

Growing Vulnerability of the Public Switched Networks: Implications for National Security Emergency Preparedness

A Report Prepared by the

Committee on Review of Switching, Synchronization and Network Control
in National Security Telecommunications

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Preface

This report concludes a multifaceted study conducted by the National Research Council's (NRC) Committee on Review of Switching, Synchronization and Network Control in National Security Telecommunications. The committee, established at the request of the Manager, National Communications System (NCS), had its first meeting in November 1986. Phase I of the committee's work involved evaluating the NCS Nationwide Emergency Telecommunications Service (NETS), which is one of three programs to improve survivability in national security emergency preparedness (NSEP) telecommunications capabilities mandated by presidential order in National Security Decision Directive NSDD-97. NETS, the largest in scope of the programs, is intended to provide survivable switched voice and data communications. The committee worked on an accelerated schedule during this phase, holding meetings every month. They concluded their work with a formal briefing to the NCS Manager and his staff in April 1987. The committee's interim report, *Nationwide Emergency Telecommunications Service for National Security Telecommunications*, was published in August 1987 and fulfilled Task 1 of the NCS study requirements.

The committee reconvened in September 1987 to address the remaining tasks of reviewing and assessing synchronization, switching, and network

control of the public switched network (PSN). The committee found that existing synchronization capabilities are likely

to be adequate to support NSEP telecommunications. An in-depth discussion of Issues in Digital Network Time and Frequency Synchronization is included in this report as [Appendix B](#) and fulfills Task 2 of the NCS study requirements. For Task 3 the committee was to review the inventory of switching installations for survivability of switching and control functions after nuclear attack, considering redundancy and alternative connectivity (see [Appendix A](#) for the complete Task 3 statement). However, for this task it was implicitly necessary to look to the future evolution of the network rather than merely to examine the current status. The future network is likely to be different from that of today because of changes in regulation, technology, competition, and customer demand. Accordingly, with the concurrence of the Deputy Manager of NCS, this report considers how the network may evolve by the year 2000, the drivers influencing its architecture and topology, and the vulnerabilities it may have.

The committee considered the implications of two opposing trends in network development: (1) a trend, driven by competition, toward the provision of many networks and (2) a trend, driven by economic forces, toward decreasing interoperability and restorability in emergencies.

The intended audience for this report is the NCS Manager and those who provide oversight to him. They include policy-level officials of the Office of the Secretary of Defense, the National Security Council, the Office of Science and Technology Policy, the Office of Management and Budget, and the Congress. The report is also addressed to the providers of public and private telecommunications facilities, to the extent that NSEP telecommunications ultimately depends on their systems.

The committee appreciates the strong support and personal involvement of the NCS staff, especially Benham E. Morriss, Deputy Manager. We are also grateful to all who provided information and insights as to where the networks are likely to be in the year 2000. These estimates were highly

valuable in helping the committee understand network trends and their NSEP implications.

The committee was ably supported by the NRC staff and the Director of the Board on Telecommunications and Computer Applications, Dr. John M. Richardson. In particular the committee thanks Wayne G. Kay, Consultant and Study Director, for his personal and professional commitment of excellence to the task. We also praise Karen Laughlin, of the staff, for her outstanding administrative effectiveness on our behalf. We also thank Lois A. Leak and Linda

Joyner, also of the staff, for their invaluable assistance. In addition, I want personally to thank my assistant, John Wohlstetter, for his able contributions. Finally, my personal thanks to each member of the committee for his time, perseverance, and dedication to this important study.

John C. McDonald

Chairman

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Public Switched Networks in the Year 2000

The public switched networks (PSN) are rapidly being transformed by the confluence of changing regulation, technology, competition, and customer demand. The committee's earlier report (National Research Council, 1987) defined the public switched networks as a national "network of networks" that are interconnected and provide voice and data transmission throughout the United States. (There are numerous private voice and data networks that are linked to the public networks but are not always interoperable with them.)

The American Telephone and Telegraph Company (AT&T) divestiture and the introduction of competition into discrete equipment and transmission markets coincided with the advent of economically available fiber optic transmission, common channel signaling, and digital switching techniques. Together, these factors have stimulated customer demand for new services that are permissible by regulation and possible through technology. These forces will continue to dominate network evolution. Nowhere on the horizon do there exist comparable counterforces to reverse that evolution; although its specifics are not all predictable, its general direction is evident.

Of course, all these influences interact. Regulation was reduced deliberately to stimulate competition, promote technological innovation, and lower prices so as to increase customer demand. Technology is an impor-

tant basis of competition, and it creates demand as well by making services both possible and affordable. Competition spurs

new technology and expands demand on the basis of improved product and price. Ideally, revenues from increased demand are fed back into research and development to create new technology.

This chapter presents an overview of the probable evolution of the public networks to the year 2000. Separate sections are devoted to the impacts of regulation, technology, competition, and customer demand. These topics are then addressed separately in greater detail in another chapter, which supports the committee's conclusions and presents associated recommendations.

REGULATION

By the year 2000, most of the existing legal and regulatory barriers to entry, which chiefly restrict exchange carriers, will probably have been removed. Only local exchange basic voice service for the small customer is likely to remain a monopoly service in any significant measure.

Competition will reach the large-customer market for local exchange carriage, and open entry will extend into video markets as well as those of voice and data.

Thus, the fundamental regulatory principles governing the public networks through the year 2000 will remain the same as today. Regulators will permit open entry where market conditions appear capable of supporting competition. They will press for timely deployment of an Open Network Architecture (ONA) to afford all competitors equal access to the customer. Carriers will be allowed increasingly flexible tariffs to price competitive services closer to cost. Rate-of-return regulation may largely be phased out. Ultimately, there will be a merging of the regulatory treatment for voice, data, and video carriage as technology permits installation of enough network traffic capacity to accommodate multiple providers on equal terms.

TECHNOLOGY

Trends in technology can broadly be grouped into transmission modes, switching, and network technologies.

Transmission Modes

The dominant force in telecommunications transmission throughout the 1990s will be the widespread deployment of optical fiber. By the mid-1990s virtually all the trunk portions of the public networks will be fiber; but fiber will be introduced only gradually into the local

loop (the feeder and distribution portions of the network). Although competition on trunk routes will add some network route redundancy, the lack of widespread competition on feeder and distribution routes and the limited availability of access tandem switches (see below) will operate to limit the benefits of trunk route diversity.

Historically, transmission technology deployment in the public networks has been diverse, that is, copper pairs, coaxial cable, microwave radio, satellites, and even waveguide. The current trend is toward consolidation of network transmission assets into optical fiber. Fiber routes will “prune” the network by aggregating much greater traffic loads in fewer lines and routes. Another essential factor will encourage concentration of fiber traffic in physically contiguous geographic routes: the high cost of obtaining new rights-of-way.

Thus, the dominance of fiber in long haul network transmission means that the 1990s public switched network transmission will become increasingly reliant on the survivability of a single transmission mode, namely, fiber. Dependence on any single transmission mode tends to increase network vulnerability to damage.

Radio will become the transmission medium of choice in areas where emplacement of fiber is economically prohibitive (Stanley, 1988). If they are

deployed widely, digital terrestrial microwave, cellular mobile radio, and portable personal communication systems will become significant alternative transmission modes. However, some number of terrestrial microwave routes track closely the rights-of-way used for coaxial and fiber cable routes. Such close physical proximity of alternate transmission mode routes limits the gain in network survivability that physical route diversity would otherwise provide within the public networks.

Satellites will be supplanted by optical fiber for voice service. However, satellites will remain the medium of choice for broadcasting, at least until fiber reaches most residences, sometime in the twenty-first century. This migration to fiber is largely due to its high quality, exceptional bandwidth potential, and freedom from the delay characteristics of satellite transmission, combined with its economic advantages for high-density communications paths. In addition, the cost per circuit mile favors the optical fiber mode. Other niche applications for satellites will include remote location, mobile access, navigation, and point-to-multipoint data. A potentially significant augmentation of network redundancy is very small aperture satellite (VSAT) technology, which can provide physically separate transmission backup. While cellular radio adds voice redundancy,

VSATs provide data transmission redundancy, with some projected to provide data, voice, and video capabilities by the year 2000.

Switching

Evolution in central switching is being driven by several conflicting trends. Very large capacity wire centers (for example, Hinsdale, Illinois) have been built to house "super switches," which act as massive connectivity nodes and control hubs for remote terminals. These hubs will control switching for substantial amounts of traffic. At the lower network echelons, more and more remote switches are being deployed in rural areas to aggregate traffic from small communities into the hub.

There is a second simultaneous trend and countertrend in switching. Within the public networks, network intelligence is being concentrated into fewer, centralized software databases, connected by signal transfer points (STPs). Distributed customer-premises switching will also grow. The public networks in the year 2000 will rely on both central-office and premises-based network architectures. To the extent that premises-based switching prevails, alternating current (AC) power generation will become the responsibility of the customer rather than the network provider. As a result, network reliability will no longer be based only on physical redundancy and diversity, but will also depend on the reliability of the electric utilities as the major source of electric power.

Switching technology will be more service specific by the year 2000. For voice transmission, electromechanical switching will be almost completely removed from the local and tandem portions of the public networks with digital time division (DTD) switching taking its place. About 50 percent of the local offices will also be on DTD. Dynamic nonhierarchical routing (DNHR) will be common. For data, switching will be by virtual circuits or packet networks. As broadband services are introduced, a new era of space division switching will be opened. Eventually, though not likely by 2000, optical or photonic switching may be employed with video capabilities.

Network Technologies

Nationwide internetworking will be complicated by the proliferation of private networks. Software-defined virtual private networks will interconnect fully with the public networks. However, physically

separate private links, especially those dedicated to data carriage, will not always prove fully interoperable with the PSN. With appropriate National Communications System planning those packet networks that are interoperable with the public networks could provide robust signaling and routing augmentation.

Signaling

By the mid-1990s, most interswitch signaling will be by common channel signaling (CCS) with Signaling System No. 7 (SS7) as the method of choice. SS7 is fundamental to the integrated services digital network (ISDN) concept, and SS7 software will be programmed to facilitate customer control of network services and to enhance network flexibility via more dynamic nonhierarchical routing.

Network Control

Software is already driving the evolution of network control. The replacement of hardware-based network control with software-driven network intelligence has opened the network and given the user more service options. Coupled with control intelligence owned by the customer and located on the customer's premises, network software will permit the transfer of effective control over many network service-oriented functions from the network provider to the customer. Remote databases will be accessible to customers who wish to reconfigure their networks. Software-defined virtual networks, already introduced for large customers, will be available for many medium and small customers.

Network Standards

Competition in terminal equipment, the AT&T divestiture, and regulatory rules mandating equal network access to providers of information services have led to a new need for effective network standards. While standards issues are being addressed today in government-industry forums, the trends at this writing augur for less ubiquity. There is a growing proliferation of options within given standards, and standards are less likely in today's environment to win industry adoption during the market lifetime of a product or service.

Prior to divestiture, the Bell System, for all practical purposes, set industry standards. Today, network standards are more a product of negotiation among competitors, both large and small, in industry

forums. As a result, telephone network standards could more and more come to resemble the computer industry's "protocol zoo," that is, a plethora of piecemeal network configurations.

Further, the abundance of options produced by individual manufacturers suggests that there is less guarantee, within a given standard, that their products will interface with other products designed to the same standards. The committee notes that multiple options within standards have contributed to nullifying interoperability goals. While this could be true to some extent, more recent standards, as, for example, for ISDNs, are meant to be fully implemented or designed to allow automatic adaption to a variety of switches or subsets. The options allow them to be tailored, on the user side, for various applications and equipment, thereby increasing their acceptability. The objective of newer standards is to be applicable to hundreds of millions of terminals so that large-scale integrated circuits, incorporating all options, are practiced.

Although industry forums have made progress in setting standards, the process of developing them has become so lengthy that, as indicated above, adoption of a final standard has sometimes occurred only after the product is no longer state of the art in the marketplace.

COMPETITION

By the mid-1980s, most domestic telecommunications markets had been opened to competition. Competition drives suppliers of equipment and services to meet customer demand as efficiently (that is, as economically) as possible. The driving forces behind the evolution of competitive telecommunications markets have been business and government demand for data transmission and data processing services. While data transmission represents roughly 20 percent of the total demand for telecommunications service, revenues from data are expected to increase more than for basic voice transmission. Hence market evolution will be determined largely by data demand.

The effects of competition are visible in many areas of telecommunications. Local exchange carriers compete with interexchange carriers from business and government networks that partially or totally bypass the pub-

lic networks. Customized tariffs are becoming a major tool for attracting business customers. Bypass “overbuild” networks give customers the means to manage their network services (Jackson, 1988). Exchange carrier network services lagged in the early 1980s because of regulatory constraints on the manner in which

carriers could employ centralized network intelligence to offer both competitive and basic services, but these regulatory constraints have been relaxed.

Competition in cellular mobile radio has stimulated the growth of cellular “super systems” centered in metropolitan hubs and ringed by smaller satellite communities. Vigorous demand for cellular service, coupled with limited spectrum availability, is driving cellular systems toward digital cellular technology, which will substantially increase channel capacity. Cellular providers are dominated by larger entities, as economies of scale enable larger companies to build cellular mobile switching nodes more efficiently.

Video services competition is increasing. Already, video service is more ubiquitous than basic telephone service: About 98 percent of U.S. households have broadcast television, while only 93 percent have telephone service (Solomon, 1988). Cable television is now the principal agent of video signal distribution into the U.S. home: Over 50 percent of domestic households receive their television signals via coaxial cable, and over 80 percent have access to cable service. Another potential major pipeline for video transmission into the home is via telephone line; currently, federal law limits telephone companies to offering cable service outside their franchise service areas (except for narrow exceptions applicable to sparsely populated areas).

Already, the Federal Communications Commission is weighing whether to recommend to Congress that telephone companies be allowed to provide video service inside their serving areas. By the year 2000 it is likely that telephone companies will be permitted to offer video dial tone; whether they will also be allowed to offer program content is unclear at this writing. A major factor in making telephone company entry into video likely is that

telephone companies are leaders in the installation of optical fiber, a medium whose unmatched signal quality makes it superbly suited to transmission of improved definition and high-definition television formats.

The impact of competition has been most evident in the extraordinary proliferation of different brands of customer-premises equipment (CPE). The great variety of equipment available has spurred customizing of business services. Also, premises-based signaling has driven value-added data network applications.

Today's network is also a repository for hundreds of information services, accessible via telephone line linkage to remote databases. Such services require that the customer possess intelligent CPE or a

personal computer in order to engage in an interactive data dialogue with the databases.

Competition will spur deployment of new innovative customized services. Favored applications will include network control and management, business database management, and customized consumer services, for example, custom local area signaling services, which allow residential customers to obtain centrally delivered network services hitherto economically available only to business customers (Wallace, 1988).

On balance, it appears that competition will have a detrimental impact on national security emergency preparedness (NSEP). While service offerings have proliferated, network interoperability has been diminished by widespread deployment of customized nonstandard network architectures. Many private data networks, both circuit and packet switched, are not fully interoperable with the public switched networks. Thus, as sources of potential network redundancy they are extremely limited, unless linked to the public networks by gateway architectures. Further, reliance on centralized databases to provide network services economically makes the network vulnerable to users who access them to damage or destroy them (Atkinson, 1988). Such harmful access capability is especially worrisome because the network is becoming increasingly dependent on software-based

services. Cellular mobile radio, however, has potentially significant capabilities for public network redundancy as cellular systems are deployed in smaller metropolitan and rural markets.

CUSTOMER DEMAND

Numerous publicly available sources have exhaustively documented the variety of service offerings that are expected to become widely available by the year 2000—indeed, many of these services have already been introduced into small market segments (Huber, 1987). In addition to basic voice service, customers will have economic access to hundreds of data services and enhanced voice storage and retrieval services. The data services will include both transport and access to information sources. Advanced video services, such as improved and high-definition television and high-resolution facsimile, will also be used by market leaders by the year 2000.

The customer demand driving the introduction of these services is influencing the public networks in several critical ways. First, the nature of user reliance on the network is undergoing fundamental

change. Historically, users viewed the public networks almost exclusively as a means of voice communication, but business users rely increasingly on the public networks as links to connect a wide variety of computers that are becoming vital to their business operations.

Thus, while today's network usage is still predominantly voice service, in the year 2000 usage will be driven primarily by the data services required to function in the information age. Among the data services that businesses rely on are remote database access, real-time links between facilities, and financial transaction capability. For such users, loss of transmission links means serious economic loss from the disruption of their business affairs.

Video usage will be greater than today. Eventually telephone companies will enter the video marketplace, but residential penetration will be modest at best by the year 2000. (Ultimately, when video is ubiquitous, its revenues

may dominate the home marketplace, and residential demand will become video driven as well as voice driven.)

A second feature of the evolving public networks is that more of the intelligence that delivers network services to the customer will reside in equipment located on the customer's premises. This is particularly true for business users. Residential users, unless they have personal computers, will continue to rely on centralized network intelligence. Premises-based intelligence will add flexibility to network usage. However, distributed intelligence is encouraging a proliferation of private networks bypassing the public ones. This tends to siphon off revenues from the public network exchange carriers and to impair their ability to provide economical services. Business users will not wait to obtain needed services from the public networks: If they cannot obtain necessary services there, they will build their own private networks.

From the standpoint of NSEP, private bypass networks, if physically separate from the public networks like VSATs, would add to network redundancy. Private networks configured from public networks resources would not do so. For example, virtual networks merely allocate public network capacity dynamically to guarantee bandwidth to the customer. Some links dedicated to private users may simply share space in a physical cable that also carries circuits dedicated to the public network.

SUMMARY

The public networks are evolving rapidly under the pressures of regulatory and technological change and pursuant to the economics of competition and commercial customer demand. By the year 2000, the public networks will be a repository of flexible, powerful technologies. Lightwave (fiber) will be the transmission medium of choice. Digital techniques will dominate both transmission and switching architectures. Radio technologies will offer route diversity. Signaling within the public networks—and in private ones as well—will be software driven and subject to customer control for many functions. Data services, as prime business revenue sources, will drive network evolution. Video services ultimately will offer, via residential

revenues, an avenue for deployment of broadband architectures, but these will not be widespread prior to the twenty-first century.

But, while customers will have a diversity of customized services from which to choose, and while technological innovation will continue, network evolution will not be well matched to NSEP needs unless changes are made. Proliferating architectures and interfaces, limited redundancy, and the absence of entities with full end-to-end responsibility for network design and maintenance make it highly desirable that planners with NSEP responsibility take steps to require augmentation of the assets of the public networks. Without augmentation of public network assets the government cannot be confident that its vital NSEP needs will be fully available from the public networks.

Chapters 4 through 7 describe in greater detail how regulation, technology, competition, and customer demand will drive the evolution of the public switched networks through the year 2000.

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