Chapter 9

The Impact of Local Competition on Network Quality

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1. INTRODUCTION

Quality is a moving target. When the role of the telecommunications network was to transport analog voice signals, quality was a relatively simple issue. Good quality meant affirmative responses to the questions: (a) When I pick up the telephone do I usually get dial tone? (b) Does the call go through promptly? or (c) When I reach the called party can the conversation be clearly heard? These subjective standards could be passed even under circumstances in which quantitative technical measurements would have shown that significant signal distortion, delay, and noise interference were present.

As the strategic importance of business communications increased and as networks evolved to incorporate digital data and multiplexed voice transport, more stringent, quantitative quality standards became necessary. If a digital line carrying hundreds of multiplexed calls is out of service even briefly or if a line carrying critical data experiences bit errors due to a high noise environment, significant financial losses can result.

In the mid- to late 1980s, small, entrepreneurial, Alternate Local Transport (ALT) companies formed to pursue the niche market for high-reliability and high-quality, dedicated, digital transport. Using fiber optics, state-of-the-art electronics, and redundant network elements, they were able to offer high-speed digital circuits of greater quality than previously available in the public network. Even though these fiber networks were of limited extent, sometimes spanning only a few miles in and around an urban center, they served important markets.

They provided long-distance carriers (IXCs—Interexchange Carriers) with local links between their multiple-switch locations (POP—Point of Presence) and/or to the switches of other IXCs with nearby POPs.

Beyond serving the IXC market, the ALT companies were also able to address a niche market of select corporate end-users. Large corporations that had locations on the ALT network could be provided with high-speed, dedicated access linking their PBXs directly to long-distance carrier POPs. Such dedicated circuits, also available from the Local Exchange Carriers (LECs), are known as *special-access* circuits, and hence ALTs are also called Competitive Access Providers (CAPs). The presence of this ALT/CAP competition stimulated a major LEC competitive response involving network development, service, and pricing for dedicated transport.

Although dedicated transport was the point of entry, competitive activity in the local exchange is growing rapidly both in terms of services offered and areas served and is commonly believed to be leading the market toward a universally competitive telecommunications marketplace in the United States, including local as well as long-distance service. New participants (e.g., cable television companies, out-of-region LECs, PCS companies, etc.) are taking an interest in this competition and are investing in alternatives to the public network. Regulatory developments at both the FCC and state level are progressively increasing the arena in which competitive entry is possible. Interconnection between ALT networks and LEC networks for both dedicated and switched access has been mandated by the FCC for interstate traffic and by some PUCs for intrastate traffic. We are headed toward a "network of networks"—an infrastructure of interconnected but competing networks of varying quality. In this future environment the potential results of competition on network quality will be more complex and perhaps more controversial.

The purpose of this chapter is to address both the current and future impact of this competition on network quality.

2. LOCAL TRANSPORT FOR INTEREXCHANGE CARRIERS

Most ALT companies began operations by serving as interexchange carriers. One application was to provide trunking between an IXC's multiple switches or "points of presence" in a large city. Another was to provide trunks between the "points of presence" of different IXCs so that they could aggregate traffic, lease capacity, and so on. Traditionally, the IXCs' choices had been either to build these facilities or to buy dedicated circuits from the LEC. The presence of an ALT created a third choice. The advantages for the interexchange carrier were that the new ALT network provided service that incorporated the latest fiber and digital technology, was priced under the LEC price umbrella, could be used to diversify network structure, was more customer responsive, and created pressure on the LEC to lower prices, improve service, and improve network quality. Thus, IXCs saw ALTs as a means to increase the quality of their local-access facilities while reducing their costs.

The IXCs were interested in obtaining local, high-speed digital links at DS-1 and DS-3 rates (1.544 Mbps and 45 Mbps—capable of supporting 24 and 672 voice channels, respectively). As greater numbers of voice-grade circuits are multiplexed onto a single, high-speed, digital-fiber channel, the potential outage impact produced by a fiber-cable cut or other malfunction is multiplied, increasing the need for high reliability. Initial ALT service and network quality were strongly influenced by the IXCs. As the dominant, and sometimes sole, customer, the major IXCs imposed their own certification standards as a prerequisite for doing business with an ALT.

High reliability was achieved by using multiplexers with redundant electronics and automatic switchover in case of component failure. Further reliability was achieved by adopting robust network architectures with the capability to automatically switch at high speed (~50 msec) from transmitting over a primary fiber to an alternate fiber in case of the loss of signal in the primary fiber. Such fiber circuits were called *self-healing* and produced network availability numbers that were previously unavailable. One measure of network reliability is *circuit availability*, presented in the form of the percentage of the time the average circuit was available for service during the year. In 1988, Teleport Communications Group, then serving predominantly the New York IXC market, reported[1] that for the year it achieved an average circuit availability of 99.99%, which is equivalent to 52.6 min of outage per year. No copper-based circuits could guarantee such performance.

Techniques for achieving high reliability continued to advance, with secondary fiber paths being physically separated from primary fiber paths to decrease vulnerability to a common disaster. Network monitoring was used to detect and counteract system quality degradation before hard failure had occurred. Diverse fiber routing usually took the form of fiber *rings* in which the primary and secondary fiber paths operated in counterrotation around the ring so that no two points could be isolated by a single cable cut. By 1991, Teleport Communications Group was reporting average circuit availability of 99.999% (equivalent to 5.26 min of outage per year) in its new Boston network. (The achievement of "five nines" is now a performance requirement for many ALT local operations managers.)

Since the initiation of fiber-optic-based competition in local transport in 1985, such competitive activity has grown steadily. By the end of 1993, over 30 ALT/CAP companies were providing services on networks in 72 Metropolitan Statistical Areas.[2] Although these networks covered over 5,000 miles, linked more than 4,000 major commercial buildings, and provided access to hundreds of long-distance carrier "points of presence," total ALT industry revenues for

1993 were less than $350 million (0.4% of total LEC revenues) with only $200 million due to dedicated transport. However, this relatively modest market capture by ALT/CAPs stimulated strong reductions in LEC tariffed prices for dedicated transport, which declined by more than 50% over this period. Interexchange carriers saw even larger price reductions on their high-traffic density routes. Through combined volume and term discounts, additional savings of up to 70% of tariffed prices were attainable.[3]

3. SPECIAL-ACCESS TRANSPORT

Nearly all ALT/CAP companies have seen their business mix begin with an initial dependence on providing IXCs with POP-to-POP links and shift to a broader market, providing end-users to POP special-access links. This progression is illustrated in the case of Intermedia Communications of Florida (one of the few ALTs whose stock is publicly traded) as shown in Table 9.1.[4]

Dedicated special-access fiber links (usually at DS-1 speed) between the premises of large telecommunications end-users and the POPs of their chosen IXCs reduce the cost of access because the circuit price is flat rated and not a function of traffic volume. Most special-access end-users are in telecommunications-sensitive industries such as financial services, telemarketing, and so on.

Although their influence is not as great in the special-access market, IXCs still play a strong role. Traditionally, IXCs have often been the purchasers of special access from LECs on behalf of end-users. Even when end-users deal directly with LECs and ALTs, their choice of vendor can depend on IXC recommendations. Therefore, the IXCs' opinion can also drive vendor network quality in the special-access market.

The market demand for ALT/CAP special-access service suddenly accelerated following a fire on May 8, 1988, in a Hinsdale, IL wire center of the Illinois Bell Telephone company. Most of the 42,000 local lines and 118,000 local and long-distance trunks in the wire center were put out of service,[5] impacting thousands of business and residential customers in Chicago's southwestern sub-

TABLE 9.1
Intermedia Communications—Evolution to End-User Dependence

Year	*% Recurring Revenue From End-User to POP Transport*
1988	0%
1989	28%
1990	38%
1991	42%
1992	48%
1993	53% (Est.)

urbs. The last circuit was not restored for 28 days. Overnight, redundancy and route diversity for special-access circuits became a focused concern of telecommunications managers at large government and corporate installations throughout the country.

Telecommunications managers sought to diversify their circuits among multiple carriers rather than to totally displace any one carrier. There is evidence that end-users with critical telecommunications requirements view the ability to acquire access circuits from multiple vendors as desirable no matter how high the quality of the network offered by any single vendor. In a section of the Boston financial district where MFS, Teleport, and New England Telephone all serve the same buildings with fiber circuits, a survey of 21 major end-users was taken by Connecticut Research in 1990.[6] The survey showed that 24% of the sample had special-access circuits from two vendors, and another 24% had such circuits from all three vendors. Although there was some functionality differentiation among the vendor services, the primary driver for the end-users seemed to be to obtain the maximum possible diversity in both network and service provider in order to assure maximum network reliability and survivability.

Local Exchange Carrier central office wire centers are often points of concentration for dedicated as well as switched traffic. In addition to a central office switch and other equipment for handling switched traffic, some wire centers are nodes for dedicated transport and contain equipment to multiplex, demultiplex, and cross-connect nonswitched traffic. In September 1992, the FCC mandated[7] that LECs must file interconnection tariffs so that ALT/CAP companies could interconnect with dedicated-access circuits at the LEC central office wire center. Except in the case of space limitations or existing PUC regulations, this interconnection was to be accomplished through physical collocation of ALT/CAP equipment in the LEC wire center. Otherwise, the interconnection was to be accomplished by virtual collocation at a point near the wire center under conditions functionally equivalent to physical collocation.

This greatly expanded the ALT/CAP-addressable market because off-net locations could be served. End-users could buy dedicated LEC transport from their location to the wire center and transfer to the ALT/CAP network for dedicated transport from the wire center to the IXC POP. This interconnection potentially raised a new set of issues bearing on network quality because overall network performance now required a certain degree of operational cooperation between competitors.

These operational issues were largely solved without major problems. LECs built out cages in the wire center for interconnectors (including ALT/CAP companies) who paid an installation charge and a monthly lease based on floor space. Interconnectors placed their own equipment inside the locked cage, purchased electrical power from the LEC, and extended their network management systems to include performance surveillance over the link into the wire center.

4. SWITCHED-ACCESS TRANSPORT

The FCC extended interconnection to include switched-access traffic as well as dedicated-access traffic. Tier 1 (>$100 M annual revenue) LECs were required to file tariffs by November 1993. The transport portion of switched access (from the central office to the IXC POP) appears no different than dedicated access. In fact, LECs have been able to increase the efficient use of dedicated circuits by combing switched- and dedicated-access traffic to use the available bandwidth (a process called *ratcheting*) of the same trunk. Switched-access traffic differs from dedicated-access traffic in that it enters the central office on a switched circuit and is billed on the basis of multiple elements including minutes of use. With collocation, ALT/CAP companies can compete only for the transport element of switched access.

Because switched-access traffic greatly exceeds dedicated-access traffic, regulators were concerned that the financial impact on LECs not be too abrupt and imposed a residual interconnection charge (RIC), initially at 80%, on interconnectors. Interconnection for switched access, as well as dedicated access, potentially increases the number of economically desirable points of interconnection from a few high-density central office wire centers in urban areas to many wire centers, even in smaller cities. Therefore, future issues of network quality will increasingly take place in an environment of a web of intimately interconnected, multiple competing networks.

5. LOCAL EXCHANGE CARRIER RESPONSE TO COMPETITION

Local exchange carriers responded to the competitive challenge to meet the high reliability needs of IXCs and special-access end-users and installed their own self-healing and diverse fiber rings. Truly diversified fiber routing throughout an entire fiber system has been difficult for both LECs and ALTs to achieve; and, in practice, many systems retain some "spurs" that are subject to single-point failure. Most LEC conduit was originally installed for star or tree-and-branch cable deployment and not for rings. Both LECs and ALTs find that building owners often object to the construction of additional telecommunications entrance facilities through the walls of their structures.

In their reports of fiber deployment, the Industry Analysis Division of the Common Carrier Bureau of the FCC began including information on LEC fiber rings in 1989.[8] Many of these LEC installations are not counterrotating rings but are path-switched, multiple-fiber systems that are often physical stars but logical rings. Generically, all these self-healing networks are referred to as *rings*. The 1989 FCC report showed that LECs had deployed fiber rings in 14 cities, primarily in the vicinity of competing ALT networks, and the 1990 report[9] showed 56 cities. By 1991,[10] the number of cities had grown to 127, and by 1992[11] to 188. GTE alone began a 50-city deployment of advanced fiber rings in 1993.

US West announced in May 1990 that it would deploy fiber rings in five major cities—Denver, Minneapolis/St. Paul, Seattle, Portland, and Phoenix—with circuit availability performance of 99.99%. This announcement also included the most aggressive performance-guarantee standard publicly offered. US West guaranteed that any customer on the ring that suffered a network outage in excess of 1 sec would receive a full month's credit of the circuit's lease rate. This was followed by other LECs offering performance guarantees for transport on new self-healing fiber networks.

In addition to deployment of self-healing fiber rings in high-density traffic areas, LECs created special units such as NYNEX's "Enterprise Services" to provide high-quality, expedited service to the customers served by these networks.

6. NETWORK QUALITY RESULTS

The Regional Bell Operating Companies have published[12] their standards for network availability of dedicated access circuits as shown in Table 9.2.

These are operational standards, and actual network availability achieved has not been reported. Because the network technology and equipment used by RBOCs and by ALT/CAP competitor networks is equally available from the same vendors, new fiber-network installations should be capable of identical system performance. However, RBOCs and other established carriers must deal with the fact that they have an installed base of copper and older fiber circuits as well as the more capable new fiber circuits.

Bell Communications Research (Bellcore), the central research organization of the RBOCs, has published standards[13] for fiber-network performance. This reference establishes an outage standard for short (<25 mile) interoffice fiber trunks[14] of 16 min per year (99.997% availability) for DS-1 and 8 min per year (99.9985% availability) for DS-3 transport.

TABLE 9.2
RBOC Published Standards for Network Availability—1992

Carrier	*Network Availability Standard*
Ameritech	99.975%
Bell Atlantic	99.925%
NYNEX	99.700% (IntraLATA)
NYNEX	99.925% (InterLATA)
Pacific Bell	99.975%
Southwestern Bell	99.975%
US West	99.700% (99.990% Fiber Ring)

Metropolitan Fiber Systems (MFS), one of the largest ALTs with 14 networks, has been outspoken on the issue of network quality. They have noted that network quality is more than physical parameters such as network circuit availability. Network quality from the end-user's perspective also includes the organizational responsiveness of the carrier in terms of installation and repair intervals. Therefore, MFS has published[15] comparisons of its own standards and performance for network availability, installation interval, and service repair interval versus those of the Regional Bell Operating Companies (RBOCs).

MFS indicated that, although its standard for network availability was 99.99%, it routinely exceeds this standard. Its average circuit availability in the first quarter of 1992 was 99.99898% (5.36 min per year) for DS-1 circuits and 99.99976% (1.26 min per year) for DS-3 circuits. For this same period, MFS achieved average installation intervals of 7.8 calendar days and 7.6 calendar days, respectively, for DS-1 and DS-3 circuits. MFS also achieved average repair intervals of 90 min and 23 min, respectively, for DS-1 and DS-3 circuits. These intervals are significantly better than the published standards of the LECs.

The only relevant parameters routinely reported through the FCC's Automated Reporting and Management System (ARMIS) for the LECs is Average Repair Interval and the Average Missed Installation Days for special-access services. Table 9.3 provides a sampling of these data.[16]

When Teleport began operations, installation intervals for DS-1 circuits from New York Telephone exceeded 90 days, and DS-3 circuits were not available. Under the competitive pressure from Teleport, NYT installation intervals have steadily decreased. Noting that its market share for private lines in Manhattan had fallen below 65%, NYT launched a "Take Back New York City" campaign in April 1993. A key element of this campaign is the NYNEX Enterprise Services offering. This service, initially available only in lower and midtown Manhattan, offers 10 speeds (including DS-1 & DS-3) of up to 100 Mbps. The network

TABLE 9.3
RBOC Reported Performance for Installation and Repair Interval—1993

Carrier	*Avg. Missed Installations (Days)*	*Avg. Repair Interval (Hours)*
Ameritech	5.0	2.3
Bell Atlantic	4.7	1.9
Bell South	3.7	4.4
NYNEX	4.2	5.9
Pacific Telesis	3.2	4.8
Southwestern Bell	4.0	2.8
US West	10.6	8.5
Contel	2.9	NA
GTE	3.0	6.2
United	NA	3.2

features a central network control center that monitors network performance 24 hours a day. End-users in buildings on the network can have new circuits activated in 24 hours. In case of an outage, service restoral in 4 hours is guaranteed. In spite of these extra features, prices are 15% to 20% less than for current private line offerings.

7. END-USER VIEWS OF COMPETITION AND NETWORK QUALITY

Although end-users do not speak with a single voice, a spokesman[17] for a group of large telecommunications users has expressed his view as follows: "Based on their experience over the last twenty years, large users believe that competition is far superior to regulation as a means of satisfying their needs. Users, therefore, strongly support the introduction of local exchange competition wherever feasible."

Particularly as competition has shifted to direct marketing to corporate end-users, LECs and ALT/CAPs have both sought to position themselves as value-added service providers. Although comprehensive quantitative data are not available, IXCs and special-access end-users believe they have seen increased network availability and reliability, enhanced service responsiveness, and lower circuit prices as a result. They believe, based on these results, that increased competition in the Local Exchange has increased network quality for special-access circuits, and it promises to do likewise for other network service offerings as competition spreads to include them.

8. OTHER MEASURES OF NETWORK QUALITY

Network availability is a very basic indicator of network quality. More detailed indicators of quality include measurements such as bit-error rate (BER), errored seconds, and so on. Such quality measurements are of greater importance as networks are used for data transmission. Most carriers and ALTs quote BERs of 10^{-9} for fiber circuits. Teleport quotes 99.9% error-free seconds. Customers with critical data needs can obtain performance standard quotations from vendors, but such standards are not routinely published nor are actual performance figures given.

9. FIBER-NETWORK EVOLUTION

Initial fiber networks were quite simple. They were, in fact, pseudo-networks, composed of collections of asynchronous point-to-point links. A voice-grade channel entering the system passed through several stages of multiplexing before being transported over the fiber link as a broadband optical signal. At a node the process was reversed through several levels of demultiplexing. The single, voice-grade signal could then be terminated or rerouted through a digital cross-connect before being remultiplexed for further transmission. This requirement for multiple interfaces and back-to-back multiplexers at every node created many potential points of failure. With the introduction of SONET (Synchronous Optical Network), this situation is changed. The synchronization in SONET allows the identification of the bits associated with a selected, single-voice channel without demultiplexing the data stream. Among other things, SONET provides the control to "drop and insert" a single-voice channel in a broadband optical signal. Therefore, with SONET, true fiber-optic networks can be created.

SONET technology found its first application in path-switched, self-healing ring structures. In this direct substitution for asynchronous links, no complexity is introduced. Traffic is still moved essentially between two points, and if the link is disrupted in the primary path, the entire signal is transmitted by the secondary path. SONET improves the ring performance only by reducing the number of multiplexing interfaces. Bellcore establishes a reliability standard for a 10-mile interoffice SONET trunk[19] of 4 min per year (99.9992% availability).

In more advanced applications, SONET rings are line switched rather than path switched. If a channel fails, the signal is looped back at the network node. This makes more efficient use of the network bandwidth and allows network structures that are not point-to-point rings but that may have distributed end-points and may be a mesh rather than a ring. Network management and operations support systems standards for fully supporting such complex networks have not been developed. Carriers have implemented SONET in various simple configurations with the intention of later upgrades to more sophisticated architectures. However, because these initial implementations lack general interoperability, they may represent barriers to future global network development and interconnection.

Widespread deployment of complex SONET mesh networks will present operational as well as technical challenges for LEC and ALT/CAP carriers with interconnected networks. Even basic timing signals, which are critical to successful SONET operation, raise the issue of maintaining master clock references across networks. Successful comprehensive operation of future interconnected networks will require a degree of cooperative interaction among competitors.

10. SUMMARY

Competition in local exchange services is at a very early stage. The impact on network quality, to date, has been limited primarily to dedicated access circuits in major urban centers. In these locations, high-volume end-users and interexchange carriers have experienced increased network quality as both LECs and

ALT/CAPS have competed for their business and have provided self-healing fiber transport. The loss of less than 1% of revenue has stimulated both tremendous LEC investment in upgrading network quality and sharply lowering prices for services subject to competition.

This competition is rapidly accelerating, and major capital investment in the deployment of fiber networks is underway by all participants. These facilities continue to incorporate more advanced technology, including SONET electronics, integrated network management, and complex, interconnected, multiple network architectures. In a fully competitive "network of networks" telecommunications environment, many issues of network performance will depend on close cooperation and coordination among competing network operators. Successful network interconnection will not be limited to physical linkage but will include network signaling and database sharing, as well as administrative and engineering cooperation.

An early test of cooperative interaction among local telecommunications competitors came in the February 1993 bombing of the World Trade Center in New York. Response to this disaster in terms of maintaining service and rerouting circuits was greatly aided by the communication and coordination processes established just 1 year earlier by the New York Carriers Mutual Aid and Restoration Pact.

Attainment of a high level of operational cooperation among network operators in a fully competitive environment can be a more important factor than network technology and architecture in future network quality. Soft issues may be a larger determinant of network quality than hardware in the networks of the future.

ENDNOTES

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14. See Note 13, Section 2-2.
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17. See Note 13, Section 2.2.4.