

Excessive(?) Entry of National Telecom Networks, 1990–2001

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Abstract

We document entry and capacity expansion in US long-distance fiber-optic networks before and during the “telecom boom.” We disentangle the many swaps and leases between networks in order to measure owned route miles versus route miles shared with other carriers. Entry appears much more moderate when these shared miles are not counted. We conclude that entry was excessive primarily with regard to swaps and leases, but much less so with regard to the physical building of the networks.

JEL classification: L11, L13, L96

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1 Introduction

During the late 1990s there was tremendous investment and entry of new firms in the North American long-haul telecommunications industry. These expansions were driven by very fast demand growth for Internet and other data-oriented telecom services and by exponential decreases in the cost per bit transmitted using fiber optic communications equipment. But by 2001, competition and slowing demand growth were squeezing the profits of these carriers, and an equally unprecedented slowdown in spending occurred. The problems in the telecommunications sector have been blamed for dragging down growth in the entire U.S. economy.

As the expansion turned to bust, discussion of “excessive entry” and a “fiber glut” became increasingly common. Generally the fiber glut story revolves around three premises. First, Internet growth was not as fast as expected, and in particular, not as fast as Worldcom claimed (Odlyzko 2003). Second, the still-high growth rate of data traffic was “. . . not nearly fast enough to use all of the millions of miles of fiber-optic lines that were buried beneath streets and oceans in the late-1990s frenzy.”¹ Third, the equipment used to send data over fiber optic cable improved dramatically so that each strand of fiber could carry many more gigabits of data: “Perhaps never before has the efficiency of an industry’s technology gotten so far ahead of demand.”²

¹Yochi Dreazen, “Behind the Fiber Glut – Telecom Carriers Were Driven By Wildly Optimistic Data on Internet’s Growth Rate,” *The Wall Street Journal*, September 26, 2002, pg. B1.

²Dennis Berman, “Behind the Fiber Glut – Innovation Outpaced the Marketplace,” *The*

These gloomy statements have become the conventional wisdom: there was excessive entry of fiber-optic networks based on overoptimism and strategic behavior. But that interpretation is hard to justify because it says that firms invested without regard to demand and without a rational way to achieve a return on investment. In this paper, we demonstrate that the conventional wisdom is misleading and in many cases just plain wrong. It arises from two errors, one conceptual, and one factual.

The conceptual error is a misapplication of railroad history to fiber networks. Though both are long-distance transport infrastructure with expensive rights of way, the economics only partially overlap. In fiber networks there is a big difference between sunk investments – actual miles of right of way – and non-sunk investments that create “virtual networks” through relatively fungible swaps and leases of conduit space and fiber. There was nothing equivalent to virtual networks in railroading, and that makes the fiber case very different.

The factual error is that most observers have simply assumed that stated route miles of fiber indicate the total length of the fiber-optic networks. This is incorrect, because most public data mix real and virtual networks, creating confusion about the actual amount of sunk investment in facilities. We have collected new data that distinguishes the two types of networks, and we find that more than half of 1990–2001 investment was non-sunk. This makes the fiber boom much easier to explain, and it also means there is less “capacity overhang” than many people think.

Wall Street Journal, September 26, 2002, pg. B1.

Before moving further, let us clarify the industry segment we are discussing. The national fiber-optic networks connect major cities using cable laid along railroad, gas pipeline, and other rights of way. This industry segment is not regulated by the FCC or other government agencies, except to the extent that there may be environmental and safety restrictions regarding rights of way. National networks sell high capacity links between specific cities and nationwide coverage to all cities. Their customers are primarily long-distance telephone companies, Internet backbone providers, and large corporations. Many of the companies are vertically integrated into some of these downstream segments. The most famous example is AT&T which during the period of this study also offered long distance telephone service; other firms like Level 3 offer their own Internet backbones.³ For this paper, we are focusing on the most basic level only – the physical infrastructure that allows these networks to operate. These firms have additional interest because many of them were involved in scandals, including Worldcom, Global Crossing, Qwest, and Enron.

There are several complementary types of infrastructure that we do not study here. These include regional and metropolitan fiber-optic networks and local access networks such as telephone and cable television – the latter two are surveyed by Woroch (2002). Most of the traffic on the national networks has to traverse these other networks as well, but they operate in distinct markets. It is not practical to provide national service by combinations of regional networks,

³Economides (2004) analyzes the Internet backbones and describes how the competition in national fiber networks has made entry quite easy in the backbone market.

nor is it practical to provide more than very limited regional service on a portion of a national network. While all types of networks experienced major investment in the late 1990s, it was the national fiber-optic networks that appeared to be the most “overbuilt” and were most implicated in the collapse.

To our knowledge there is no economics literature analyzing the national networks’ growth and decline. Indeed, very little data has been collected on which firms entered when and where. Until 1998, Jonathan Kraushaar of the Federal Communications Commission published a yearly update on long distance fiber optic networks, but this was discontinued just as industry investment took off. In this paper we present newly collected data that merges Kraushaar’s work with publicly available information on firms’ entry decisions up to the end of 2001.

Section 2 discusses the relevant theory of firm entry, investment, and sunk costs and applies it to the national fiber-optic network industry. We also compare the telecom crisis to the problems of late nineteenth century railroads. In section 3, we describe our data sources and methods of data collection. We analyze the pattern of entry and the decrease in industry concentration in section 4. Section 5 concludes.

2 Sunk Costs and Fiber-Optic Networks

The building of the national fiber-optic networks is another chapter in the peculiar history of U.S. infrastructure industries. This history started with

the canal boom of the early nineteenth century, reached its most dramatic episode in the railroad booms and busts of the late nineteenth century, and has continued since then with electricity transmission, trucking and Interstate highways, and cable television among others. All of these industries have been politically as well as economically important, and all have been characterized by financial instability and/or heavy government regulation.

In particular, the recent telecom boom and bust has been compared to the nineteenth century railroad experience, and the two do appear similar (Miller 2005). In both cases, a large number of firms gained access to rights-of-way between major cities, built multiple parallel routes, and then engaged in intense competition that left many of them bankrupt. But we discuss below that the key to this comparison is the nature of sunk costs in the two industries, and that in fact the two are quite different in this regard.

We can think about sunk costs more precisely by looking at the game-theoretic literature in industrial organization. Sutton (1998) has argued that for any technology-intensive industry, entry can be modeled in two stages. In stage 1, firms make irreversible investments that determine their characteristics, such as product variety or quality or geographic reach. These investments are industry-specific sunk costs, so the firms do not exit the market later in the game. In stage 2, the firms compete according to Cournot, differentiated Bertrand, or some other type of competition. The terms of this competition are affected by the stage 1 decisions. Sutton suggests that a very loose requirement for a solution to this game is a criterion of “viability.” That is, firms will not

make stage 1 investments that they cannot recoup as operating profit in stage 2. So one question for us concerns the viability of the initial, sunk investments in fiber-optic networks.

Conceptualizing these two stages in telecom is difficult because of the complexity of the technology. In the related area of local broadband networks, Faulhaber and Hogendorn (2000) argue that the basic game structure can be refined: In stage 1, firms invest in *network scope* that determines where they can offer service in geographical space. Then stage 2 can be divided into two parts. In stage 2a, firms invest in *traffic capacity* that determines how much they can produce in each area that they serve, and in stage 2b they compete in each area subject to these traffic capacity constraints. The key to this interpretation is that network scope is a sunk cost because investments like rights-of-way, conduits, and utility poles have no alternative use and are not fungible. But traffic capacity is not sunk because investments like telephone switches and fiber-optic terminals can be resold or redeployed and are therefore fungible.

Under this interpretation, the key to competition between infrastructure firms is geography, since the sunk network scope investments mean that once a firm enters a territory it can commit not to leave. Traffic capacity, on the other hand, may affect short-run competitive outcomes (for example, it might lead to Cournot outcomes in the manner of Kreps and Scheinkman (1983)), but it does not carry long-run commitment value.

When we apply these ideas to long-haul fiber optic networks, we will see

why these networks are so different from railroads and many other types of infrastructure. The difference is not in Stage 1. In that stage, building fiber network scope involves securing a right of way, burying protective conduits in this right-of-way, building “huts” to house equipment at intervals along the route, and placing fiber-optic cable inside the conduit.⁴ Each strand of fiber has very large data capacity, each cable contains many strands of fiber, and many networks are built with multiple conduits.⁵ It is prohibitively expensive to acquire new rights-of-way, so the networks generally follow highways, railroads, and natural gas pipelines. In fact, several of the major networks are associated with companies that own these rights-of-way. Williams, for example, was a natural gas pipeline owner, while Qwest was originally a division of the Southern Pacific Railroad. There is some irony in the comparison with nineteenth century railroads because in many cases the very same rights of way were used during the fiber boom.⁶

The difference with the railroads comes in Stage 2a, where traffic capacity is installed. Fiber networks use terminal equipment that takes electronic data from many sources, switches and combines it into channels, and converts it to optical signals using lasers. This is called “lighting” the fiber in the industry jargon. Such equipment is expensive but can be moved, resold, expanded, and contracted given sufficient lead time. There are some sunk costs involved, so

⁴Planning of these networks is described and modeled in Lanning et al. (2000).

⁵There are periodically advances in the quality of fiber-optic strands, so systems in which it is easier to install new fiber have an advantage in the long run.

⁶The geographic distribution of Internet infrastructure is discussed in Greenstein (forthcoming).

the quantity of lit fiber has some short-run commitment value. But the key is that the amount of traffic capacity is not closely tied to the sunk network scope, since more or fewer conduits can be used, and more or fewer fibers can be lit.

Firms that owned real network scope took advantage of this flexibility. They sold “indefeasible rights of use” (IRUs) by means of which firms could obtain either space in conduits or dark fiber (fiber-optic cable with no terminal equipment attached at the ends). Since most networks contain several conduits and many fibers, it is possible to sell IRUs to the same route several times. For example, two major networks, Frontier and GTE, obtained IRUs to most of the route miles in Qwest’s network in 1997 and 1998.

IRUs convey many of the rights of ownership, but they are typically limited to 20 years, can be dissolved by mutual agreement, and are frequently abrogated by bankruptcy courts. Furthermore, despite the careful language of IRU agreements, in an industry with rapidly changing technology there are likely to be many noncontractables that could render an IRU economically obsolete earlier than its legal expiration.

Let us define the two types of network scope more precisely:

Definition: *Real network scope* consists of the actual ownership of rights-of-way, conduits, and buildings that support a fiber-optic network.

Definition: *Virtual network scope* consists of indefeasible rights of use that allow a carrier to install fiber and/or electronics within the real network of another carrier.

This, then is the key difference that largely invalidates the railroad analogy: many fiber-optic networks are based on IRUs, so total *real* network scope is much less than the number of national networks would suggest. Firms that go bankrupt and hold IRUs are likely to exit the industry once and for all. Only those firms that actually own real networks are committed to continuing employment of their assets even in the face of bankruptcy reorganization. Since 2001, the owners of real network scope have recognized hundreds of millions of dollars in “termination revenue” when IRU are returned to the networks. Examples include 360Networks handing back all IRUs to Level 3 in 2005 in TouchAmerica handing back its IRUs to Qwest in a 2003 bankruptcy settlement.⁷

Contrast this situation to the nineteenth century railroad boom. Arthur Hadley (1885) discussed how the sunk-cost nature of railroad rights-of-way created perpetual instability in the railroad industry. When competition on a route (New York to Chicago was particularly competitive) was too great to support all the lines on the route, some railroads went bankrupt. But their hard investment in right-of-way had no alternative use, so the insolvent line

⁷See Level 3’s 10-K Filing with the SEC, March 3, 2007 pg. F-28, and Qwest’s 10-K March 11, 2004, pp. 25–26. Qwest’s March 18, 2005 10-K, pg. 47 provides a nice description of the termination revenue: “In 2003 we recorded gains totaling \$82 million related to the early termination of services contracts and IRU arrangements with certain customers. Under these arrangements, we received cash up-front and we were recognizing revenue over the multi-year terms of the related agreements. In these cases where the customers elected to terminate the agreements prior to their contractual end and we had no continuing obligations, we recognized the remaining portion of the deferred revenue as other income as of the termination date.”

simply emerged from bankruptcy with its debt reduced, and the number of competitors remained the same. This pattern, and the companies' collusive attempts to combat it, eventually led to regulation of the industry.

3 Data

Given this essential characteristic of the fiber industry, our goal was to collect data that carefully differentiate between *real route miles* which measure real network scope versus *virtual route miles* which reflect virtual network scope based on IRUs. The sum of these, *total route miles*, gives a measure of short-run industry concentration, while real route miles alone gives an upper limit on concentration if all IRUs were dissolved.⁸

During the period 1986-1998, the FCC collected route-mileage data from the inter-exchange (long distance) telephone companies. These data were compiled and analyzed by Jonathan Kraushaar in what was then the Commission's Common Carrier Bureau, and the reports continue to be available at the FCC's website. The FCC data collection proceeded through voluntary questionnaires and telephone calls, and they received a high response rate. Toward the end of the sample period, they expressed concern that fiber route miles were being double-counted, precisely for the reasons we discussed above.

⁸Note that each route mile typically contains many strands of fiber-optic cable, so measures of "fiber miles" or "strand miles" are usually many times larger than route miles.

3.1 Which Firms Were in the Industry?

Our first step was to define the universe of firms involved in national fiber-optic networks. Our source was the map “North American National and Regional Fiberoptic Long-Haul Routes Planned and In Place” published by KMI Research and dated May 2002. The following U.S. national carriers are listed on this map and also incorporated in our data:

Name	Former Name(s)
360 Networks	Worldwide Fiber
AT&T	
Broadwing	IXC
Digital Teleport (DTI)	
ENRON	
EPIK	Florida East Coast RR
Global Crossing	Frontier
Level 3	
McLeod USA	CapRock
Metromedia	
Pathnet	
Qwest	Southern Pacific RR, LCI
Sprint	
Touch America	Montana Power
Velocita	PF.net
Williams	WilTel
Worldcom	MCI, LDDS

Table 1: National Fiber-Optic Networks on KMI Map and Included in Sample

Of these, 360Networks is the only Canadian carrier with a U.S. national network. Several of the carriers (DTI, EPIK, Metromedia, Pathnet, and Touch America) are essentially regional networks that expanded to national reach through IRUs. Because of their national profile, we include them in our data. Two other U.S. national carriers are listed on the KMI Map but not included in our data. The first is Aerie Networks, which was proposed but never built.

The second is Business Telecom which was a North Carolina regional carrier with some IRU capacity on the east coast of the United States.

The sample is limited to firms that either achieved national reach or had announced aspirations to national reach. Regional networks (which include the local telephone companies) are not counted. They actually include the majority of fiber in the United States, but they do not compete in the same national market. Providing national coverage by piecing together circuits from regional networks is too expensive and unreliable to be competitive. Regional networks listed on the KMI Map but excluded from our data are Alltel, Black Hills Fibercom, C3 Networks, Columbia Transcom, Connectiv, Dominion Telecom, Dukenet, El Paso Global Networks, Electric Lightwave, Entergy, Florida Fiber Network, FPL Fibernet, GPU Telecom, Iowa Network Services, ITC Deltacom, Kentucky Data Link, Logix Communications, MP Telecom, NEON, Norlight, Onvoy, Palmetonet, Progress Telecom, SON Communications, Telergy, Time Warner Telecom, and Valley.net. We also exclude firms that purchased access to national networks but did not own any mileage of their own and did not participate in any swaps of IRUs; these were customers, not peers, of the carriers listed.

While compiling data on the firms listed in Table 1, we discovered IRU transactions with three additional carriers, and we added them to the sample. They are listed in Table 2.

Dynergy is an energy company which purchased a single, large IRU from Level 3 in 2001. XO is a telecom services firms which purchased IRUs to a

Name	Former Name(s)
Dynegy	
Genuity	GTE
XO	NEXTLINK

Table 2: National Fiber-Optic Networks not listed on KMI Map

nationwide network in 2000. Genuity was based on a national virtual network acquired by GTE in 1997-98. It also did not own its own national fiber, but it did purchase a midwest regional network that included real route miles. This regional network was not counted as part of Genuity’s national network totals in their own documents or in our data.

3.2 Route Mile Data

For each network, we obtained a network map, either from the company’s web site (in most cases) or from an Internet service provider reseller (for Qwest, MCIWorldcom, McLeodUSA, and ENRON). We first checked these maps against the KMI Map discussed above, and found only minor inconsistencies which related to routes planned but not actually constructed. These are generally shown on the KMI Map but not on the networks’ own maps.

For each carrier, we checked the firms’ annual reports and investment prospectuses as filed with the Securities and Exchange Commission and available through the online EDGAR database (primarily forms 10-K and S-4). Some companies included very meticulous network data with these filings, while others simply mentioned route miles in passing.

For AT&T, Sprint, and MCI, the networks were substantially complete in

1990, the company reports matched the FCC figures, and we have no evidence that these companies engaged in any trades involving IRUs prior to 1998. Thus, we used the FCC figures for these networks up until 1998. For all other networks we were able to reconstruct the process of building the network on a route-by-route basis, matching location and route-mile data from company reports against the route maps and cross-checking with the FCC data where applicable. Note that we did not attempt to compute route-mileages from the maps, but simply used them to be sure that all pieces of the network were accounted for in the company reports.

In nearly all cases, the promotional and technical materials made available by telecom firms do not differentiate between the two types of route miles. But as we built up data on each network, we determined which routes are based on IRUs and which real right of way. In some cases, routes are jointly owned, in which case we count one-half the miles for each of two owners and one-third for each of three. Jointly owned routes are a much smaller portion of total mileage than are IRUs and do not greatly affect the totals.

To supplement the maps and company reports, we also searched each company's press releases using the archives on LEXIS/NEXIS. In many cases, firms obtained routes by swapping IRUs to their own right of way for IRUs to the right of way of their competitors. The firms often announced and promoted these swaps as an inexpensive way to build their network quickly. In several cases, firms swapped access to a preexisting IRU for a preexisting IRU on another firm's route, so that the swaps could be more than one layer deep. Be-

cause of this, we frequently know that a route is based on an IRU but cannot definitely determine the source of that IRU. Fortunately, this problem does not affect the computation of virtual versus real route miles.

Although we are quite confident that the routes identified as shared are in fact shared, there are probably additional IRUs and swaps that were not reported. As such, the database is conservative since it attributes all other miles as owned. We were not able to find as complete data on Sprint as on other networks. All our sources suggest that Sprint's network was largely completed before the sample period and not significantly expanded thereafter. For years in which no data was available for Sprint, we have assumed no expansion and entered the previous year's figure.

4 Entry and Investment

We now document the pattern of entry and show that a large proportion of investment is virtual miles. When only owned miles are considered, entry appears more moderate and industry concentration more typical of a high-sunk-cost industry.

Table 1 shows total network route miles (owned plus shared) by firm for the period 1990-2001. We include both "lit" and "dark" miles since the dark miles would still be expected to exert competitive pressures in the long run. During the early 1990s, three large long distance companies, AT&T, MCI, and Sprint, had been joined by Williams, a natural gas pipeline company that built

a nationwide fiber optic network. Williams sold this network to Worldcom in 1995.⁹

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
360 Networks (Worldwide Fiber)									1,181	7,971	11,976	14,176
AT&T	32,398	32,500	33,500	35,000	36,022	37,419	38,704	38,704	39,576	39,576	42,551	46,500
Broadwing (IXC)	914	914	914	1,257	1,357	1,365	2,025	5,500	9,300	15,700	18,500	18,500
DTI								927	1,500	7,250	14,360	17,835
Dynegy												16,000
ENRON									3,400	16,281	16,281	16,281
EPIK (Florida East Coast RR)										3,801	11,500	1,244
Genuity (GTE)								5,283	12,000	17,500	17,500	20,800
Global Crossing (Frontier)								4,932	9,620	13,000	20,000	20,000
Level 3									410	9,084	15,236	15,639
MCI	16,000	16,700	17,040	19,793	21,460	21,049	23,096	25,234				
McLeodUSA (+CapRock)	332	332	332	332	519	519	621	866	5,052	8,036	16,600	26,000
Metromedia									3,099	18,000	18,000	18,000
Pathnet										478	1,500	
Qwest (Southern Pacific RR, +LCI)	1,210	1,406	1,406	1,406	1,408	1,408	3,977	7,101	15,000	25,500	25,500	23,700
Sprint (limited data)	22,093	22,725	22,799	22,996	22,996	22,996	23,432	23,574	23,574	23,574	23,574	23,574
Touch America (Montana Power)								2,770	9,770	10,466	17,370	21,370
Velocita (PF.net)												4,000
Williams	9,700	9,700	9,700	9,700	9,700	0	0	0	9,300	17,000	20,800	28,700
Worldcom/MCIWorldcom (LDDS)					1,300	11,000	12,589	19,619	47,529	47,806	47,806	47,806
XO (NEXTLINK)											16,000	16,000
Total	82,647	84,277	85,691	90,484	94,762	95,756	104,444	134,510	190,311	281,023	355,054	396,125
% change		2.0%	1.7%	5.6%	4.7%	1.0%	9.1%	28.8%	41.5%	47.7%	26.3%	11.6%

Table 3: Total Route Miles, 1990-2001

In 1997 – two years after the Netscape initial public offering launched the Internet as a major commercial force and one year after passage of the Telecommunications Act – growth in route miles increased rapidly. This was a combination of expansion by existing networks and *de novo* entry. By 2001, there were 19 national networks, but profits were low and Pathnet had exited the market, while EPIK contracted back to its Florida base. In 2002, almost all of these firms were in bankruptcy.

EPIK’s sudden contraction from national to regional network demonstrates that the network scope of some of these companies did not consist of sunk assets. Tables 2 and 3 show *real* route miles of each firm in each of the years

⁹The FCC’s Worldcom data appears to include regional networks. We use only national route miles reported by Worldcom (and its predecessor LDDS) in SEC filings.

and the percentage of total route miles that were real.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
360 Networks (Worldwide Fiber)									1,181	3,709	5,309	6,764
AT&T	32,398	32,500	33,500	35,000	36,022	37,419	38,704	38,704	39,576	39,576	41,064	44,009
Broadwing (IXC)	914	914	914	1,257	1,357	1,365	2,025	4,647	6,028	11,186	12,666	12,666
DTI								927	1,500	1,900	4,650	4,900
Dynegy												0
ENRON									1,740	1,740	1,740	1,740
EPIK (Florida East Coast RR)										790	894	1,244
Genuity (GTE)								0	0	0	0	0
Global Crossing (Frontier)								0	0	0	0	0
Level 3									410	9,022	15,174	15,577
MCI	16,000	16,700	17,040	16,793	18,207	17,858	19,595	25,234				
McLeodUSA (+CapRock)	332	332	332	332	519	519	621	866	5,052	8,036	9,475	9,740
Metromedia									0	255	255	255
Pathnet										239	980	
Qwest (Southern Pacific RR, +LCI)	1,210	1,406	1,406	1,406	1,408	1,408	3,977	7,101	14,467	16,322	16,322	14,522
Sprint (limited data)	22,093	22,725	22,799	22,996	22,996	22,996	23,432	23,574	23,574	23,574	23,574	23,574
Touch America (Montana Power)								137	3,263	3,308	7,820	8,147
Velocita (PF-net)												1,462
Williams	9,700	9,700	9,700	9,700	9,700	0	0	0	1,830	10,101	14,812	17,800
Worldcom/MCIWorldcom (LDDS)					1,300	11,000	12,589	13,878	41,788	42,065	42,065	42,065
XO (NEXTLINK)											0	0
Total	82,647	84,277	85,691	87,484	91,509	92,565	100,943	115,068	140,409	171,822	196,798	204,463
% change		2.0%	1.7%	2.1%	4.6%	1.2%	9.1%	14.0%	22.0%	22.4%	14.5%	3.9%
Total owned as % of total	100%	100%	100%	97%	97%	97%	97%	86%	74%	61%	55%	52%

Table 4: Real Route Miles, 1990-2001

At the beginning of the 1990s, all networks were owned outright by the carriers. But entry in the later 90s involved so many swaps and IRUs that many “national” carriers owned only a small percent of their rights of way, and in a few cases owned none at all. The IRU strategy does not appear to have been a temporary expedient to expand network reach, since most carriers were decreasing their percentage owned even as they served more route miles.

The bulk of total investment in network route miles came during 1998, 1999, and 2000. The majority of the new miles in this period were shared. New right of way built in this period is mostly accounted for by upgrades to the old AT&T and MCIWorldcom networks and the entry of three new major networks, Qwest, Level 3, and Williams (see Figure 1). One way to interpret this is that four incumbents were joined by three entrants and fringe firms that

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
360 Networks (Worldwide Fiber)									100%	47%	44%	48%
AT&T	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	97%	95%
Broadwing (IXC)	100%	100%	100%	100%	100%	100%	100%	84%	65%	71%	68%	68%
DTI								100%	100%	26%	32%	27%
Dynegy												0%
ENRON									51%	11%	11%	11%
EPIK (Florida East Coast RR)										21%	8%	100%
Genuity (GTE)								0%	0%	0%	0%	0%
Global Crossing (Frontier)								0%	0%	0%	0%	0%
Level 3									100%	99%	100%	100%
MCI	100%	100%	100%	85%	85%	85%	85%	100%	100%	100%	57%	37%
McLeodUSA (+CapRock)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	1%	1%
Metrmedia									0%	1%	1%	1%
Pathnet										50%	65%	61%
Qwest (Southern Pacific RR, +LCI)	100%	100%	100%	100%	100%	100%	100%	100%	96%	64%	64%	61%
Sprint (limited data)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Touch America (Montana Power)								5%	33%	32%	45%	38%
Velocita (PF.net)												37%
Williams	100%	100%	100%	100%	100%	100%	100%		20%	59%	71%	62%
Worldcom/MCI/Worldcom (LDDS)					100%	100%	100%	71%	88%	88%	88%	88%
XO (NEXTLINK)										0%	0%	0%
Total	100%	100%	100%	97%	97%	97%	97%	86%	74%	62%	56%	53%

Table 5: Real as a Percentage of Total Route Miles, 1990-2001

were partially dependent on the seven major networks.

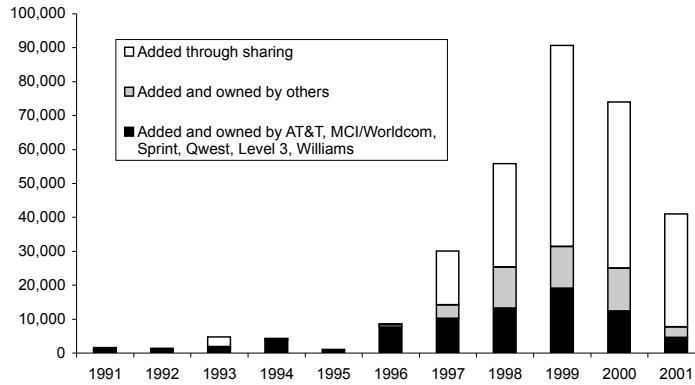


Figure 1: Yearly Additions to Total Route Miles, 1990-2001

These data suggest that the industry did not experience overbuilding and ruinous competition along the same lines as the railroads of the late 1800s. Rather, actual construction of new rights of way represented more modest entry, but the swaps of IRUs created a very competitive environment in which prices fell.

4.1 Measuring Concentration

One goal of this paper is to answer the question of whether too many national networks were built. We can take a first cut at this answer by simply looking at the total number of firms in the industry. The first column of Table 6 shows the number of networks with a positive number of total route miles for each year. These numbers are quite high even in 1990, and rise to a very competitive industry of 19 firms by 2001. As we have seen, however, many of these networks were based on virtual route miles, so the second column of Table 6 shows the lower number of networks that had positive *real* route miles. The number is still very large for a very high fixed cost industry.

Year	> 0 Miles		> 9,700 Miles	
	Total	Real	Total	Real
1990	7	7	4	4
1991	7	7	4	4
1992	7	7	4	4
1993	7	7	4	4
1994	8	8	4	4
1995	7	7	4	4
1996	7	7	4	4
1997	11	9	4	4
1998	15	12	6	4
1999	17	15	11	6
2000	18	15	17	7
2001	19	15	17	8

Table 6: Number of National Networks, 1990-2001

Clearly not all of the networks were equal, and route miles can be used as a measure of geographical coverage and market power. We have confined the sample to networks that publicly aspired to national network coverage. Pathnet and Velocita did not actually achieve such coverage during the sample period,

while all the others served all major American cities. (Pathnet announced a larger network but went bankrupt while building it, and Velocita completed such a network after 2001.)

Other than incumbents AT&T, MCI, and Sprint, the earliest entrant network was WilTel, which reached 9,700 route miles in 1989 and was sold to Worldcom in 1995. This network served 78 US cities, including New York, Washington, D.C., Atlanta, Chicago, Minneapolis, St. Louis, Dallas, Houston, Denver, Los Angeles, and San Francisco.¹⁰ Thus we use 9,700 route miles as a threshold for national presence.¹¹ The remaining columns in Table 6 show the number of firms with networks above this threshold, using both total and real route miles as measures. This does not change the totals much using total miles, but for owned miles the number of firms falls drastically.

Another important aspect of fiber-optic networks is *route diversity*. Data networks depend on extremely high reliability, and even outages of less than 1 second can cause significant financial damage to customers because systems may crash, take time to reboot, and important pieces of data may be lost. To prevent these problems, networks strive to develop multiple routes between all cities and employ switching systems that can reroute traffic within milliseconds if a link is cut. In the process of developing route diversity, more small cities can also be served, adding to the competitive strength of the network.

As a result, networks of various sizes can serve different types of traffic.

¹⁰Josh Gonze, "LDX, WilTel To Merge Net Forces," *Network World*, 6/22/87, pg. 9.

¹¹In Table 3, EPIK appears never to have reached this threshold, but it briefly rose above it during 2001 before giving up its IRUs and reassuming its regional network role in Florida.

Prior to attaining national coverage, a network can serve a limited set of city-pairs. A sparse national network can add nationwide networking to its menu of products. Denser networks can serve more secondary cities and they can also offer a higher level of reliability.

Thus, the competition for basic connectivity between major U.S. cities is essentially symmetric between all networks above a certain size, but the competition for basic connectivity in smaller cities and for high-redundancy networks is less symmetric. Larger networks have an advantage in these latter two markets. We use a Herfindahl-Hirschman Index (HHI) based on route miles to give some sense of the level of competition in these other markets. The HHI and the equivalent number of equal-sized firms (calculated from the inverse of the HHI) for each year based on total miles and owned miles appear in Table 7. Not all of the networks use their capacity equally, but these measures based on route miles do provide a guide to the potential long-run industry structure.

The difference between competition in terms of total miles and owned miles is striking. Using total miles, the industry moved from an oligopolistic HHI to a very competitive one. But using owned miles, the industry remained above the 1,000 limit for government scrutiny of mergers based on the Department of Justice's *1992 Horizontal Merger Guidelines*. Still, there were eight equivalent equal-sized firms using owned miles, which is a large number of competitors by the standards of previous infrastructure developments such as railroads and early telephone.

Year	HHI Total Miles	HHI Owned Miles	Equal-Sized Firms Total Miles	Equal-Sized Firms Owned Miles
1990	2,767	2,767	3.6	3.6
1991	2,743	2,743	3.6	3.6
1992	2,764	2,764	3.6	3.6
1993	2,740	2,788	3.6	3.6
1994	2,658	2,696	3.8	3.7
1995	2,723	2,770	3.7	3.6
1996	2,529	2,561	4.0	3.9
1997	1,778	2,233	5.6	4.5
1998	1,425	2,110	7.0	4.7
1999	892	1,546	11.2	6.5
2000	708	1,315	14.1	7.6
2001	674	1,299	14.8	7.7

Table 7: HHIs and Equivalent Number of Firms, 1990-2001

4.2 Were Investments in Route Miles Needed?

We cannot directly observe the output of these communications networks; such data are difficult to measure even for the owners of the networks themselves and are not publicly available. But we can proxy for industry output with two measures: industry revenue and Internet traffic. For the revenue measure, the revenues of the networks themselves are the seemingly logical focus of interest, but many firms, such as AT&T, derive most of their revenue from lines of business not directly related to their long-haul networks. The firms do not report sufficiently disaggregated revenue to correct for this problem. As an alternative, we use total revenue of the U.S. telecoms industry as an index for opportunities to build additional route miles. The source for these data is the International Telecommunications Union *Yearbook of Statistics*, 2003 and 2000 editions. Revenue is measured in 1995 dollars using the consumer price index.

Year	Industry Revenue	Revenue per Mile	
	\$ Billions	Total	Real
1990	156	1.89	1.89
1991	155	1.84	1.84
1992	160	1.86	1.86
1993	163	1.80	1.87
1994	170	1.80	1.86
1995	175	1.83	1.89
1996	206	1.97	2.04
1997	220	1.64	1.91
1998	230	1.21	1.64
1999	247	0.88	1.44
2000	259	0.73	1.32
2001	261	0.66	1.28

Table 8: Revenue and Revenue per Mile, 1990-2001
(1995 dollars)

Industry revenue is reported Table 8. We then attempt to create some notion of capacity utilization by calculating industry revenue per mile. We report this measure for both total and real miles in the final two columns of Table 8.

In 1990 there appear to have been modest opportunities to expand route miles since there was a gradual increase in miles in the succeeding years. An interesting feature of these data is that in 1995-97, there were arguably opportunities to add route mileage (based on revenue), particularly when looking at real miles only. By the end of the sample period, revenue per mile had fallen sharply. Real miles show much less of this trend than total miles due to the extensive use of shared mileage.

5 Conclusion

We have reviewed the conventional wisdom that there was “excessive” investment in national fiber-optic networks that ended with a crash in 2001. We showed that there is a conceptual and a factual problem with this conventional wisdom. The conceptual problem is that sunk investment in rights of way is not closely tied to non-sunk investment in traffic capacity that allows these networks to be used. This invalidates the analogy with early railroad investment, where right of way and traffic capacity were inextricably linked.

The factual problem with the conventional wisdom is that previous data on network route miles has not distinguished between real route miles representing right of way and virtual route miles representing leased capacity within others’ rights of way. We have sorted through each firm’s SEC reports and press releases, and we have been able to discover which routes are based on sunk investments in right of way and conduit and which are based on relatively non-sunk investment in IRUs. We find that more than half of total route miles added during the period 1990–2001 were based on non-sunk forms of investment. We conclude that the loss-producing level of competition that prevailed circa 2001 was due more to the willingness of firms to sell IRUs than to actual over-investment like that which occurred in the nineteenth century railroad boom.

We calculated industry-wide changes in revenue per route mile. This measure suggests that there were opportunities for increased investment in route miles in the mid-1990s, but that investment after that proceeded faster than

revenue growth.

Our general conclusion is that the “excessive” element of national fiber-optic network investment was the very extensive sharing of route miles using IRUs. This sharing led to remarkably low concentration for an industry with such high fixed, sunk costs. Not including sharing, the underlying investment in owned route miles was more moderate, and led to more reasonable (if still low) industry concentration.

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