MARKET TRENDS

SONET: Is the Glass Half Full?

B. W. Stuck

The carriers have unveiled massive spending plans for fiber optic transmission. The ripple effects will be felt for years to come.

B. W. Stuck is president of Business Strategies LLC (Westport, CT), a consultancy specializing in network computing and telecommunications.

In September 1992, Ameritech announced a $5 billion capital program to deploy fiber transmission systems. The next year Pacific Bell announced a $16 billion program, and last year Bell Atlantic and Southern New England Tel said that they would spend $8 billion and $3 billion, respectively. Despite these announcements, we are still in the infancy of deployment, and we have yet to feel the impact it will have on the economics of telecommunications services.

Make no mistake, however: The economics will change. A single pair of optical fibers can carry more than 1 terahertz, a capacity more than adequate to handle all of the switched telephone traffic in the U.S. during a single peak busy hour. Carrier prices for optical fiber transmission should drop significantly, both because of the characteristics of fiber and because there will be new entrants in the carrier marketplace.

While the deployment of fiber transmission systems has led to predictions of futuristic residential equipment and service offerings, most of the current action continues to be in the business equipment and services markets—LAN interconnection, remote LAN access and videoconferencing. Optical fiber transmission meshes well with high-speed switching technologies such as Asynchronous Transfer Mode (ATM).

TABLE 1A Optical Fiber Transmission System Route Miles* for U.S. IXCs

Carrier	1985	1987	1989	1991	1993
AT&T	5,677	18,000	28,900	36,871	39,705
MCI	3,025	10,267	13,839	16,700	20,630
Sprint	5,300	17,476	22,002	22,725	22,996
Other	6,037	12,980	15,095	15,671	16,032
Total	20,039	58,723	79,836	91,967	99,363

*An optical fiber route mile is one mile of optical fibers.
Source: FCC, May 1994

TABLE 1B Thousands of Optical Fiber Miles for U.S. IXCs**

Carrier	1985	1987	1989	1991	1993
AT&T	136.2	432.0	838.4	1146.9	1197.5
MCI	83.9	259.3	304.2	413.7	565.5
Sprint	122.4	343.2	450.8	466.7	467.2
Other	113.2	258.8	306.1	320.3	317.3
Total	455.7	1293.3	1899.5	2347.6	2547.5

** An optical fiber mile is one mile of optical fibers multiplied by the number of optical fibers in that mile.
Source: FCC, May 1994

TABLE 1C Fraction of Optical Fiber Miles Lit for U.S. IXCs

Carrier	1988	1989	1990	1991	1992	1993
AT&T	41.6%	45.5%	49.6%	44.6%	49.5%	50.9%
MCI	40.0%	56.7%	64.3%	NA	NA	NA
Sprint	31.0%	50.4%	53.9%	55.1%	65.1%	NA

Source: FCC, May 1994

Market Trends

The global market for optical fiber synchronous transmission equipment market was more than $1 billion in 1994. Tables 1a and 1b show how much optical fiber plant the U.S. interexchange carriers (IXCs) have installed. Anywhere from one-half to two-thirds of the plant is already "lit"—i.e., operational—(see Table 1c), which suggests that as demand ramps up, capacity can be turned on in short order.

Tables 2a and 2b present similar statistics for U.S. local exchange carriers (LECs), and there is also a third group, the Competitive Access Providers (CAPs), who provide fiber transmission directly to businesses connecting them also to IXCs and LECs. As shown in Table 3a, the CAPs have been aggressively deploying fiber.

Tables 4a and 4b show market projections for optical fiber network elements. At the IXC level, the market is growing at about 10 percent per year, and at the LEC level at about 40 percent. These figures are based on current technology, which limits the maximum distance between signal amplifiers to about 25 miles (40 km) at 1,300 nanometers (nm), and 50 miles (80 km) at 1,550 nm. Newer technologies, which are based on optical signal amplification and optical soliton modulation, have begun to appear, and they dramatically extend these distances.

During the past three years, the major change in the optical fiber transmission market has been the migration from country-specific asynchronous standards to global synchronous standards, which are based on Synchronous Optical Network (SONET) in North America and Synchronous Digital Hierarchy (SDH) elsewhere. In North America, oversight of SONET standards is the responsibility of the Exchange Carrier Standards Association (ECSA) under its Telecommunications-1 (T-1) committee. In Europe, the PTTs are developing SDH standards through internal groups within the ITU-Telecommunications (ITU-T) organization.

The move to standards has been motivated by highly pragmatic considerations—carriers in the Pacific Rim are under pressure to upgrade capacity as quickly as possible, and in a way that delivers interoperability with other carrier networks. In addition, every carrier is seeking to reduce staff for operations, administration and maintenance (OA&M). Standards-based systems also promise a long-term payoff through lower requirements for spare circuit packs and by stimulating competition—multiple suppliers can bid on the equipment (see Figure 1).

TABLE 2A Optical Fiber Transmission System Route Miles for Major U.S. LECs

Carrier	1985	1987	1989	1991	1993
Ameritech	3,200	6,700	10,800	15,200	21,500
Bell Atlantic	1,240	6,730	11,943	19,170	25,250
BellSouth	3,830	11,727	19,781	29,677	40,460
GTE	NA	NA	11,655	17,196	24,459
Nynex	1,606	4,956	9,221	14,680	20,514
Pac Telesis	2,318	2,964	3,767	6,564	9,820
Southwest	1,913	5,970	9,100	16,046	22,079
US West	3,527	6,937	13,425	22,152	31,301
Other	NA	NA	20,391	21,867	30,145
Total	17,634	48,568	110,263	161,552	225,582

Source: FCC, May 1994

TABLE 2B Optical Fiber Miles for Major U.S. LECs

Carrier	1985	1987	1989	1991	1993
Ameritech	77,700	147,100	228,400	400,700	802,100
Bell Atlantic	83,085	227,507	373,398	809,740	1,251,290
BellSouth	50,807	218,489	445,452	768,597	1,120,974
GTE	NA	NA	164,395	276,139	489,948
Nynex	83,384	207,077	357,766	636,954	964,383
Pac Telesis	84,310	101,090	126,944	248,418	374,919
Southwest	70,490	182,911	270,300	477,654	775,040
US West	47,341	107,782	234,851	542,309	1,042,547
Other	NA	NA	95,830	228,000	459,980
Total	497,117	1,206,192	2,297,336	4,388,511	7,281,181

Source: FCC, May 1994

Rolling out the Product

The initial SONET rollout in North America has been along high-capacity (OC-48—2.488 Gbps) routes, where it is relatively straightforward to demonstrate payback. The next set of upgrades will be targeted at OC-3/OC-12 (155.52/622.08 Mbps) routes.

Indeed, the way SONET is rolling out, a three-tier network is emerging:

- **Tier 1:** A "next-generation" Digital Loop Carrier (NGDLC), which can provide voice service to a cluster of 100 to 500 subscribers. Access to the backbone network is via OC-3, and the interface to subscriber buildings is via copper wire pairs and coaxial cable, which can be upgraded for videoconferencing and video on demand.
- **Tier 2:** A backbone network concentrator that handles multiple NGDLCs at OC-3 rates and interconnects to a backbone network at OC-12. The input and output interfaces use optical fiber and SONET.
- **Tier 3:** A backbone network node that interconnects to other backbone nodes at OC-48 and higher rates, and to other concentrators at OC-3 and OC-12.

The dominant equipment vendors (see Figure 2) include Alcatel Network Systems (Richardson, TX), AT&T Network Systems (Morristown, NJ), DSC Communications (Plano, TX), Fujitsu Network Transmission Systems (Richardson, TX) and Northern Telecom (Nashville). In 1994, SONET passed a major threshold—equipment sales topped $1 billion—and they may grow at a compound annual growth rate of 20 to 25 percent over the next three years.

SDH is experiencing the same dynamics as the North American market, but it is moving more slowly. The European PTTs have historically employed switching systems for concentrators rather

TABLE 3 Competitive Access Provider Optical Fiber Transmission Systems

	Route Miles			Optical Fiber Miles		
Company	**1989**	**1991**	**1993**	**1989**	**1991**	**1993**
Teleport Com. Group	232.6	427.1	1,953	13,030	21,398	90,700
Metropolitan Fiber Sys.	199.6	528.0	1,298	13,374	29,338	62,154
Other	361	1,143	2,309	7,628	4,404	88,773
Total	793	2,098	5,560	34,032	55,140	241,627

Source: FCC, May 1994

than for digital loop carrier transmission. As a result, SDH must not only prove economical, it must overcome a network planning methodology that favors switching over transmission. The economics of SDH are compelling enough that the PTTs are purchasing large numbers of SDH add/drop multiplexers, but European deployment still trails that in the U.S.

During 1991–1992, most SONET deployed in the U.S. was OC-3 and OC-12, and transmissions ran up to 40 km with a bit error rate under one bit per billion. In 1996, distances will extend to 80 km for terrestrial transmission and 7,000 km for transoceanic transmission.

In 1992–1993, SONET equipment became available at OC-48 rates, and in 1993–1994, further capacity increases were implemented using wavelength division multiplexing (WDM). The initial application for WDM is to provide redundancy—a single OC-48 can be multiplexed into two OC-48 paths, with the second used for backup. During 1995–1996, the vendors will start to deliver equipment that runs at OC-192 (9.8 Gbps) and even higher.

Within the next 12 to 24 months, the market also will see SONET "edge" multiplexers, from both traditional T1 multiplexer vendors and startups. These premises-based products will provide direct connectivity between Ethernet LANs and ATM, and SONET WANs.

Costs for SONET transmission equipment continue to drop as SONET/SDH application-specific integrated circuitry (ASIC) becomes available from companies like TranSwitch (Shelton, CT) and Sierra Semiconductor (Vancouver, BC), as well as from the system vendors' internal semiconductor shops. Transmission rates will continue to increase as lasers and drive circuitry are built with higher power levels.

Market economics and dynamics will affect how the technology evolves. Even though 80 percent of network nodes are used for network access and only 20 percent are tandem or backbone nodes, the capacity, price and profit for a backbone node is four times that of a network access node. After their initial market ramp-up, edge multiplexers are expected to be high-volume, low-price products, while backbone multiplexers are likely to be lower-volume, higher-priced products.

Emerging SONET Applications

Like almost any new technology, SONET/SDH enables customers to implement existing applications in a different way—in this case, through massive circuit/line consolidation—as well as to provide applications that were either not economical or not feasible earlier.

Electric utilities—including San Diego Gas and Electric, Chicago Edison and Duke Power—are among the leading SONET users. With competition and deregulation in their core businesses looming in the future, the electric power utilities are looking to SONET to improve internal net-

TABLE 4a SONET Network Element (NE) Installed Base

Year	NGDLC NEs	OC-3/OC-12 NEs	OC-48 NEs
1992	1,894	10,745	3,286
1993	10,365	23,722	8,239
1994	25,271	40,923	15,810

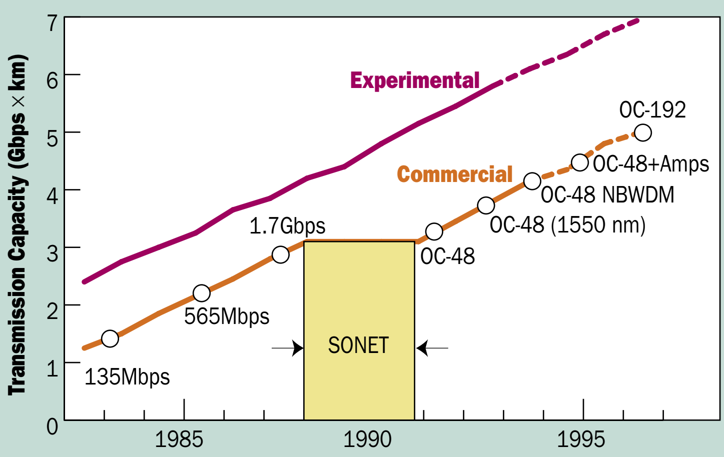
Source: Alcatel Network Systems, AT&T Network Systems, DSC, Fujitsu Network Transmission Systems, Northern Telecom and Business Strategies

TABLE 4b SDH Network Element (NE) Installed Base

Year	STM-1 NEs	SMS-4/16 NEs
1992	1,322	453
1993	7,845	861
1994	16,276	1,856

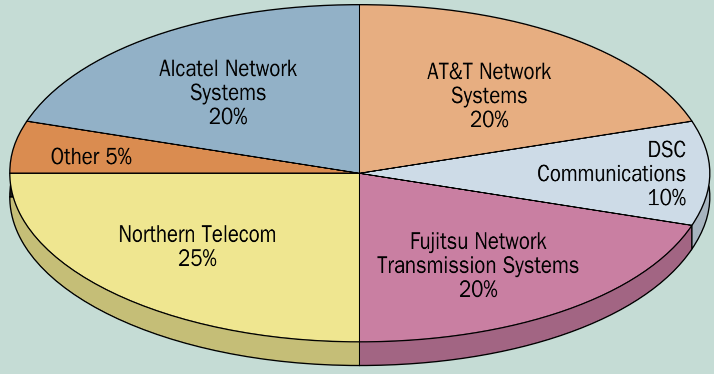
Source: Alcatel Network Systems, AT&T Network Systems, DSC, Fujitsu Network Transmission Systems, Northern Telecom and Business Strategies

FIGURE 1 Performance Evolution: Figure of Merit* by Year



* Figure of Merit = Maximum Transmission Capacity × Maximum Repeater Spacing
Source: Northern Telecom

FIGURE 2 SONET/SDH Equipment Market Shares



Source: Vendor-supplied data

Electric power utilities are looking to SONET to improve internal network operations and as a means to resell network capacity

Importance of System-Level Reliability

Nobody can dispute optical fiber's tremendous carrying capacity and its associated ability to lower transmission costs, but the downside is that a failure can be devastating—a single OC-48 can carry over 30,000 64-kbps channels (DS0s) or telephone lines. Today, a major fiber cable cut occurs every 10 days within the United States, and the more fiber is deployed, the more frequent these cable cuts will become.

As a result, redundancy is a high priority—the six-week outage in Hinsdale, IL, that occurred on Mother's Day, 1988, has been burned into the memories of network planners and carriers around the world. The simplest type of redundancy is "one for *N*" sparing: When a failure is detected, the network automatically switches to an identical but spare network component.

To illustrate the power of 1:*N* sparing, suppose a shelf of equipment in a node has 10 identical boards, each with a mean time to failure (MTTF) of 10,000 hours, and a mean time to repair (MTTR) of two hours; since there are 10 boards, a board will fail on average every 1,000 hours. If a spare is added to the shelf, and is switched into service when an active board fails, the total system mean time to failure is [(10,000/10) × (10,000/2)]—or 500 times the MTTF of a single board.

Beginning in 1993, vendors began offering a variety of reliability options for SONET/SDH ring transmission systems, including unidirectional path switched rings (UPSRs), bidirectional line switched rings (BLSRs) and completely matched service nodes. Bidirectional interoffice networking allows a single cut of fiber or failure of a node to be automatically handled via protection switching, while path-protected end offices have redundant paths to reach nodes on the fiber ring (UPSRs and BLSRs are discussed in *BCR,* June 1994, pp. 61–64).

Proactive monitoring of a link can provide an "early warning" system—identifying potential failures early on, such as deviations from past test data, as well as spotting long-term trends that result from power supply fluctuations and/or component aging. At the system level, two rings sharing two common nodes, called matched nodes, or Dual Ring Interconnect (DRI), illustrate the state of the art in high-reliability technology. Network managers can balance the cost of this type of redundancy against a UPSR or BLSR and against the cost of supporting operations staff □

work operations and as a means to resell network capacity to major businesses.

It comes as no surprise that the financial services industry is also moving on SONET. Companies like Bear Stearns, Fidelity and Charles Schwab continually reevaluate their networking technology, and their emphasis is on systems that provide high reliability and the capability to supply "capacity on demand" for disaster recovery, archiving records at a remote site and videoconferencing applications.

Health facilities are also exploring SONET, in part for medical imaging. Duke University Hospital (Durham, NC) and firms such as Burroughs Wellcome and Glaxo in neighboring Research Triangle Park are pursuing high-speed transmission for high-resolution imaging applications.

SONET is also being examined for distance learning applications, and the Universities of Michigan and California are using SONET to reach students at different campuses or at work locations. The University of North Carolina is exploring how to best present training and instructional material over video networks.

The distribution of commercial TV is also a potential SONET application, but it is still very much in its infancy. Even though TV transmission is analog, virtually all of the major CATV system operators are deploying optical fiber and SONET (or proprietary versions) to improve the reliability of their systems. In addition, Vyvx (Tulsa, OK) provides a fiber-based TV transmission service that delivers sports programming to television networks across the country. The Vyvx networks are multinode, and traffic is carried to digital headends where it interconnects with CATV and other TV networks.

Good News/Bad News on Network Management

Among the most promising applications for SONET/SDH is network management. Unlike predecessor transmission systems, which only addressed fault and test management, SONET/SDH was designed from the start to also handle configuration management and billing. SONET/SDH has been architected for "true" network management—it assumes a hierarchy consisting of network elements, element managers and regional and national network management centers. During the past three years, high-quality, industrial-strength management software for SONET/SDH has emerged from companies like AT&T Network Systems, Retix (Santa Monica, CA), TCSI (Berkeley, CA), Marben (Paris, France) and Objective System Integrators (Sacramento, CA).

SONET or ATM?

With optical fiber transmission systems running at gigabit speeds and interconnecting to high-speed multiple-bit-rate switching systems, it's not surprising that people are wondering where a SONET transmission ends and ATM switching begins. There's no question that multimedia services will run over optical fiber transmission technology—either SONET/SDH with its Virtual Tributaries or Asynchronous Transfer Mode (ATM) with AAL1 Circuit Emulation.

A number of integrated circuit designers argue that since "pure" ATM requires fewer gates in an integrated circuit chip set, it is simpler to implement. ATM also has both a technical and cost advantage over SONET because ATM encompasses both multiplexing and switching in a single step.

These technical issues notwithstanding, ATM's real advantage may lie in the market power of those driving its development. ATM has solid backing from the computer industry, and its support from the telecom industry is growing. In contrast, SONET has significant support from the telecom vendors, but little or no support from the computer industry. The computer networking industry has a better track record than the telecommunications industry when it comes to quickly identifying and satisfying end user needs.

In 1994, the global market for optical fiber synchronous transmission equipment market was more than $1 billion, while the comparable figure for ATM equipment was roughly $100 million. Still, ATM gets greater press coverage, and it probably deserves it□

SONET/SDH has been architected for "true" network management—a hierarchy of elements, managers and management centers

That's the good news. The bad news is that at this stage of development, there is very limited interoperability of SONET/SDH transmission equipment from multiple vendors, in part because of the different network management capabilities each vendor provides.

For example, the vendors use different data models so configuration management isn't consistent. In addition, most vendors already deliver testing capabilities that go beyond parameters established by the standards and, most important, the carriers really haven't had to handle requirements for interoperability—there are virtually no SONET circuits that originate on equipment from one vendor and terminate on equipment from another.

Another issue confronting SONET network management is the differences between carrier-based network management systems and how private network management is implemented. SONET operations, administration and maintenance is based on OSI's CMIP (Common Management Information Protocol), while the vast majority of private data networks in the U.S. rely on SNMP (Simple Network Management Protocol). As a result, private network managers will be able to access only a subset of the capabilities of SONET network elements and will be unable to access CMIP's more extensive monitoring and control capabilities.

Considerable work is under way on network management standards, particularly the addition of more network management capabilities in different fields of the SONET/SDH frame. However, the penalty for all this development work is that it is taking longer for SONET equipment to get into the market. The equipment vendors have no choice other than to deliver equipment with the promise that it will be upgraded to conform with standards once they're finalized.

Similarly, Telecommunications Management of Networks (TMN), an emerging international network management standard for carrier networks, is also evolving. TMN will support configuration management and provisioning, fault management, billing, traffic engineering and quality of service (QOS). Over time, carriers can be expected to offer contracts specifying different levels of service with rebates to customers if the contractual obligations are not in fact met.

A New Business Model for SONET/SDH Services

There is a school of thought that SONET/SDH will enable the carriers to run under a business model similar to that of the airlines. Airlines hold seats in inventory using computerized inventory management and reservation systems. Travel agents, airlines and others buy airline seats in bulk and then resell them through a variety of channels.

With SONET/SDH, carriers, telecom agents, and value-added service providers will be able to buy basic transmission capacity at wholesale and then resell it. Technologies like Signaling System 7 (SS7) and TMN will enable services to be delivered on demand, just as the online reservation system manages airline seat inventories.

However, the telecommunications world lacks the sophisticated inventory management and yield prediction tools that the airlines have developed over the past two decades. Although just because the telecom carriers don't have these tools today doesn't mean they won't have them in the future. SONET/SDH will be the foundation for a great deal of activity and change throughout the rest of the decade□