Fiber Deployment as of Yearend 1986

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Introduction

Fiber optic communication systems utilize small strands of glass for the transmission of information by means of light energy. Due to their very high capacity, small cross section and declining cost, so called "lightguides" or fiber optic systems will play an increasingly important role in the telecommunications industry over the next decade. This report summarizes the development of major fiber communications systems in 1985 and 1986 and has been prepared as part of the Commission's continuing efforts to monitor developments in the telecommunications industry. Also included is information on deployment of fiber by the regional Bell holding companies.

Background

Current high capacity fiber optic systems use what is termed single mode fiber cable with repeater spacings of about 18-25 miles. Transmission electronics and "optronics" (optical electronics) presently provide for up to 6,048 circuits per fiber pair on 405 Mb/sec systems and over 8,000 circuits per fiber pair on 565 Mb/sec systems. New 1.7 Gbit/sec transmission systems to be available in a few years will allow existing single mode fiber pairs to support over 25,000 circuits per fiber pair and improvements in fiber dispersion characteristics provide the promise of as much as doubling current repeater spacing. The attractiveness of fiber investment in terms of cost per available unit of capacity has motivated many fiber ventures in the U.S.

Identified in this report are more than a dozen separate ventures in the U. S. for installation of fiber optic transmission systems. In the past year a significant amount of additional construction and some consolidation has taken place, most notably the merger of GTE Sprint and U.S. Telecom into a jointly owned long distance subsidiary known as U.S.-Sprint. There is a great deal of fiber which has now been deployed by the interexchange carriers. Most entities appear to be adhering to their plans and a few have completed their systems.

The outgrowth of this is five major nationwide fiber systems which have been built by NTN (National Telecommunications Network -- a consortium of several regional companies); Lightnet; GTE and U.S. Telecom referred to above; MCI; and AT&T. The technology development and resulting system capacities may prove to provide a virtually limitless supply of circuits using the underlying fiber investment made by these companies and significantly affect the relative switching and transmission economies and resulting cost of service for years to come. The impact of significantly lower transmission cost on full service carriers and ultimately on end users rates, however, will probably be mitigated by the many other elements contributing to interexchange rates.

This report reflects the results of a recent survey of carrier fiber deployment and includes data on the interexchange carriers and the Regional Bell Holding Companies. The activities at the local level, while not directly affecting the interexchange carriers, will in many cases enhance the local operating companies' ability to provide access for advanced digital services employing an integrated switched digital network or ISDN. Although fiber has primarily been deployed by the local companies for interoffice interconnections, the promise of even lower future fiber cost and new termination technologies will make it an increasingly attractive means to reduce local loop costs in the future, particularly for certain customers. Services so provided may well reduce the attractiveness of certain forms of facility bypass. This report does not focus on subscriber loop fiber data nor does it deal with metropolitan fiber systems now being deployed in several large metro areas by carriers other than the local exchange carrier. Developments in these areas, however, merit further study.

<u>Sources</u>, <u>Methods</u>, <u>and</u> <u>Limitations</u>

This report is based on survey work conducted during the fall of 1985 and 1986 and is based both on a series of telephone interviews with key representatives of major interexchange carriers and on publicly available sources. 1 The interviews were directed at total fiber deployment as of yearend 1985 and 1986. Responses were checked for possible double counting where contracts were involved. Most of the data presented here was obtained through informal channels. I have no basis to fully evaluate the accuracy of the underlying data or to insure that my requests were properly understood. I have, however, cross-checked some of the reported data against information appearing in the trade press and have used the average fiber cross section as a means to check data validity. I believe that inasmuch as data being collected by the carriers themselves is accurate and measured in a consistent manner, this report mirrors that data. The data included here is limited to publicly available information and avoids the use of proprietary sources. I have focused on fiber miles as the best parameter to evaluate potential capacity. 2 In some instances, estimates of average fiber cross section had to be used to arrive at the number of fiber-miles deployed. It is expected, however, that these estimates provide a conservative figure of the total fiber deployed to date by the interexchange carriers.

The number of fiber-miles is an important parameter, since it enables one to determine the total number of equivalent voice circuits which can be made available when the terminal technology is specified. Since the number of voice circuits which can be multiplexed onto a single optical fiber depends so significantly on terminal and repeater technologies, such a measure would have provided a misleading picture of available capacity. For example, new 1.7 Gbit/sec terminal technology which will be available within a few years will support up to about 25,000 2-way circuits on a single fiber pair, more than 3 times the capacity of existing transmission technologies. 3 Because entrants are only equipping a limited number of fiber pairs initially with transmission electronics and "optronics" (at

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1 A number of news oriented references, such as the New York Times, November 13, 1986, p.D-1 and D-8 and Fortune Magazine, January 7, 1985, p.100 were used. Useful background information can be found in several publications of the IEEE. <u>See</u> IEEE Spectrum August 1985, p. 30 and IEEE Communications Magazine, August 1985, Vol. 23, No. 8, p. 37 and May 1985, Vol. 23, No. 5, pp. 31-45.

2 A fiber cable containing 20 fibers and extending 100 miles would, for example, add 2,000 fiber-miles to the total.

3 See I. E. E. E. Communications Magazine; August 1985, Vol. 23, No. 8, p. 37.

repeater and terminal locations), it will be possible to minimize initial investment and to take advantage of such new transmission technologies when they become available as future circuit requirements dictate.

Discussion

Early publicly reported estimates of the magnitude of fiber deployment tended to be high for several reasons. First, there was some double counting of those who planned to use fiber by contract and those who planned to construct systems. In addition, reported construction did not always reflect capacity sharing arrangements. Second, it is not unusual to expect a carrier to build a significant amount of spare capacity in cable systems due to the relatively high cost of laying cable. [4] By deferring expenditures on repeaters and terminal equipment used to activate individual fibers, a carrier can reduce its up-front investment and risk. There is evidence, however, that some entrants have scaled back their original proposals, possibly in response to dire predictions of a capacity glut. One of the larger ventures, Fibertrak, indefinitely suspended its plans. Third, the reporting of circuit-mile capacity by the press did not consider the fact that there may be large differences in cost and capacity resulting from different repeater and termination technologies. This has also tended to obscure the fact that a significant additional investment may be needed to fully exploit that capacity. Often press reports did not draw a proper distinction between route miles of fiber and fiber-miles of fiber.

Although I have attempted to deal with the above problems, other problems which may be inherent in the data provided to me include possible confusion over definitions and terminology relating to the status of each fiber in a cable. In some instances there may also be differences in the way a company gauges fiber system completion. My approach in this report has been to try to avoid a capacity measure which could easily be overestimated and at the same time to provide a means for evaluating potential available capacity. In keeping with this approach I have attempted to report information relating to total fibers installed rather than just fibers which now carry voice circuits.

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4 While only a limited amount of loading data is available, it is estimated that typically less than 30% of installed fibers are now carrying traffic. The remaining "dark" fibers are available to be equipped with repeater and multiplexing equipment in the future.

Many entrants are constructing systems which will provide from 8 up to about 24 fibers. One carrier reportedly has plans for single mode fiber system cross sections as large as 40-50 fibers. Typically, some form of joint construction or contractual arrangements are being made for the largest cross sections. U. S. Telecom and Lightnet, for example, had made some sort of contractual arrangement to share the high construction cost of these systems by using a single cable in some routes for both of their systems. Although it is possible that some of the joint ventures whose costs may be offset by shared construction may anticipate cross sections larger than 24 fibers, care must be exercised to avoid double counting of capacity where partial data is available.

It is estimated that over 900,000 fiber miles of new long haul fiber systems will be installed by yearend '86, or be completed early in '87, primarily in the eastern half of the U. S. A conservative capacity estimate of 5,000 circuits per fiber pair yields a total potential capacity of more than 2 billion long haul circuit-miles. 5 Of this amount about 650,000 fiber-miles will be installed by carriers other than AT&T. AT&T's fiber capacity thus accounts for less than one-third of the total. Nevertheless, AT&T's indicated fiber capacity alone, in terms of the number of potential equivalent circuit- miles using present technology, is comparable to the number of active circuit miles in AT&T's Long Lines telecommunications network just prior to divestiture. 6

In addition to these long haul facilities, 18,000 route miles (more than 400,000 fiber miles) had been deployed by yearend 1985 by the local Bell operating companies by an amount that was comparable to the entire amount deployed by the interexchange carriers. This is expected to increase by more than 50% and may nearly double again by yearend 1986. However, 1986 data for all operating companies is not yet available. These findings were somewhat surprising in light of the fact that the Bell operating companies' operations up to now have generally been limited to intra-LATA markets.

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5 One can conservatively translate this into 6 billion monthly minutes of use on fully developed systems, assuming only 50 hours of average use per month per circuit and an average length of haul of 1,000 miles. The length of haul for the average conversation carried by AT&T prior to divestiture was between 500 and 600 miles and average montbly usage, while more difficult to estimate, appears to have been closer to 80 hours.

6 As of yearend 1983 the total active capacity in AT&T's Long Lines network was about 700 million circuit miles.

While there were a number of problems in obtaining consistent operating company data in accordance with the objectives outlined in this report, it does not appear that any gross magnitude error is inherent in the data. 7

I have tabulated both fiber deployments of interexchange carriers and local operating company deployment. Due to potential problems noted above with some of the operating company data and partial availability of 1986 data, the discussion here primarily deals with the interexchange carriers. Data for both the interexchange carriers and the Bell Operating Companies aggregated to the Regional Holding Company level is summarized in tables 1 and 2. The five largest interexchange carrier systems range in size from about 130,000 fiber miles up to about 260,000 fiber miles. This corresponds to route mileage ranging from a little over 3,500 miles up to about 11,000 miles. There are, of course, risks associated with this significant deployment of capital inherent in the above ventures which represent more potential long haul capacity than the total heretofore available using existing technologies. Nonetheless, these systems provide a delayed benefit as they are one means for reducing future carrier costs of providing service.

There appear to be three or four major national networks emerging, besides that of AT&T, in which both resellers and full service carriers are participating. One of the more interesting approaches is that of the National Telecommunications Network (NTN) which will link up 7 small or regional systems, but will provide corporate autonomy for the participants. 8 The recent merger of GTE Sprint and U.S. Telecom into a jointly owned

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7 Problems with operating company data included confusion over which fibers were to be reported and in some cases the lack of data covering the specific requested data definition. Pacific Telesis, for example, reported for 1985 only fibers equipped to handle traffic and did not include so-called "dark" fibers. The 1986 data estimated all fibers. Similar problems may have caused the average fiber cross section for Southwestern Bell to change dramatically in 1986. Wide variations in the average fiber cross section suggests other possible data problems such as the possible inclusion of subscriber loop fiber in the total without an appropriate notation. Resolution of many of these problems will be made when 1986 data becomes available and thus could not be included in this report.

8 This venture consists of Litel, Microtel, Southern Net, Southland Fiber Net, LDX Net Consolidated Network, Inc. and Williams Telecommunications. (See table I.) After 1986, it is planned to add other planned regional networks to this system, thereby extending coverage to the West Coast.

subsidiary will result in another very large national network. Early plans did not include extending fiber to the West Coast. 9 MCI claims that 5,580 route miles will be completed by yearend 1986 comprising more than 150,000 fiber miles of potential capacity. Lightnet also has a significant amount of construction complete and appears to have the largest average fiber cross section of any of the carriers. Significant change in average cross section from 1985 to 1986, however, leads me to suspect possible problems with the Lightnet data .

AT&T, MCI, U.S.-Sprint and other carriers with large nationwide construction programs all appear to be spreading their construction over 3 or more years, while many of the participants constructing smaller regional networks have already completed their networks or plan to have the bulk of their networks completed by yearend 1986. AT&T's present construction plans extend into the early 1990's. It appears that the larger carriers typically use 18 to 24 fibers in the major portions of their networks. Although the incremental cost of additional fibers in an initial build may be less that $1000 per fiber mile, it appears that carriers building significantly larger cross sections may be taking on added risk of excess capacity. The fact that new transmission technologies providing 3 or 4 times the capacity of existing technologies over the same fibers should be available in a few years adds to that risk.

It is estimated that total investment in interexchange carrier fiber systems by yearend 1986 will easily exceed 2 billion dollars and may be as high as 4 or 5 billion dollars. 10 The initial active circuit loading levels of fiber networks is typically quite low. Thus, the initial cost per active circuit is significantly higher than the level the carriers have likely used to justify their construction. It is the potential capacity of these systems and cost per unit of exploitable capacity, however, which is especially striking because newer technology will likely permit the underlying fiber to carry many more circuits than now seem feasible. This

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9 The cost of laying fiber over the Rocky Mountains is probably the main reason that early deployments have been limited to the Eastern United States. Digital microwave may be a more cost effective alternative in mountainous terrain. At least one company has plans for use of digital microwave in portions of its network.

10 In large fiber systems such as the ones dealt with in this report it is estimated that system investment ranges between $65,000 and $115,000 per route mile or between $2,600 and $5,200 per fiber mile.

and the declining cost of fiber systems per unit of capacity in relation to older technologies has made capital ventures by new entrants into telecommunications markets attractive. While present termination technologies could provide in excess of 2 billion 2-way circuit miles on the planned deployments as of yearend 1986, new 1.7 G bit/s terminal and repeater technologies which should be available in as little as two years would easily triple or quadruple that capacity. It should be evident that while the short term risks are high, those carriers with an adequate base of installed fiber and the ability to survive a period of low utilization will be in the best position to compete over the long term.

Several recent developments may slightly alter the picture which was evident last year. The first is the recent merger of U. S. Telecom and GTE-Sprint into a jointly owned subsidiary. Further, merger or consolidation activity may occur. Second, total reported yearend 1986 fiber system deployment has just about doubled from yearend 1985. While this rapid growth is expected to abate, further system expansion is expected by several of the carriers. Finally, developments to significantly increase the potential capacity of existing investment appear to have accelerated and systems providing as many as 25,000 circuits on a single fiber pair may be available within only two years.

It is expected that overall interexchange carrier capacity will continue to grow but at a slower rate than that experienced to date. 11 Many entrants seem to be providing duplicate capacity on certain routes by following a pattern set by AT&T and are adhering fairly closely to AT&T's existing and planned cable routes. This, in part, is due to the fact that many of the routes follow railway lines and areas of heavy commerce. Perhaps the most dense corridor will be the one connecting Washington, Philadelphia, or New York in the East with Chicago in the Midwest. In the Chicago-Cleveland corridor, AT&T and at least 3 other providers have their own systems. Adequate "filling" of systems with revenue producing circuits is necessary to take advantage of fiber system economies and may be accomplished through greater network ubiquity. This will require interconnection of regional networks and extensions of routes to the West coast and other population centers. Despite obvious risks, such considerations provide both a stimulus for completion of the proposals and an obvious motivation for mergers and joint ventures.

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11 Probably the best leading indicator of new fiber construction is sales of raw fiber. Indications are that this is down significantly from last year, despite the fact that 1986 construction may have doubled the installed fiber base at yearend 1985.

Conclusions

There is little doubt that even if there were no further fiber construction, an enormous expansion in long haul transmission capacity has already occurred during 1986 alone, and a very significant amount of potential capacity now exists. This is particularly the case in certain route cross sections, such as the Chicago-East Coast corridor. It should also be noted that new low dispersion fiber, will permit wider repeater spacing, allowing future fiber system construction costs to decline further. While the present rate of construction may be slowing, this may stimulate continued construction in the future. In addition, new transmission technologies will increase the total available capacity on existing investment. These factors, along with the desire to increase overall network loadings by providing greater network ubiquity will provide the basis for future competition in the interexchange markets. While the extent of overall excess capacity does not appear to be as exaggerated as some early press reports suggested, over the long term the effects of the available base of installed fiber will likely become apparent as repeater and terminal technologies improve, interexchange carrier access charges decline and competitive advantages of particular carriers become more visible.

Table I

Estimated Fiber Deployment by Major Interexchange Carriers

	Route- Miles		Fiber -Miles		Average Fiber Cross Section	
Year:	1985	1986	1985	1986	1985	1986
NTN Partners:						
Litel	881	971	13720	14800	15.6	15.2
Microtel	800	1070	8000	10700	10.0	10.0
Southern Net	188	1616	1880	16160	10.0	10.0
Southland Fiber Net	277	277	2770	2770	10.0	10.0
LDX Net	670	1336	16080	32064	24.0	24.0
Consolidated Network	310	360	4030	4680	13.0	13.0
Williams Telecommunications	214	2824	2140	52008	10.0	18.4
NTN Subtotal	3340	8454	48620	133182	14.6	15.8
RCI	580	580	6960	6960	12.0	12.0
Electra	493	493	10194	10194	20.7	20.7
MCI	2560	5580	79200	167400	30.9	30.0
AT&T	5677	10893	136248	261432	24.0	24.0
GTE-Sprint	1200	*	24000	*	20.0	*
U. S. Telecom	4100	*	98400	*	24.0	*
U. S. - Sprint	*	9073	*	172469	*	19.0
Lightnet	2200	3512	52800	158785	24.0	45.2
Totals	20150	38585	456422	910422	22.7	23.6

* As of July 1986 U. S.-Sprint was set up by merger of U. S. Telecom and GTE toll facilities. U. S.- Sprint is now a jointly owned subsidiary of U. S. Telecom and GTE.

Notes: NTN is an acronym for National Telecommunications Network.
See text for data qualifications.

Table II

Estimated Fiber Deployment by Local Operating Companies
Aggregated to Regional Holding Company Level

	Route- Miles		** Fiber- Miles		Average Fiber Cross Section	
	1985	1986	1985	1986	1985	1986
Ameritech	3200	4500	77700	109200	24.3	24.3
Bellsouth	3830	*	50807	*	13.3	
BellAtlantic	1240	*	83085	149174	67.0	
NYNEX	1606	*	83384	*	51.9	
Pacific Telesis **	3647	*	26109	80210	7.2	
Southwestern Bell **	1268	2783	66389	73054	52.4	26.3
U. S. West	3527	5017	47341	70082	13.4	14.0
Total	18318		434815		23.7	

* Data not yet available

** Fiber mileage was supposed to reflect total fiber installed, including so called unequipped or dark fibers. Pacific Telesis 1985 data, however, only includes equipped or traffic carrying fiber. Similar differences in reporting by the other regional holding companies, while not expected, may have resulted in underestimates of the total amount of fiber in the ground. Significant variation in average fiber cross section as can be seen in the Southwestern Bell data is a possible result of this problem.

Note: Data shown for 1986 is estimated.

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