Dark Fibers and Free Bandwidth

The Future of Telecommunications

George Gilder

The onrush of microchip and fiber optics technology is impelling the convergence of industries and technologies. Whether between companies or nations, the lines that divide are giving way to ever richer links of communication. The telephone, computer, consumer electronics, publishing, broadcasting, entertainment, postal, and educational industries are all becoming a single digital medium.

Advances in semiconductors will yield a 100 million transistor chip by 1995 and a one billion transistor device by 2000. Advances in optics will produce a 25-trillion-hertz all-optical network by the turn of the century. Together, those advances will mean a millionfold rise in the capacity of computer and communications hardware during the next 10 to 15 years. Those advances will follow what I call the law of the microcosm: innovation will push computer power and intelligence to the cheapest machines and the edges of networks, where it is most difficult to regulate and control.

The convergence of technologies into a new array of multimedia industries—from digital cellular phones to TV teleputers to digital films and publishing—is now the driving force of world economic growth. Apple Computer chairman John Sculley has predicted that by 2002 global multimedia will be a $3.5 trillion market—close to the size of the entire U.S. economy in the early 1980s.

George Gilder is a senior fellow at the Discovery Institute and author of Life After Television.

As early as the mid-1960s, the Federal Communications Commission had recognized that technological innovation was beginning to blur the lines between computers and communications. As a result, the Commission began its First Computer Inquiry to develop guidelines governing whether and how telephone companies could use their computers to provide data processing services to customers.

Still, the two industries remain mostly distinct, with little real overlap in markets and services. Computers function on low-power digital microchips, running the on-off codes of bits and bytes. Still heavily analog in connecting to homes and offices, phones use waves that imitate the sounds of voices. While computer systems are centrifugal, communications systems are centralized and governed by the economics of scarce radio frequencies. The computer industry spawned thousands of entrepreneurial companies. The telecommunications industry, wired and wireless, broadcast and telephone, foreign and domestic, yielded huge companies jealously guarding "natural monopolies" ruled by governments and their regulators.

In the next 10 years the convergence of the worlds of computers and communications will create a powerful new industry. Bursting far beyond the confines of current regulatory structures, the industry will be overwhelmingly digital, based on the bits and bytes of computers. But the driving force of growth in the digital empire will be the linking of computers in wider and more intimate webs of communications.

The new world of computer communications will span two domains—the "fibersphere" and the atmosphere. The fibersphere comprises all-optical networks with vastly expanded communications power and dramatically reduced error rates. The potential capacity for communications in the fibersphere is a thousand times greater than all the currently used frequencies in the air. Because communications in the fibersphere will be so radically free of error, they will mandate an entirely new model of wired telecommunications. The atmosphere offers a similar but lesser bandwidth explosion. It will provide links as mobile and ubiquitous as human beings and will force an entirely new model of wireless networks.

Transforming the Global Economy

The new world of communications will transform the global economy. Over time, technological advances have restructured nations and economies. A new invention can radically reduce the price of a key factor of production and precipitate an industrial revolution. Before long, every competitive business in the economy must wring out the residue of the old costs and customs from all its products and practices. The steam engine, for example, drastically reduced the price of physical force. Power once wrenched at great expense from human and animal muscle could pulse cheaply and tirelessly 24 hours a day from machines burning coal and oil. Throughout the world, dominance inexorably shifted to businesses and nations that reorganized themselves to exploit the suddenly cheap resource. Eventually, every human industry and activity, from agriculture and sea transport to printing and war, had to centralize and capitalize itself to take advantage of the new technology.

The integrated circuit has put the world through a similar technological wringer over the past three decades. Invented by Robert Noyce of Intel and Jack Kilby of Texas Instruments in 1959, the integrated circuit put entire systems of tiny transistor switches, capacitors, resistors, diodes, and other once-costly electronic devices on one tiny microchip. Made chiefly of silicon, aluminum, and oxygen—the three most common substances in the Earth's crust—the microchip eventually reduced the price of electronic circuitry by a factor of a million.

Electronic designers now treat transistors as virtually free. Indeed, on memory chips they now cost some 250-millionths of a cent. To waste time or battery power or radio frequencies may be profligate acts, but to "waste" transistors is the essence of thrift. Today we use millions of transistors to slightly enhance a TV picture or to play a game of electronic solitaire or to fax *Doonesbury* to Grandma. If we do not use transistors in our cars, offices, telephone systems, design centers, factories, farm gear, and missiles, we will go out of business. If we do not waste transistors, our cost structures will cripple us. Our products will be too expensive, too slow, too late, or too low in quality to attract buyers.

During the next decade or so, industry will go through another new technology wringer and learn to live under a new law: the law of the "telecosm."

Reversing the centralizing thrust of the previous era, the microchip endowed every information age engineer or computer hacker with the creative potential of a factory owner of the industrial age. All nations and businesses had to adapt to the centrifugal law of the microcosm. They flattened hierarchies, outsourced services, liberated engineers, and shed middle management. Those who did not adapt their business systems to the new regime were no longer players in the world balance of economic and military power.

During the next decade or so, industry will go through another new technology wringer and learn to live under a new law: the law of the "telecosm." Just as the microcosm yields exponential gains by connecting increasing numbers of transistors on individual microchips, the telecosm yields exponential gains by increasing connections between chips. The new wringer is the all-optical network, a communications system that runs entirely in glass. Unlike existing fiber optic networks, which convert light signals to electronic form to amplify or switch them, the all-optical network is entirely photonic. From the first conversion of the signal from a phone or computer to the final conversion to voice or data at the destination, the message flies through glass on wings of light.

Just as the integrated circuit put entire electronic systems on single slivers of silicon, the all-optical network will put entire communications systems on seamless webs of silica. Wrought in threads as thin as a human hair, the silica is so pure that we could see through a 70-mile thick window of it. But what makes the new wringer roll with all the force of the microchip revolution before it is not the purity but the price. Just as the old integrated circuit made transistor power virtually free, the all-optical network will make communications power virtually free. Another word for communications power is bandwidth. Just as the world needed to learn to waste transistors, it will now have to learn how to waste bandwidth.

The Digital Dawn

Over the past two decades, the Federal Communications Commission, under the leadership of Mark Fowler, Dennis Patrick, and Alfred Sikes, has generally accelerated the role of marketplace rather than federal regulation of telecommunications. In the early 1990s the Commission gave the digital movement a decisive push in the critical area of broadcast video. Although European and Japanese companies long remained committed to analog high-definition television, the FCC adopted its regulations to favor a future of advanced digital television. Partly as a result, the television and computer industries are converging first in the United States.

The emerging regulatory issues focus on the key current development in communications: the explosion of bandwidth both in the air and in fiber optics.

In 1993 a digital dawn is illuminating the telephone industry. Once again, the FCC has the choice of accommodating freedom and progress or driving it overseas. The emerging regulatory issues focus on the key current development in communications: the explosion of bandwidth both in the air and in fiber optics. In the air the new bandwidth comes from ever higher levels of frequency reuse in ever smaller cells and from the movement of communications systems to higher frequencies in the electromagnetic spectrum. Together, these bandwidth expansions enable what are called personal communications services.

Within the next decade, the most common personal computer will be a portable digital phone that calculates, records, stores, and forwards digital voice and data around the globe. As mobile as a watch and as personal as a wallet, it will follow its user everywhere. It will manage communications, recognize speech, navigate streets, take notes, maintain schedules, assemble personalized news and other information, and collect electronic and voice mail. It will open the door, start the car, and transmit emergency medical data. This new telecomputer industry will emerge from scores of companies in scores of different forms and will eclipse all current boundaries between phones, computers, radios, and notebooks. Invented and developed mostly in the United States, it will be the spearhead of a new global economy of information.

Central to all those developments, however, will be the empowerment of telephony with digital computer technology. The network will need ever more intelligence. The system must be able to follow a user from place to place. It must be able to provide mail and other data without burdening the handset with power-hungry memories and processing. The system must be able to identify different protocols and modulation schemes so that it obviates heavy hybrid phones. As the FCC has said, the system should supply universal service—soon.

The Paradox in Intelligence

There is a paradox in intelligent networks, however. The key to an advanced intelligent network is to keep the intelligence out of the network itself. As physicist George A. Keyworth puts it, the networks themselves should be "as dumb as a stone." Just as in computer communications today, the intelligence will be provided from platforms on the fringes of the networks. With the local loop of the telephone company filling up with a proliferation of new personal communicators, notebook computers, cellular phones, and other fast-moving computer technologies, the network's switching fabric cannot keep up with the computational creativity on its periphery.

The cheapest and best answer is to provide the intelligence from outside the network itself. For example, McCaw's intelligent system, which provides seamless roaming, call forwarding, and other services for cellular customers throughout most of North America, is based not in the cellular switches but in four Tandem fault-tolerant computers connected to the network.

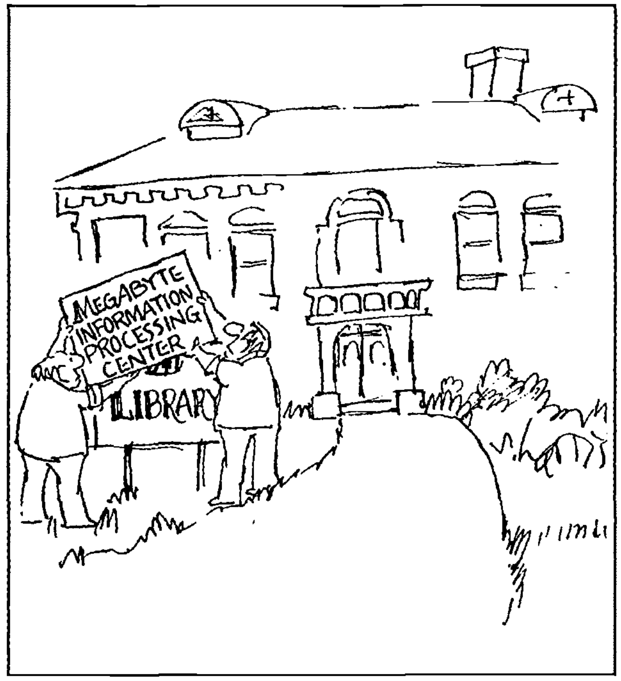
Under the current regulatory structure, we can most efficiently enjoy universal personal communications service if nationwide licensees use existing networks. To start from scratch would require expensive overlay networks that would delay adoption until the next century.

Personal communications services need not compete with cellular and wireline networks; they are necessary complements. Ideally operating at tens of milliwatts, the handset could be used at home, in the office, and in pedestrian traffic and could be plugged into a cellular system in automobiles for high-powered transmissions. At home and in the office the service would use the digital switching in which the phone companies are rapidly investing. In automobiles the service would use the digital cellular systems now being developed for vehicular communications.

Local telephone companies alone cannot deploy the full range of personal communications services. To create the new infrastructure for wireless information technology, the providers of those new services will have to tap the full capabilities of long-distance, cellular, computer network, software, packet radio, and database firms and will face competition from all of them.

Nowhere in the world economy is there an arena that will be as competitive during the next decade as the local loop in the United States. Like the personal computer industry of the 1980s, the personal communicator industry of the 1990s will see literally thousands of companies competing and collaborating to supply thousands of new products and services. From that crucible will emerge the commanding technologies of a new era of personal mobility, freedom, knowledge, and power.

By fully accommodating the emerging technologies of the atmosphere and fibersphere, the FCC can lay the foundations for U.S. economic leadership into the next century. Fully accommodating personal communications services means opening up spectrum to allow the huge diversity of services and systems that the new digital technologies will enable. Fully accommodating personal communications services means inviting all companies into the competition and taking advantage of the huge



investments of the local exchange carriers. Fully accommodating personal communications services means creating national licenses that allow the emergence of national standard interfaces and world-class manufacturers. That is the combination that has given the United States world leadership in the computer industry, with three times as much computer power per capita as Europe or

Like the personal computer industry of the 1980s, the personal communicator industry of the 1990s will see literally thousands of companies competing and collaborating to supply thousands of new products and services.

Japan. Over the next decade, that combination can work for the new personal communications industry as well.

The Case for Darkness

Although personal communications services are developing, the fibersphere still faces significant regulatory obstacles. The creation of all-optical networks depends upon direct access to fiber, as opposed to access only through the electronic facilities of the telephone companies. Fiber optics can potentially operate at a bandwidth of 25 trillion cycles a second, but electronics can only function at between two and three billion cycles a second. To use the full capacity of fiber optics, therefore, it is necessary to connect photonically rather than electronically.

Today, approximately one-third of all the fiber in the telephone system is "dark," or unused, and thus potentially available for all-optical communications. But the telephone companies do not want to open that resource to direct business connections. They want instead to process and count all the bits themselves in their electronic systems and charge for them under typical phone company tariffs. But that means reducing the potential capacity of the fiber by a factor of some ten thousand.

All-optical networks created at IBM and elsewhere already offer the cheapest bandwidth on the face of the earth: 9.6 gigabits per second at a cost of $16,000 per terminal.

This problem prompted a number of large corporations, led by Electronic Data Systems, to take an active role in *Southwestern Bell Telephone Company et al.* v. *Federal Communications Commission*. Known as the "dark fiber" case, the proceeding has recently been mooted by an FCC decision to require the local exchange carriers to provide dark fiber connections to companies that want them. Beyond all the legal posturing, the question at issue is whether fiber networks should be dumb, dark, and cheap—the way Electronic Data Systems, Shell Oil, the information services arm of McDonald Douglas, and long-distance provider Wiltel like them—or bright, smart, and "strategically" priced—the way the telephone companies want them.

Dark fiber is simply glass fiber-optic thread with nothing attached to it—no light being sent through it. In this "unlit" condition, it is available for use without the intermediation of phone company electronics or intelligent services. In the mid-1980s the Bells leased some of their dark fiber lines to several large corporations on an individual-case basis. Those companies learned to love dark fiber. But when they tried to renew their leases with the Bells, the Bells refused. They offered instead to provide interconnections and develop protocols and offer intelligent services on a metered basis. Preferring the dumb fiber, Electronic Data Systems and the other firms rejected the offer. When the Bells persisted in an effort to deny new leases, the companies petitioned the FCC to require the Bells, as regulated common carriers, to continue supplying dark fiber.

Although the FCC seems to have settled the immediate legal problem, the deeper portent of dark fiber casts a long shadow over the industy. It raises what for the next 20 years will be a central issue in communications law and technology. The issue will shape the future of both the computer and telephone industries during a period when they are merging to form the spearhead of a new information economy.

It is safe to say that none of the participants fully comprehends the significance of their courthouse confrontation. To the Bells, after all is said and done, the key problem is probably the price. Under the existing tariff, they are required to offer their service to anyone who wants it for an average price of approximately $150 per strand of fiber per month. As an offering that competes with their T-3 45 megabit-per-second lines and other forthcoming marvels, dark fiber threatens to gobble up their future as vendors of broadband communications to offices, even as cable TV preempts them as broadband providers to homes. Since the Bells' profits on data are growing some 10 times as fast as their profits on voice telephony, they see dark fiber as a menace to their most promising markets.

Technological Portents of the Triumph of Dark Fiber

The technological portents of the triumph of dark fiber are far more significant than even the legal and business issues. The coming triumph of dark fiber will mean not only the end of the telephone industry as we know it but also the end of the telephone industry as they plan it: a vast, intelligent fabric of sophisticated information services. It could also mean a thoroughgoing restructuring of a computer industry increasingly dedicated to supplying smart networks. Indeed, for most of the world's communications companies, professors of communications theory, and designers of new computer networks, the triumph of dark and dumb means "back to the drawing board," if not back to the Dark Ages.

But the new dark ages cannot be held back. Springing out of the depths of IBM's T.J. Watson Research Center is a powerful new invention—the all-optical network—that will soon make dumb and dark the winning rule in communications. All-optical networks created at IBM and elsewhere already offer the cheapest bandwidth on the face of the earth: 9.6 gigabits per second at a cost of $16,000 per terminal.

Just as the law of the microcosm made all terminals smart—distributing intelligence from the center to the edges of the network—so the law of the telecosm creates a network dumb enough to accommodate the incredible onrush of intelligence on its periphery. Indeed, with the one-chip supercomputer on the way, manufacturable for under a hundred dollars toward the end of the decade, the law of the microcosm is still gaining momentum. The fibersphere complements the promise of ubiquitous computer power with equally ubiquitous communications.

What happens, however, when not only transistors but also wires are nearly free? As leading telecommunications theorist Robert Lucky of Bellcore observes, "Many of us have been conditioned to think that transmission is inherently expensive; that we should use switching and processing wherever possible to minimize transmission." That is the law of the microcosm. But Lucky speculates, "The limitless bandwidth of fiber optics changes these assumptions. Perhaps we should transmit signals thousands of miles to avoid even the simplest processing function." That is the law of the telecosm: use bandwidth to simplify everything else.

Daniel Hillis of Thinking Machines Corporation offers a similar vision, adding to Lucky's insight the further assertion that massively parallel computer architectures are so efficient that they can overthrow the personal computer revolution. Hillis envisages a power-plant computer model, with huge thinking machines at the center tapped by millions of relatively dumb terminals.

All those speculations assume that the law of the telecosm usurps the law of the microcosm. But in fact the two concepts function in different ways in different domains. The law of the microcosm makes distributed computers—smart terminals—more efficient regardless of the cost of linking them together. The law of the telecosm makes dumb and dark networks more efficient regardless of how numerous and smart the terminals are. Working together, however, those two laws of wires and switches impel ever more widely distributed information systems.

It is the narrow bandwidth of current phone company connections that explains the persistence of centralized computing in a world of distributed machines. Narrowband connections require smart interfaces and complex protocols and expensive data. We get online information from only a few databases set up to accommodate queries over the phone lines. We also receive television broadcasting from a limited number of local stations. Using the relatively narrowband phone network or television system, it pays to concentrate memory and processing at one point and to tap into the hub from thousands of remote locations.

The all-optical network will triumph for the same reason that the integrated circuit triumphed: it is incomparably cheaper than the competition.

Using a broadband fiber system, by contrast, it will pay to distribute memory and services to all points on the network. Broadband links will foster specialization. If the costs of communication are low, databases, libraries, and information services can specialize and be readily reached by customers from anywhere. Online services lose the economies of scale that lead Mead Data Systems and Knight-Ridder's Dialog to attempt to concentrate most of the world's information in one set of giant archives.

By making bandwidth nearly free, the coming of the fibersphere will radically change the environment of all information industries and technologies. In all eras companies tend to prevail by maximizing the use of the cheapest resources. In the age of the fibersphere, they will use the huge intrinsic bandwidth of fiber—all 25,000 gigahertz or more—to replace nearly all the hundreds of billions of dollars worth of switches, bridges, routers, convertors, codecs, compressors, error correctors, and other devices, together with the trillions of lines of software code, that pervade the intelligent switching fabric of both telephone and computer networks.

The makers of all this equipment will resist mightily. But there is no chance that the old regime can prevail by fighting cheap and simple optics with costly and complex electronics and software. The all-optical network will triumph for the same reason that the integrated circuit triumphed: it is incomparably cheaper than the competition. Today, measured by the admittedly rough metric of millions of instructions per second per dollar, a personal computer is more than one thousand times more cost effective than a mainframe. Within ten years, the all-optical network will be hundreds of times more cost effective than electronic networks. Just as the electron rules in computers, the photon will rule the waves of communication.

The all-optical ideal will not automatically usurp other technologies. Vacuum tubes, after all, reached their highest sales in the late 1970s. But just as the integrated circuit inexorably exerted its influence on all industries, all-optical technology will impart constant pressure on all other communications systems. Every competing system will have to adapt to its cost structure. In the end almost all electronic communications will go through the wringer and emerge in glass.

That is the real portent of the dark fiber debate. The future of the information age depends on the rise of dumb and dark networks to accommodate the onrush of ever smarter electronics. Ultimately at stake is nothing less than the future of the computer and communications infrastructure of the U.S. economy, its competitiveness in world markets, and the consummation of the information age.

Together the new technologies of sand and glass—computers and telecommunications—will overthrow all businesses and regulatory regimes based on the notion that computation is expensive, spectrum is scarce, and information industries possible to monopolize. Thus, the entire regulatory structure of the present is based on obsolete premises.

No current regulatory technique can master the new regime of vast floods of photons pouring through tiny pipes of glass, or can supervise the huge efflorescence of wireless computer devices thronging the air with encrypted digital messages. Such government bodies as the U.S. Postal Service, the FCC, and the 50 state public utilities Commissions will all become mostly obsolete. All are based on the idea that spectrum is scarce rather than boundless, that telecommunications is a natural monopoly rather than the most competitive arena in the world economy, and that technology advances incrementally rather than in massive and ever-accelerating leaps.

In a regime of boundless bandwidth and computational abundance, the key scarce resource will be the human mind. Contributing the bulk of the value added and gaining most of the profits, human creativity will become ever more valuable and more highly rewarded. Slipping inexorably away into the trackless realms of human minds, economic activity will become ever harder to regulate, tax, or control. That is the real challenge and promise: the convergence of microcosm and telecosm in new constellations of liberty.