as color, audio, full-motion color, and video are available. It is estimated that by 1995 approximately 200 million of these PCs will have been sold.

(7) Software Evolution for Parallel Programming. In ten years, heterogeneous networks of workstations will be common. Programmers will develop programs of different types and languages to interact in this environment. To do this, new programming methods will evolve using formalized procedures to develop, proof, and test each program.

8.3 Issues and Actions Impacting Telecommunications

This section includes four major issues: 1) standardization, 2) Government policies, 3) the telecommunications infrastructure, and 4) privacy, security, and fraud. A further breakdown for each follows:

8.3.1 Standardization

Standardization issues include those concerning the user's role in the entire standards-setting process, which has been largely indirect. Solving technical interface problems is hard. In a national multivendor environment, it's more difficult. And, solving hard technical problems in the international arena is almost impossible due to the large number of participants and issues involved. National interests may have to take a back seat and world markets taken into account when selecting what standards should be adopted.

8.3.2 Government Policies

The list of policy issues includes

- Issues involving security and emergency actions critical to the national welfare
- Policies of Department of State concerning international standards
- Regulatory policies of the FCC (e.g., ONA)
- Judicial policies concerning interexchange carriers and RBOCs (e.g., COMP III)
- Spectrum management policies
- Congressional policies affecting users (e.g., Communications Act of 1934).

8.3.3 Telecommunications Infrastructure

Issues in this category include

<u>Bypass Issues</u>. The user has a number of options (e.g., satellite, microwave radio, PCN) which provide capabilities to bypass the public network with a private network either in the local area or totally. There are a number of reasons for bypass. One is cost, another service and performance. Sharing the public network

may be detrimental due to the different traffic types (e.g., continuous, intermittent, or interactive). Bypassing the RBOCs provides competition in the local area, but at the same time may be detrimental to the public telecommunications infrastructure. This could become a policy issue.

Survivability and Reliabilitv Issues. These issues include the complex problems of cross-connecting competing networks to make a whole, and then providing adequate network management for this whole. Resolving survivability and reliability issues is of paramount importance to the user whose entire business depends on the infrastructure.

8.3.4 Privacy, Security, and Fraud

The issues in this category include

- Intellectual property protection
- Equitable access
- Customer control
- Computer virus protection
- Call screening and related features
- Caller identification and related features
- Network management
- Security technologies
- Authentication
- Access control
- Data confidentiality
- Data integrity
- Non-repudiation
- Vulnerability of software-controlled networks and systems.

8.3.5 A Comment Concerning Issues

Its noteworthy how often the user appears in every category. User concerns and needs are always an issue. When service providers, equipment suppliers, policy makers, and standards developers are unresponsive to users' needs, users tend to go elsewhere.

9. CONCLUSIONS AND RECOMMENDATIONS

"Would you tell me, please, which way I ought to go from here?" asked Alice.
"That depends a good deal on where you want to get to," said the Cat.
"I don't much care where," said Alice.
"Then it doesn’t matter much which way you go," said the Cat.

Lewis Carroll, Alice’s Adventures in Wonderland

Telecommunications has gone from POTS to PCS, and from PCs to integrated workstations and multimedia desktop terminals. Switching systems have advanced from analog to digital, from switching packets and cells to possibly photons. LAN technology is moving from coax to fiber, and even to wireless. Traffic, once carried by circuit switched or dedicated lines, now travels in packets and cells. Information rates have gone from kilobits/s and megabits/s to gigabits/s and even terabits/s.

Computers have more capacity, operate faster, are cheaper and smaller. Networks are faster, cheaper, more reliable, and service oriented. Terminals are more integrated, more intelligent, more usable, more mobile, and there are more of them.

New technologies were introduced with new names like ATM, SDH, SMDS, AI, VSAT, FDDI, and HDTV. Network technologies like 802.6 LANs, DBDQ MANs, and AIN WANs were explored. New standards from organizations like CCITT, ISO, ANSI, T1, and IEEE, based on models called OSI, ONA, and TMN, are leading to new layered architectures called B-ISDN, PCN, and UPT using new standard protocols. These networks range in scope from local to regional and from national to international. Some are public, some are private, some are regulated, some are not.

Today’s cable delivers 100,000 times as much bandwidth to users as their telephone, yet costs about the same (Rosner, 1990). LAN speeds have increased from 100 Mb/s to 1 Gb/s, memory capacity from 1 Mbit/chip to 500 Mbit/chip, yet costs constantly decrease. Transmission speeds over fiber are going from Gbit/s to Tbit/s and processing speeds from MIPS to BIPS, and still costs continue to fall, foreshadowing spectacular achievements in the future.

The report shows how PCN, VSATS, and microwave radio might bypass LECs to provide competition in that last holdout. How fiber and ATM and SONET could provide a host of new broadband services. How PCN could add mobility so that the global infrastructure could provide services to anyone, anywhere, anytime. It also indicates why the generation, organization, manipulation, and distribution of information is so critical to our nation's future.

It is predicted that by the year 2002 there will be a global infrastructure, managed and controlled by artificially intelligent machines, providing universal service using photonic switching and storage systems, and connecting distributed computing systems or multimedia terminals operating at gigbit rates. Others agree! Rappaport (1991) believes that a wireless revolution is forthcoming. Over the past few years, interest in wireless has been spectacular. Cellular radio had 50% growth rates, pagers 70%, and PCN research has been intense. Still others like Robinson (1992) note that "the intelligent global communication network is the engine that will provide simplified and universal access to any medium for anyone, anywhere ... on demand." Kleinrock (1992) concurs and states that "telecommunications, based on some of the most exciting technologies available, is changing rapidly and influencing almost every aspect of business, commerce, education, health, government, and entertainment."

Like Alice, one wonders which way to go from here. There are a number of trends yet to be explored and much more detail to be added for the most promising ones. It is recommended that future efforts be used to expand on the level of detail. The basic technonogies that should be examined for their "impact" are listed below.

- Fiber optics and photonics
- Synchronous optical network (SONET)
- Asynchronous transfer mode (ATM) - WANS & LANS
- Broadband-ISDN
- Personal communications systems (PCS)
- Switched multi-megabit data service (SMDS)
- Wireless LANs

These technologies will form the foundation for most of the telecommunication services which will be prevalent ten years hence.

In the past, our nation's economy depended on natural resources like oil, minerals, and crops. In the future, the strategic resources will not come just from the ground but will be the ideas and information that come out of our minds. The new technologies that support telecommunications provide the means to use and expand this new strategic information resource efficiently and on a global basis.

10. REFERENCES

Amarel, S. (1991), AI research in DARPA's strategic computing initiators, *IEEE Expert*, June, pp.7-11.

Anonymous (1990), Fiberworld overview, *Telesis,* Vol. 17, Nos. 1 and 2.

Anonymous (1991), Under a blue sky, Editorial, *Communications Week*, April.

Anunasso, F., and I. Bennion (1990), Optical technologies for signal processing in satellite repeaters, *IEEE Communications Magazine,* February, pp. 55-64.

Asatani, K., K.R. Harrison, and R. Ballart (1990), CCITT standardization of network node interface of synchronous digital hierarchy, *IEEE Communications Magazine,* August, pp. 15-20.

Ballart, R., and Y. Ching (1989), SONET: now it's the standard optical network, *IEEE Communications Magazine,* March, pp. 8-15.

Barnes, G. (1991), PCN versus microwave: the spectrum battle, *Telecommunications,* December, pp. 38 and 42.

Bellcore (1990), Advanced intelligent network, Release 1, Baseline Architecture, Special Report SR-NPL-00155, March, Livingston, NJ.

Bellcore (1991), ISDN deployment data, Special Report SP-NWT-002102, October, Livingston, NJ.

Bonatti, M., S.S. Katz, C.F. Newman, and Varvaloucas (1989), Guest editorial, *Journal on Selected Areas of Communications,* Vol. 7, No.8, October, pp. 1161-1165.

Bourne, J., and J. Roth (1985), Technology as a network enabler, *Telesis*, No.3, pp. 5-11.

Brown, C.L. (1985), Reach for a new goal: universal information services, *Telephone Engineer and Management*, November, pp. 69-71.

Brule, J., and I. Ebert (1990), Fiberworld: an overview, *Telesis,* Vol. 1/2, pp. 5-17.

Cargill, C.F. (1989), *Information Technology Standardization,* (Digital Press, Bedford, MA), Chapters 10-13.

Carpenter, B.E., L.L. Landweber, and R. Tirler (1992), Where are we with gigabits, *IEEE Network*, March, pp. 10-13.

Catlett, C.E. (1992), In search of gigabit applications, *IEEE Communications Magazine,* April, pp. 42-51.

CCITT (1988a), Recommendations of the IXth Plenary Assembly, Blue Books on ISDN, Fascicles 111.7, 111.8, and 111.9, Geneva, Switzerland.

CCITT (1988b), Recommendations of the IXth Plenary Assembly, Blue Books on Signaling System Number 7, Fascicles V1.7, VI.8, and V1.9, Geneva, Switzerland.

CCITT (1988c), Recommendations of the IXth Plenary Assembly, Blue Books on Open System Interconnection (OSI), Fascicle VIII.4, Geneva, Switzerland.

CCITT (1988d), Recommendations of the IXth Plenary Assembly, Blue Books on Network Management, Fascicle IV.l, Geneva, Switzerland.

CCITT (1988e), Recommendations of the IXth Plenary Assembly, Blue Books on General Aspects of Transmission Systems, Fascicle III.A, Geneva, Switzerland.

CCITT (1992), Principals of intelligent network architecture, Draft Recommendations I.312-I.329.

Cerf, V. (1990), Thoughts on the national research and education network, Network Working Group, Request for Comments No. 1167, July.

Cerf, V., and K. Mills (1990), Explaining the role of GOSIP, Network Working Group, Request for Comments No. 1169, August.

Chandy, K.M., and C. Kesselman (1991), Parallel programming in 2001, *IEEE Software Magazine,* November, pp. 11-20.

Clark, D., L. Chajun, V. Cerf, R. Braden, R. Hobby (1991), Towards the future internet architecture, Network Working Group, Request for Comments No. 1287, December.

Claus, J., F. Lucas, and G.K. Helder (1991), New network architectural functionality, *Telecommunications Journal,* Vol. 58-XII, pp. 907-914.

Communications Act (1934), U.S. Code, Title 47, Para. 151.

COS (1987), COS protocol support, Version I, Corporation for Open Systems, COS/SFOR 87/0004.01, McLean, VA.

Daddis, G.E., and H.C. Lorng (1989), A taxonomy for broadband integrated switching architecture, *IEEE Communications Magazine,* Vol. 27, No.5, May, pp. 32-42.

Duran, J.M., and J. Visser (1992), International standards for intelligent networks, *IEEE Communications Magazine,* February, pp. 34-42.

Ekas, W. (1991), Photo-nic finish, *TE&M Magazine,* December, pp. 39-43.

Elgen, D.J. (1990), Narrowband and broadband ISDN CPE directions, *IEEE Communications Magazine,* April, p. 39.

Fahey, M. (1991), Study sees $4.5 billion loop market in a decade, *Lightwave Magazine,* October, pp. 6-7.

FCC (1970), Computer I Decision, 28 FCC 2d at 291.

FCC (1973), Computer I Decision, 40 FCC 2d at 293.

FCC (1977), Computer II Decision, 77 FCC 2d at 384.

FCC (1986), Computer III Decision, Mimeo numbers 86-252 and 86-253, June.

Federal Standard 1037B (1991), Glossary of Telecommunication Terms, General Services Administration, Office of Information Resources Management, Washington, DC.

Fluent, M. (1987), Pursuing the dream: Mountain Bell's Phoenix ISDN trial, *Connections,* March, p. 6.

Fraser, A.G. (1991), Design considerations for a public data network, *IEEE Communications Magazine,* October, pp. 31-35.

Gant, S. (1990), White paper to management, *Network Management,* May, p. 44.

Gold, E.M. (1992), Video conferencing closes in on the desktop, *Network Management,* January, pp. 42-46.

Gould, J.D., S.J. Boires, and C. Lewis (1991), Making usable useful productivity, *Communications of the ACM,* Vol. 34, No.1, January, p. 77.

Green, H.H. (1983), United States vs AT&T, Modified Final Judgment 552F. Supp 131, 229.

Grubb, J.L. (1991), The travelers dream come true, *IEEE Communications Magazine,* November, pp. 48-51.

Hart, J.A. R.K. Reed, and F. Bar (1992), The building of the internet, *Telecommunications Policy,* November.

Herr, T.J. (1986), The impact of technology divestiture and deregulation, International Wire and Cable Symposium, Reno, NY, November.

IEEE (1992), Special issue on gigabit networks, *Communications Magazine,* Vol. 30, No.4, April, 124 pp.

Irven, J.H., M.E. Nilson, T.H. Judd, J.F. Patterson, and Y. Shibata (1988), Multimedia information services: a laboratory study, *IEEE Communications Magazine,* June, pp. 27-44.

Jabbari, B. (1991), Common channel signaling system No. 7 for ISDN and intelligent networks, *Proc. IEEE,* Vol. 79, No.2, February, pp. 155-169.

Jacobsen, G.M. (1992), An inevitable evolution, *Telephony,* January, pp. 20-28.

Jansky, D.M., and M.C. Jeruchim (1987), *Communication Satellites in the Geostationary Orbit* (Artech House, Inc., Norwood, MA).

Jaske, R.P. (1991), Using VSATs for energy industry applications, *Telecommunications,* December, pp. 27-90.

Jennings, R.D., R.F. Linfield, and M.D. Meister (1993), Network management: a review of concepts, standards, and current status, NTIA Report 93-295, April.

Jones, S. (1991), National ISDN-1, *Telecommunications,* September, pp. 18-25.

Katz, J.E. (1990), Social aspects of telecommunications security, *IEEE Technology and Society Magazine,* June/July, pp. 16-24.

Kleinrock, L. (1985), Distributed systems, *Communications of the ACM,* Vol. 28, No. 11, November, pp. 1200-1213.

Kleinrock, L. (1991), ISDN - The path to broadband networks, *Proc. IEEE,* Vol. 79, No. 2, February, pp. 112-117.

Kleinrock, L. (1992), The latency/bandwidth tradeoff in gigabit networks, *IEEE Communications Magazine,* Vol. 30, No.4, April, pp. 36-40.

Korpi, N.A. (1991a), Evaluating frame relay - Part 1, *Telecommunications,* October, pp. 54-58.

Korpi, N.A. (1991b), Evaluating frame relay - Part 2, *Telecommunications,* November, pp. 41-46.

Krechner, K. (1991), A review of U.S. mobile communication standards, *Telecommunications,* July, pp. 43-44.

Kung, H.T. (1992), Gigabit local area networks: a systems perspective, *IEEE Communications Magazine,* Vol. 30, No. 4, April, pp. 79-89.

LaBlanc, R.E., (1992), Special Report: when competitors become allies, *TE&M Magazine,* January, p. 6.

Linfield, R.F. (1990), Telecommunications networks: services, architectures, and implementations, NTIA Report 90-210, December.

Lodge, J.H. (1991), Mobile satellite communications systems: toward global personal communications, *IEEE Communications Magazine,* November, pp. 24-30.

Lyles, J.B., and D.C. Swinehart (1992), The emerging gigabit environment and the role of local ATM, *IEEE Communications Magazine,* April, pp. 52-58.

Madrid, J., S. Sheldon, and G. Cheadle (1991), Not just another digital hybrid, *TE&M Magazine,* August, pp. 42-45.

Martin, J. (1991), There's gold in them thar networks! or searching for treasure in all the wrong places, Network Working Group, Request for Comments No. 1290, December.

Mason, C. (1991), Spectrum tops all PCS debate, *Telephony,* December, pp. 9-10.

Matheson, R.J. (in press), Spectrum conservation: adjusting to an age of plenty, NTIA, Boulder, CO.

Mayo, J.S. (1985), The evolution to universal information services, *Telephony,* March, pp. 40-46.

Mayo, J.S., and W.B. Marx, Jr. (1989), Introduction to universal information services, *AT&T Technical Journal*, March/April, pp. 2-4.

McLacklan, G. (1992), 100 Mb/s copper vote nears, *LAN Computing Magazine,* Vols. 3/4, April, pp. 1.

McQuillan, J.M. (1991), Cell relay switching, *Data Communications Magazine*, September, pp. 58-69.

Medwinter, J.E., and M.G. Taylor (1991), The reality of digital computing?, *IEEE Lightwave Communication Systems Magazine,* May, pp. 40-44.

Millar, C. (1991), All light now, *IEEE Review,* January, pp. 35-91.

Miska, P.A., M. Peshavaria, G.M. Reed, and R.J. Wilson (1992), The emerging world of wireless communications, *AT&T Technology,* Vol. 6, No. 4.

Mayers, W. (1991), The drive to the year 2000, *IEEE Micro,* February, pp. 10-74.

Modarressi, A.R., and R.A. Skoog (1990), Signaling system No. 7: a tutorial, *IEEE Communications Magazine,* July, p. 34.

Mushin, L. (1991), Social responsibilities of the telecommunications business, *IEEE Technology and Society Magazine,* Summer, pp. 29-30.

Noam, E. (1988), The future of the public network: from star to the matrix, *Telecommunications*, March, pp. 58-65.

National Telecommunications and Information Administration (1991), Telecommunications in the age of information, NTIA Infrastructure Report, Special Publication 91-26, U.S. Department of Commerce.

Pelton, J.N. (1988), ISDN: satellites versus cable, *Telecommunications,* June, pp. 35-80.

Rappaport, T.S. (1991), The wireless revolution, *IEEE Communications Magazine,* November, pp. 52-65.

Robinson, C.A. (1992), Digital optical science bears smart pocket communicator, *Signal Magazine,* June, pp. 28-36.

Robrock, R.B. (1991), The intelligent network - changing the face of telecommunications, *Proc. IEEE,* Vol. 79, No. 1, January, pp. 7-20.

Rosner, R. (1990), Structure wideband communications: looking at the future, *Journal of Network Management,* Spring, pp. 16-21.

Ryan, R.J. (1991), Back to the future, *Telephony,* January, pp. 30-32.

Schilling, D.L., L.B. Milstern, R.L. Pickholtz, M. Mullback, and F. Miller (1991), Spread spectrum for commercial applications, *IEEE Communications Magazine,* April, pp. 66-79.

Shumate, P.W. (1989), Optical fibers reach into homes, *IEEE Spectrum,* February, pp. 43-47.

Smith, R. (1992), Cautious-not complacent, *TE&M Magazine,* January 15, pp. 31-39.

Stallings, W. (1989), Internetworking: a guide for the perplexed, *Telecommunications,* September, pp. 25-30.

Stallings, W. (1990), CCITT standards foreshadow broadband ISDN, *Telecommunications,* March, pp. 29-41.

Stallings, W. (1992), The role of SONET in the development of broadband ISDN, *Telecommunications,* April, pp. 21-24.

Sue, M.K. (1990), A satellite-based personal communications system for the 21st century, Proc. of the Second International Mobile Satellite Conference, Ottawa, Canada, June.

Tamarin, C. (1988), Telecommunications technology applications and standards, *Telecommunications Policy,* December, pp. 323-331.

Taylor, S.A. (1989), Plain talk about frame relay, *Network Management,* January, pp. 55-60.

Timms, T. (1989), Broadband communications: the commercial impact, *IEEE Networks Magazine,* July, pp. 10-15.

Vanston, L.K., R.C. Ling, and R.S. Wolf (1989), How fast is new technology coming? *Telephony,* September, pp. 49-52.

Vickers, R., and T. Vilmansen (1987), The evolution of telecommunications technology, *IEEE Communications Magazine,* July, pp. 6-18.

Viterbi, A. (1991), Wireless digital communication: a view based on three lessons learned, *IEEE Communications Magazine,* September pp. 33-36.

Wallace, R. (1992), AT&T lays plans for broadband SDN, *Network World,* March 23, pp. 1 and 44.

Warr, M. (1991), The pursuit of photons, *Telephony,* December 23, p. 22.

Weissberger, A.J. (1991a), Comparing alternative fast-packet network technologies, Part I, *Telecommunications*, September, pp. 58-65.

Weissberger, A.J. (1991b), Comparing alternative fast-packet network technologies, Part II, *Telecommunications,* October, pp. 53-69.

Wright, D.L., J.B. Balombin, and P.Y. Shon (1990), Advanced communication technology satellite (ACTS) and potential system applications, *Proc. IEEE,* Vol. 78, No.7, July, pp. 1165-1175.