PRESENT STATUS AND FUTURE TRENDS IN TELECOMMUNICATIONS

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The purpose here is to define the present and examine the future of telecommunications over the next ten years. Emerging and anticipated products and services are viewed from both a technical and a social impact perspective. Systems including those providing voice, data, images, video, and integrated services are investigated in terms of technical feasibility, standardization, and global applications. Networks and concepts discussed include; LANs, MANs, WANs, wireless networks, switched multimegabit data service (SMDS), ISDN, B-ISDN, asynchronous transfer mode (ATM), and synchronous optical networks (SONETs). The information gleaned from this study is summarized in a series of tables and charts that characterize the critical parameters of various switching and transmission systems and concepts as well as the network architectures. The major architectural concepts and systems expected to have critical impact on the future telecommunications infrastructure are presented along with important issues expected to affect their evolution.

1. INTRODUCTION

"One thing about the past, it's likely to last!"

Ogden Nash

The telecommunications industry in the United States is growing approximately 12% per year. Its contribution to the Gross National Product (GNP) by the year 2000 is expected to be greater than 20%. Today this $335 billion dollar industry is approximately 6% of the GNP. Computers and computing services are approximately 10% of the GNP. The U.S. represents approximately one third of the world market in telecommunications.

This report emphasizes telecommunications and what one might expect this important technical area will look like ten years from now. Recognize, however, that Ogden Nash's quotation above will continue to apply. The telecommunications infrastructure even today still uses many analog mechanical switches, plain old telephone service (POTS), teletypewriters, and

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1.2kb/s data modems. In looking at future trends, as is done here, it should always be kept in mind that the imbedded plant has lots of inertia and replacing the old with the new is a long process. The report begins by examining the past and the current posture of telecommunications.

1.1 Yesterday and Today

Twenty-five years ago there were no fiber optics, no microelectronics, no video recorders, no compact discs, and no cellular telephones. The public switched telephone network was metallic with analog switches and copper transmission facilities. Systems and services like FM stereo radio, color TV, cellular radio, T-carrier, audio cassettes, cable TV, and communication satellites were just beginning to emerge. The telephone industry, dominated by AT&T and Western Electric, was extensively regulated. There were no public packet switched networks, no stored program controlled switching, no personal computers (PCs). The fields of computer based operating systems, distributed processing, and cellular telephones were still to come.

Today, nearly everyone has a PC in the workplace and two FM radios at home. Fiber optical transmission, digital switching, and communications satellites are taken for granted. Local area networks (LANs) interconnect a multitude of personal computers. Each desktop PC has as much raw processing power as a fairly large main-frame computer had just ten years ago. Fiber optical transmission facilities proliferate. Network evolution continues to migrate toward information packetization, packet switching, and digital transmission with more and more features and functions under customer control. Today's distributed computing networks handle bursty, high-speed, high-volume traffic with low delay.

In the United States, deregulation and procompetitive initiatives have superseded many of the traditional monopolistic practices. An increased reliance on a market economy has led to greater efficiencies in networking and innovative products are providing higher standards of living.

Voice and data communication growth has expanded globally with some 700 million telephone terminals and data terminals in existence worldwide (Brule and Ebert, 1990). Figure 1-1 indicates the phenomenal growth in worldwide voice and data terminals over the past 15 years.

A similar increase in local area networks (LANs) to interconnect these terminals, metropolitan area networks (MANs) to interconnect LANs, and wide area networks (WANs) are

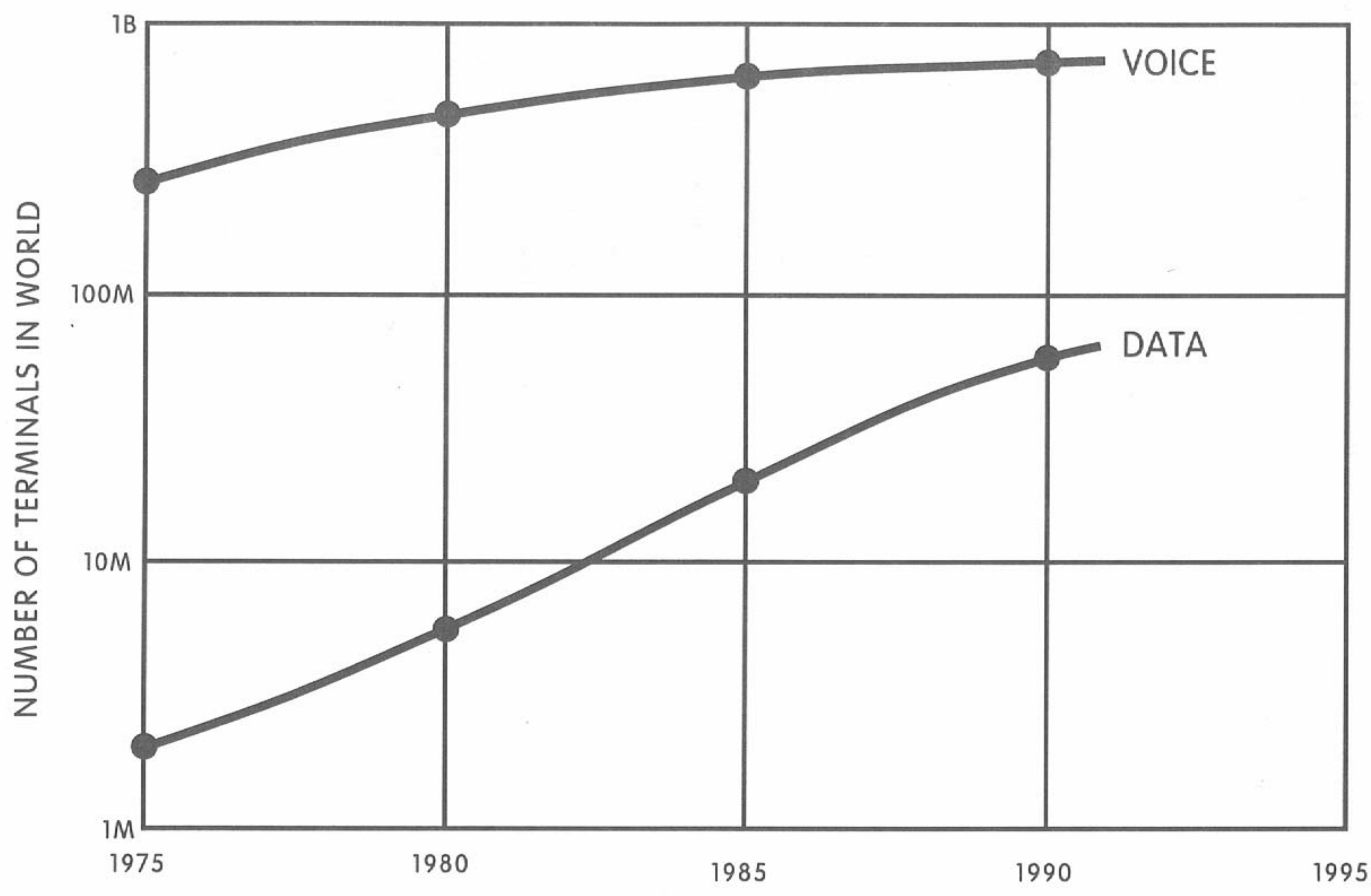

Figure 1-1. Growth of voice and data communications (Elgen, 1990).

common place. Public Switched Telephone Networks (PSTN), Public Data Networks (PDNs), as well as LANs, MANs, and WANs are rapidly changing technologies that are discussed in Section 7 (The Evolution of Networks).

The phenomenal growth of LANs, MANs, and WANs is causing profound changes in the way business is conducted. Information no longer must reside in some centralized computer but can be distributed throughout the network and in the desktop PC or multimedia terminal. Distributed processing appears to be the wave of the future. No longer can one large computer handle the complex problems of today, but many large and small computers interconnected by telecommunication networks can perform the necessary parallel processing functions.

1.2 Tomorrow

Future networks are being envisioned that will boost productivity, enhance services, and enrich our lives by extending social interaction to many diverse cultures. As Mayo and Marx (1989) have pointed out, these information networks of the future could provide everyone, anywhere, and at any time access to voice, data, images, and video in any combination by plugging a terminal into a universal port. Future wireless systems can even eliminate the plug. The aim is to educate, entertain, exchange ideas, and manipulate data and create information around the globe. It is apparent that the world is entering a new era where extraordinary advances in technology are leading us into the information age where there will be virtually no limit to the amount or type of information that can be accessed or distributed.

This report is concerned with tomorrow's networks. What directions will future network architectures take? What new features, functions, services can be expected? How will traffic characteristics, rates, delays, and requirements change? What will be integrated, digitized, packetized, privatized, or standardized? What are the new technologies currently on the horizon that may be implemented? And what will be their impact?

Future service provisioning will be determined by a number of technical factors, as well as the interaction of several major forces including market forces, government policies, and global influences. Network architectures will be influenced by what customers want and what they are willing to pay, by what and when the advanced technologies are available, and by what regulatory constraints are in place, expected, or removed.

A major force moving the U.S. into this information age has been the merging of the telecommunications and computer industries under a generally favorable deregulatory environment. Computers are the information processing systems while telecommunications provides means for information dissemination. Computers are also the brains of the networks, providing control and management functions.

This computer and telecommunications merger raises a number of jurisdiction issues, both national and international. Standards is one such jurisdictional issue. National interests may sometimes conflict with global interests. World markets must be taken into account when considering what standards should be adopted in the future.

Other factors that will influence the network architectures of the future are indicated in Figure 1-2. In addition to national and international standards, factors such as technology, government policy, and users' needs are discussed in detail in subsequent sections of this report.

The evolutionary directions that future network architectures may take or are taking are depicted in Figure 1-3. In each case, the path to the future begins with an existing structure. This is an important point to remember throughout this report. Seldom does a new creative concept displace or replace the existing structure instantaneously. Rather, each concept evolves over time as economics and demand allows. Embedded facilities are gradually replaced with new technologies (e.g., fiber replacing copper for long-haul transmission, and digital replacing analog for switching and transmission) over periods of time and depending on cost benefits and amortization schedules. These changes result from government regulations, new technologies, and the market place, with technology being the major agent of change. Whatever induces the change, the result is that the network infrastructure is seldom static but always a mix of the old with the new. This is demonstrated in Figure 1-4, showing the level of deployment of major long-haul switching technologies over the years. (The asynchronous transfer mode (ATM) is a packetized multiplexing scheme discussed in Section 3.4 of this report.) This constantly changing structure may be expected to continue in almost every aspect of the network. Other examples are given throughout this report.

The fact that networks of the future must continue to coexist with present networks for some time adds complexity to the standards-making process, to interoperability, and to the design of the telecommunication switching, transmission, and control facilities.

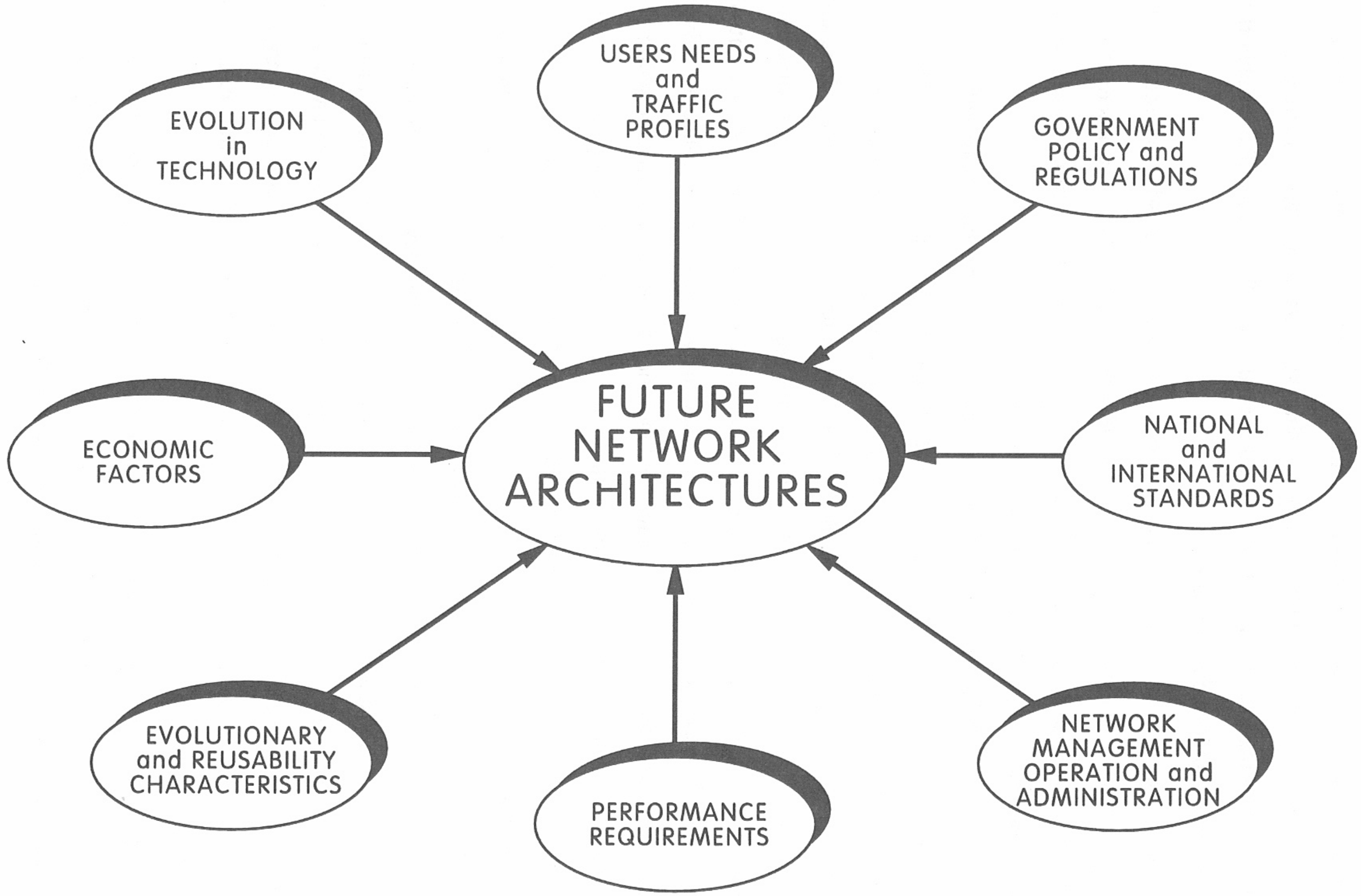

Figure 1-2. Factors influencing architectural definition.

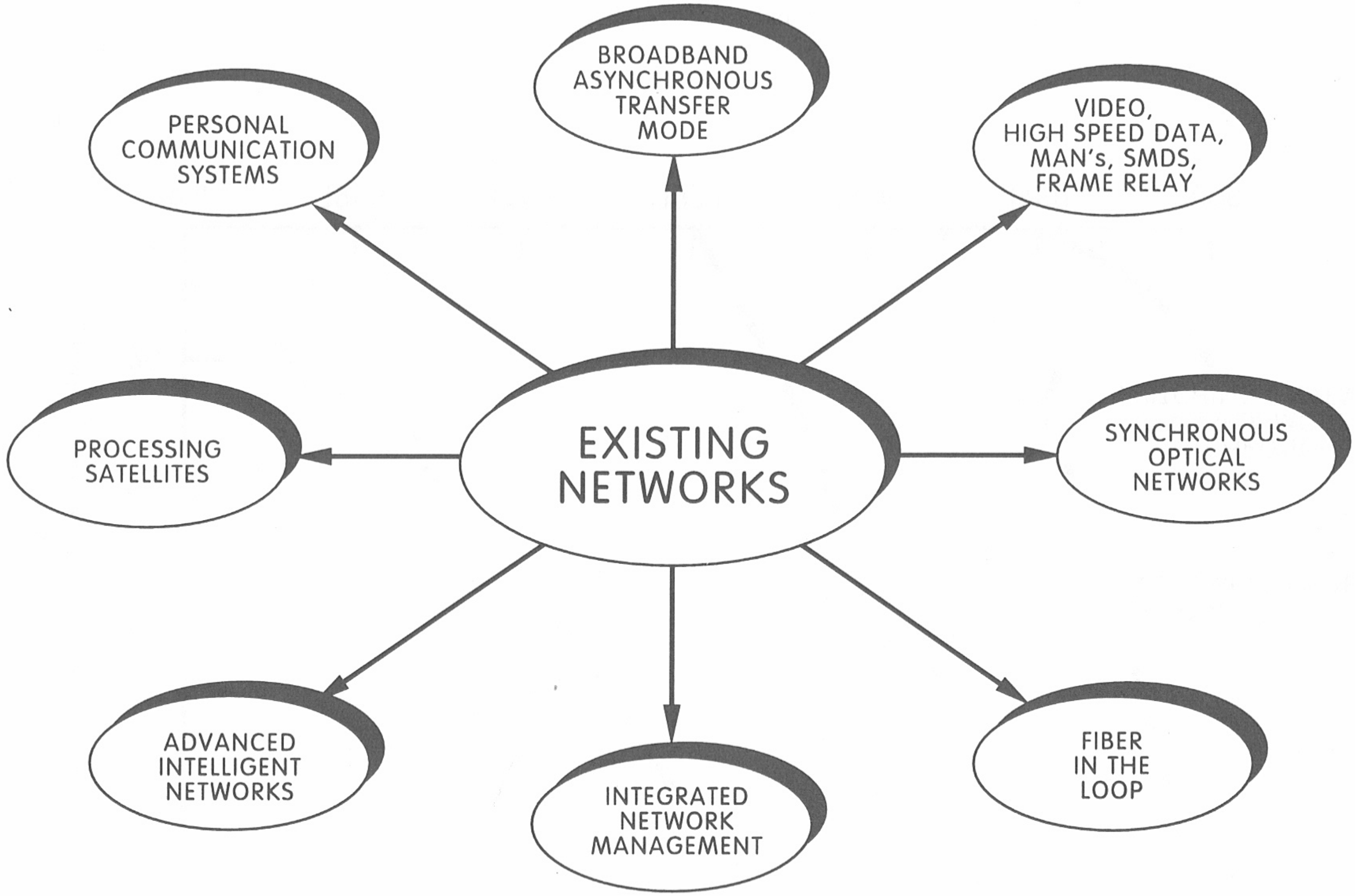

Figure 1-3. Evolutionary directions in telecommunications.

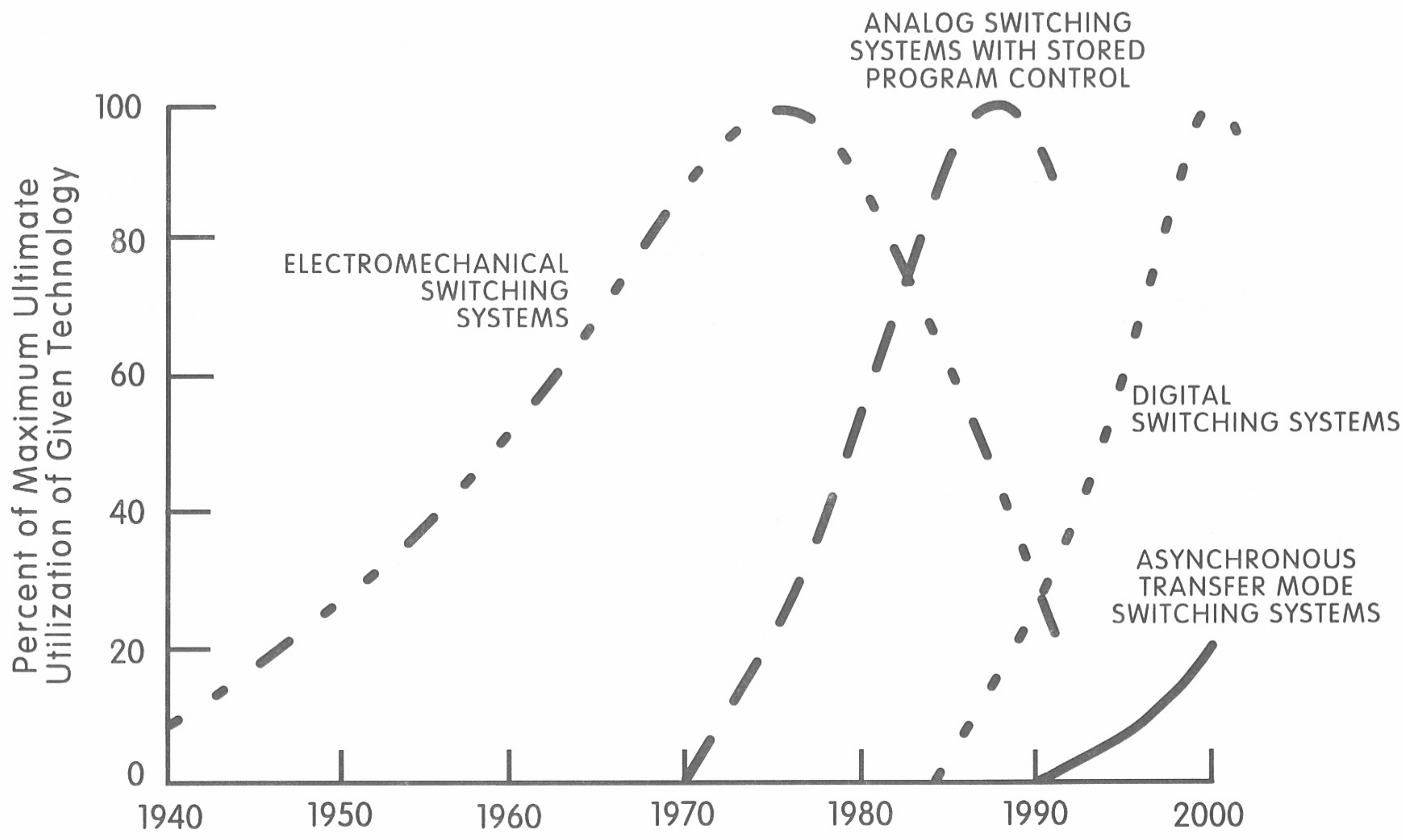

Figure 1-4. Switch technology deployment (from Katz, 1990).

1.3 Report Synopsis

The topics of Sections 2 through 9 of this report are interrelated in a complex way, as shown in Figure 1-5. This is because numerous factors and forces influence the evolving telecommunications infrastructure. For example, information is a key economic resource and our society is becoming increasingly involved in information services. Information has one distinctive character defined by its "half life," the time for a given pattern of information to lose 50% of its value or meaning. Thus, the use of telecommunications to disseminate information fast and accurately lies at the heart of social activity. This coming information age is discussed in Section 2. As the United States moves into a knowledge-based, service-oriented economy, the telecommunications infrastructure becomes an important factor for economic development. Some important new technologies impacting this infrastructure are described in Section 3. The directions it takes in the future depend on several forcing functions. These include government regulations and standards described in Section 4, along with market forces and users needs as covered in Section 5. All of these factors—technology, government policy, market forces, and users needs—combine to generate new products, systems, and services as described in Section 6. These in turn have a major affect on the actual network infrastructures as described in Section 7. The information contained in Sections 2 through 7 serves as the basis for the summary Section 8 concerning major trends and issues. Finally, Section 9 closes with conclusions and recommendations. A reference list is provided in Section 10.

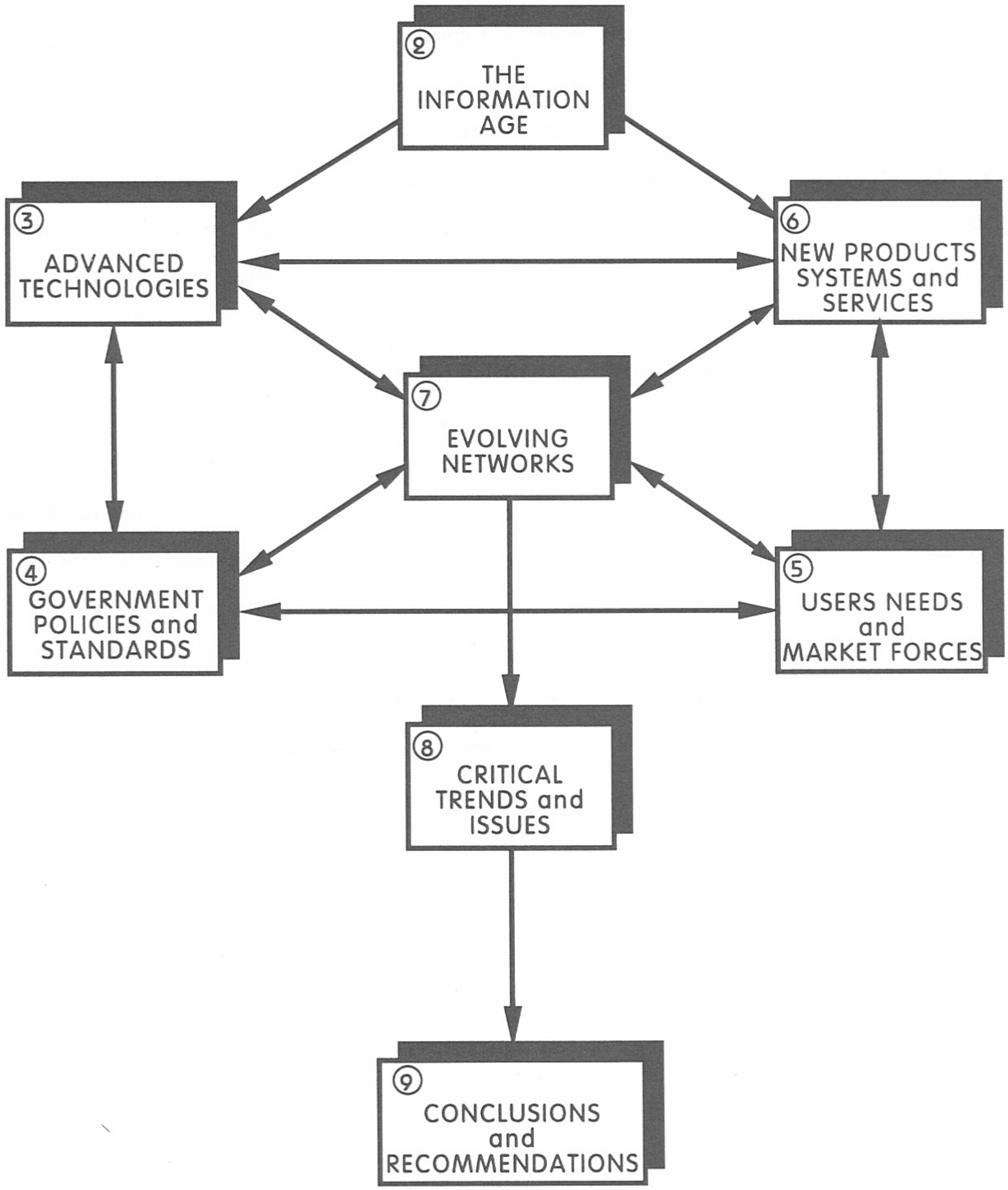

Figure 1-5. Interrelatedness of topics covered in this report.

2. THE COMING OF THE INFORMATION AGE

"The opportunities presented by universal information services are stunning. While the telephone extended the reach of the human voice, universal information services promise in the decades ahead to extend the reach and capability of the human mind. "

C. L. Brown, Chairman of AT&T, 1985

In order to assess the future course of telecommunications in the U.S. and to develop future architectural concepts, it is useful to examine the critical events that have taken place in the past. Table 2-1 indicates a division of the evolution of telecommunications into four epochs --the age of creation (1850-1900), the age of ubiquity (1900-1950), the age of diversity (1950-2000), and the age of information exploration (2000-2050). The age of creation is when the critical underlying inventions occurred (e.g., the telegraph, the telephone, and the wireless). Near the end of this period, the Bell patents expired and competition in telecommunications really began.

In the early 1900's, a universal service was the major goal. Over 90% of American households had radios by 1950 and telephones by 1970. The Communications Act of 1934 that created the FCC was a driving force. Until mid-century, the FCC regulated communication service on the assumption that it could best serve the public as a monopoly. Universal service would be provided by rate averaging and affordable service would result from the economies of scale.

Around 1960, the government began to consciously follow a different policy--that of promoting competition in the industry. Milestones in this era include the Carterphone decision in 1968 (expanding the terminal equipment market), MCI decision in 1969 (resulting in a specialized carrier industry), the Department of Justice's antitrust suit in 1974 (leading to divestiture of the Bell Operating Companies (BOCs) in 1984), and Computer Inquiries I, II, and III (to define jurisdictional responsibilities as the field of communications and computers converged).

The complete evolutionary picture must include an age of information exploration covering the period 2000-2050. This period applies the tremendous information base that is available to everyone in order to expand knowledge. Universal service and information access will be the foundation of this new information age.

Table 2-1. Periods of Telecommunications Developments

EVOLUTIONARY AGE	YEAR	TECHNOLOGY	POLICY
AGE OF CREATION	1850	1842 - Telegraph 1876 - Telephone 1886 - Wireless Telegraph	1893 - Bell patents expire (Start of competition)
AGE OF UBIQUITY	1900	1921 - Mobile Phone	1907 - AT&T refuses interconnection 1910 - Mann-Elkins Act (ICC Regulation) 1913 - Kingsbury Commitment (Interconnection Required) 1927 - Radio Act 1934 - Communications Act 1949 - AT&T refuses interconnection 1949 - AT&T antitrust suit
AGE OF DIVERSITY	1950	1950 - Microwaves 1954 - Transistor 1955 - CATV 1957 - Satellites 1964 - Carterphone 1970 - Fiber Optics 1971 - Microelectronics 1988 - ISDN 1994 - PCS Cell Relay SONET 1994 - Intelligent Network 1	1956 - Consent Decree 1962 - All Channel TV Receiver Act 1966 - Computer Inquiry I 1968 - Equipment Interconnection 1969 - MCI Microwave Approved 1970 - Satellite Policy 1974 - AT&T Antitrust Suit 1984 - BOC Divestiture 1988 - ONA Plans
AGE OF INFORMATION EXPLORATION	2000	• Advanced Intelligent Networks (AIN) • B-ISDN via ATM & SONET • Integrated workstations (voice, images, data, video) • Information centers • Distributed processing • Wireless access • HDTV • Photonic Switching • Networks of Networks	• Further Deregulation • ONA • Global Standardization • OSI
	2050	?	?

Developments in the field of information technology have already paved the way for a new age when the collection, generation, and dissemination of information is paramount. New applications of information services pervade all areas of society from offices and manufacturing plants to schools and homes. And these applications are constantly increasing. Computers are becoming more and more a pervasive influence in our daily life. The origination, storage, manipulation, and distribution of information is critical to the success of any modern business venture. Distribution has caused a need for expanding network capacity resulting in a tremendous bandwidth explosion.

This so called "information age" is actually upon us now, but its full potential has yet to be realized because people are in the midst of changing the very foundations upon which this new age is based--namely telecommunications. The power to create and manipulate information is critical, but information exchange at a distance, i.e., telecommunications, provides the means to make it accessible to all. New services that were unthinkable just a few years ago, like voice messaging, cordless telephones, mobile systems, imagery, high definition TV, and more, are now available to users. New features and functions continue to be added constantly. Changes in the telecommunications infrastructure today are so dramatic that it is nearly impossible to provide a true course for the future. One can only look at where the world is now and where its wants to go.

People have just embarked on the information age and have only caught a glimpse of its ultimate potential. According to NTIA (1991) "The power to create and manipulate information is critical to capturing the promise of the information age, so also is the ability to move that information from point to point. This latter capability is, of course, provided by telecommunications, and it is why the U.S. telecommunication infrastructure is commonly referred to as the "highway" of the information age." This "highway" is expected to play a critical role in improving domestic economy in the U.S., the welfare of its citizens, and their ability to be competitive in the future marketplace of the world.

More will be said about the major features and functions of the network infrastructure for future decades in the following Sections 3 through 7. These trends and issues are then summarized in Section 8.