Testimony of

Eli M. Noam

Professor of Finance and Economics
and
Director, Columbia Institute for Tele-Information
Graduate School of Business
Columbia University

Hearing on

Network Reliability and Regulatory Oversight

Before the
Subcommittee on Government Information, Agriculture and Justice
U.S. House of Representatives

October 2, 1991
Mr. Chairman, members of the Subcommittee, thank you for the opportunity to testify here today on a matter of growing importance. I appreciate your efforts to consider the issue of network reliability. I speak here as an academic, but also as a former state public service commissioner.

My message to you today has five parts:

1. **Competition solves some issues of reliability, but exacerbates others.** It is not the overall problem-solver for reliability.

2. **Concerns about reliability and the consequences of network failure will only grow in the future.** Network diversification and complexity and our growing economic dependence on information transport and processing means that network reliability problems will not disappear with a wave of a magic technological or regulatory wand.

3. **It is not economically possible or even desirable to avoid all reliability problems; our goal must be to provide an ability to choose a level of reliability commensurate with our willingness to pay.**

4. **Regulatory oversight in this area should go beyond the collection of information.** In particular, it should include incentives that tie reliability and quality to financial performance, a role for government as a catalyst for inter-industry collaboration in this area, and international cooperation.

5. **The investment by government agencies in telecommunications reliability is not necessarily optimal.**

Recent events have brought the critical matter of network reliability to the public’s
attention. The FCC’s recent proposal to collect more information from carriers suffering outages is certainly welcome. But I believe that collecting more information, convening meetings, accelerating research on other industries or even establishing special staff task forces should be supplemented by economic incentives. I will outline a proposal to that effect.

I. The sources of problems of reliability include the following:

1. The growth of the information economy. The information economy has yielded a heightened reliance on the information transport infrastructure, especially by the service sector, which in the past decade has been the economy’s main growth area.

   A recent study by the New York City Partnership in collaboration with Booz Allen & Hamilton estimated that the loss of telecommunications service for a single day in Manhattan would disrupt more than $1 trillion in financial transactions. The ripple effect on other institutions across the country could well be even larger.

   Data-dependent users are aware of their vulnerability. According to a survey of banking, securities and insurance executives, network reliability was ranked more important to business location decisions than technology availability, service/support or cost.

2. Economies of scale have led to a growing concentration of network traffic. The economies of scale of network transmission and switching made possible by recent advances in fiber optics and electronic switching have concentrated telecommunications traffic. As a
result, vulnerability is increased, especially at information "chokepoints" such as the nodes where long-distance networks interconnect with local exchanges. Thus, while it is a marvel that two hair-thin fiber optic lines can carry 80,000 telephone calls at one time, it also means that one mistake with a backhoe can disrupt millions of calls, affecting more customers than ever before. And fiber trunks take longer to repair than coaxial lines.

3. **Diversification of networks and the emergence of competition.** As new networks enter the market, and as users supplement or replace public transmission and software-defined offerings with customized additions, the technical complexity and diversity of the overall network system increases. Competition in telecommunications has led to faster cycles of introduction of new services, technologies and software, and to alternative transmission paths, which are good things, but also to shorter testing periods. We can expect more such cases, and they may happen more frequently.

4. **Increased network sophistication and complexity.** It's not just a matter of someone being asleep at the switch. Many of the problems associated with the best-known network failures have been direct outgrowths of network sophistication. The FCC staff's recently found that "most [reliability] problems are attributable to inadvertent side effects of efforts to upgrade network capabilities." Consider, for example, the January 15, 1990, AT&T failure when a bug in the computer code that operates AT&T's digital Signaling System 7 (SS7) caused a nationwide network failure for nine hours affecting every switch in the network. SS7 is useful and efficiency enhancing. But, it is also new and has experienced unanticipated
problems. It is almost impossible to totally ensure that a bug, hidden within millions of lines of computer code, would be detected before the problem began. This is one negative side-effect of the positive impact of competition on telecommunications progress.

Similar problems have affected other countries, too. Japan and Sweden, two of the world's best telecommunications systems, had to contend with SS7 failures.

5. **Network interconnectivity and interdependence.** The interconnectedness of networks means that faults may become difficult to pinpoint and remedies harder to implement. A break in one carrier's service can have effects on customers of other networks, and degrees of quality offered by the various components become interdependent. When transmission links interconnect into each other in a "chain of transmission" as is common, without anybody having end-to-end responsibility, competitive pressures can lead to a quality free-rider problem, as carriers allow their own link to degrade so as to avoid extra costs associated with maintaining their link above the network's weakest link.

The literature does not provide unambiguous answers on what to expect to happen to quality as regulatory restrictions are being reduced. As one article states, "Economists now have at their disposal a well-developed body of analysis dealing with price and quality behavior in various market structures, but they have no comparable body of analysis relating to the qualitative and alterable attributes of products that consumers value." Starting with

---

Chamberlin, the literature held that a monopolist would provide quality lower to a competitive industry with similar cost conditions. But this thinking was challenged by Swan and then Levhari and Peles who found market structure to have no impact on quality. This non-intuitive result was first viewed as depending on seven strict assumptions, but subsequent work showed that several of them could be relaxed. Swan's argument still holds under certain conditions, including constant returns to scale. "A monopoly offers the same product as a competitive industry; its only sin is to charge more." The implication is that regulation, by lowering rates, may also lower quality.

But this, too, is disputed. Some authors found that price regulation or a maximum price

---


6 Levhari & Peles, op. cit.; Swan, op. cit.
ceiling may actually improve quality. For example, an unregulated monopolist would set quality specially low for those users who hold weak preference for quality in order to be able to charge an extra premium to users with a high quality preference. If a price cap is set on the latter price, the lower quality of the option will rise. But other analyses found that under certain conditions price regulation lowers quality.

Thus, the economic literature is of only limited help, even without getting into the particularities of telecommunications — network externalities, interconnectivity, and multidimensional or product dimensions.

Taking a look at the actual marketplace, it is plain that liberalization of entry and competition has led in recent years to manifestations of rivalry in quality. For example, AT&T's 1989 advertising includes claims that MCI's fax network leads to 87% more unreadable pages than if AT&T had been chosen. US Sprint, similarly, stressed the signal quality of its all-fiber network that lets the user "hear a pin drop." But it should be noted that the provision of user choice need not necessarily lead to the selection of higher quality. Given the option, many customers could well select lower technical quality if the price is right. Some users prefer a jalopy to a Cadillac.


9 One should also note that there has been some quality rivalry even in a monopoly system through internal performance competition among corporate managers and sub-units.
This also gets to what economists call the "lemon" problem: If consumers are unable to verify the quality or reliability of goods they are being offered, they make suboptimal quality choices and excessively rely on price factors, to the detriment of quality.\textsuperscript{10}

Furthermore, advantages of competition may be partly or fully offset by reducing overall economies of scale and scope, and by adding technical incompatibilities and planning problems - between different networks, between networks and customer equipment, and between equipment types. And while these arguments have lost weight by some self-serving use in the past, they cannot be ignored.

6. Private Burdens on the Public Network. The interconnected network of networks poses new challenges to network reliability. For example, the traditional "public" network is available as a back-up if faults develop in a private network or if capacity is reached; hence private networks can adopt a less costly standard for reliability. This, in turn, leads to a greater variance of traffic flow in the public network, which complicates the engineering of such networks for peak capacity.

Thus, with the decentralization of networks and their interconnection, independent suboptimizing decisions on investment and capacity might not result in overall efficiency.

7. Incentives for redundancy are decreasing. Because of increases in competitive

market forces, network providers are not likely to build as much redundancy into their networks as in the past. Traditionally, networks are engineered with sufficient redundancy to cope with breakdowns — failure in one location channels traffic through an alternate route. But some portion of that redundancy may be ascribed to what economists call the Averch-Johnson effect and regulators call "goldplating." Many economists believe that the incentives in traditional rate-of-return regulation has often encouraged overinvestment in quality. Under the incentive-based price-cap regulation that is becoming more widespread, the cost of overinvestment is borne by shareholders rather than ratepayers. Even if this results in lower quality, this does not necessarily mean a less efficient outcome from a societal standpoint. Quality, without reference to cost, is a meaningless concept. Furthermore, to reduce all risk of failure leads to what statisticians call a Type II error, in this case, by overcaution leading to excessively slow introduction of new technology.

The problem is that carriers may not pick the optimal point of reliability. Price caps reward network operators for cutting costs. While this should come through increased productivity and efficiency, the price cap plan also provides incentives for cutting back on maintenance costs and network investment.

Offsetting this problem to some extent is that under price caps, a customer lost is a profit lost to the carrier, because one cannot simply burden the remaining customers in the way possible under rate-of-return regulation.

This is not to suggest that price caps per se must be dropped. Rather, the price cap formula should be modified to include quality, as I will suggest below. In New York State, network quality at first declined with a rate freeze, but then rose after more vigilant regulatory
attention. In the United Kingdom, consumer complaints about service quality increased at the same time as price caps were implemented, but subsequently declined again.\textsuperscript{11}

8. **Incentives for Government Users to Invest in Redundancy.** As noted above, private sector executives in data intensive industries rank network reliability as a top concern. Large private sector users have a bottom line to protect, and with full information available they are likely to make the economically correct investment — at least from their perspective — in expensive redundancy. Public sector agencies such as the Federal Aviation Administration, on the other hand, do not have the same incentives, because they do not stand to lose any business. Given tight budgets, they may well try to falsely economize. They may end up driving a car without a spare tire,\textsuperscript{12} and at times, predictably, get a flat. To set incentives for government agencies right is something this Subcommittee should look into.

**II.** *What should government do?*

1. **Will competition work? The economic literature.**

   Overall, my reading of the theoretical literature is that it is divided on the question of whether competition leads to higher or lower quality levels.

---


2. Should there be government-set standards?

User choice, when accompanied by information, would settle many reliability issues by allowing users to choose the level of reliability most appropriate to their needs and pocketbooks. However, enduser choice may impose negative externalities; in an interconnected network, one subscriber's lower-reliability allowing choice may negatively affect those who wish to reach that person. Thus basic levels of reliability may need to be protected if a slide is observed, while higher grades should be left to user choice where technically feasible.

Many of the larger states impose minimum quality standards on public networks, such as seconds to dial tone, restoration time of interrupted service, etc. These standards vary somewhat across the country, matching local needs and requirements. Many states, in fact, are quite active in this regard and collect more data than the FCC. I am not aware of any state standards that are unacceptably low and thus require a federal floor. On the other hand, if a federal floor on local service would be set high to pull up some of the states, it will cause some unhappiness about yet another federal mandate that states, through ratepayers, have to pay for. Federal quality standards for local service would be appropriate if it could be shown that inconsistency or low standards in the states were a major problem for national service. But that would still leave the possibility of the FCC joining NARUC in a scheme of nationwide reporting of service quality. Also, for interstate service, the FCC could set minimum quality standards

---

13 For example, one could institute "interruptible service" tariffs similar to that offered by electric utilities, which would allow substantial savings by clipping the expensive peak loads. (Key infrastructure services should be discouraged from using such interruptible service.)
to deal with those situations where competition and incentives did not do the job — in effect, safety nets for the unsafe nets. Perhaps these hearings could provide such information.

3. Disclosure

For user choice to be effectively exercised, accurate information is imperative. One of the FCC's responsibilities should be to require the disclosure of quality performance in a way that is useful to users, much as the SEC mandates disclosure to investors rather than judge the merits of securities.

4. Catalyst for Carrier Information Cooperation

Another flow of information that needs to be assured is the interchange of operating information among carriers. Where one carrier detects and solves an operational reliability problem likely to affect other carriers, it should be obliged to report such information, just as airlines must report problems to the FAA for the benefit of other airlines, too. Ultimately, we are all better off. A similar information exchange is needed among various countries. The U.S. is not unique in experiencing service problems with new technology.

In New York State, one of my last actions as a PSC Commissioner was to convene a government-carrier-user meeting on network reliability. What was especially heartening was the willingness of all participants to cooperate, once prodded. Parts of this effort are now being continued at the municipal level in New York City in an effective display of cooperation.
5. Catalyst for Carrier Operational Cooperation

Another way to create collaboration would be for the FCC to initiate measures that grant mutual access between all or a majority of physical networks, both public and private, in times of emergency, beyond the TSP system. Such a system could be modelled on the Emergency Broadcasting System for broadcasters, or on the passenger transfers by airlines. Traffic priorities for emergencies need to be established.

6. Incentives

But most important for network performance is to link reliability and quality performance to financial rewards. One possible scheme would involve the following steps:

a. **Identify the relevant dimensions of reliability and define reliability criteria.**

   One metric for service reliability was suggested in previous testimony of John C. McDonald to this subcommittee. He proposes a logarithmic measure based upon the number of erlangs lost in each failure. This is helpful in quantifying the effects of network failures. But it is less useful in capturing deterioration of quality. Many other additional dimensions define service quality — for example, time to dial tone, network busy times, etc. It would therefore be better, though more complex, to adopt an aggregate index of overall reliability. To do so, one must first pick the most relevant 5—10 dimensions of quality and reliability.

b. **Assign weights to reliability factors, thus creating an index.**

   Since all reliability factors may not be of equal performance, weights are assigned to
them based on user surveys on their relative importance.\textsuperscript{14}

c. \textbf{Monitor reliability.}

With this system one can measure the overall reliability performance of a network. It would be left to a carrier how it would reach a target quality index. The strength of this system is that it permits flexibility by allowing network operators to respond to their markets and costs in a variety of ways as long as overall reliability is above a target level. If improvements in all dimensions of reliability cost the same, improvements would first be undertaken for the most critical dimensions, and for those most economical to fix. If marginal improvements differ in cost, as seems likely, a company could calculate the optimum improvement strategy. The results would be more reliability for the money, and greater managerial flexibility in reaching the overall goal.

d. \textbf{Linking Network Reliability to Financial Incentives.}

Overall reliability can then be linked to a system of financial rewards and penalties. It would become part of a price cap formula by factoring the overall reliability index into the equation, just as it is done now for inflation and productivity. This would provide incentives for increasing overall network reliability by rewarding reliability and punishing for its absence.

III. CONCLUSION

The broader question which is posed here today is whether competition will provide quality and reliability. The conclusion is that this will not necessarily be always the case.

Reliability will thus require regulatory attention. This would include:

1. The setting of incentives in the rate cap formula for improvements in reliability. This is a superior approach in comparison to micro-managing companies' reliability investments and performance along many dimensions.

2. Disclosure of information on reliability performance and problems should be required. International exchange of information should be encouraged.

3. Task forces of industry and government should be covered to provide collaborative attention to the issues of reliability.

4. Intercarrier emergency operations procedures should be instituted.

5. Users should be assured the ability to select appropriate redundancy levels.

6. Government agencies should not be permitted to underinvest in redundancy.

By initiating these various steps or recommending them to others, the FCC would signal to service providers and users alike its seriousness to protect the information transport infrastructure of a society increasingly dependent on information flows.

Such a role is, more generally, part of the FCC's mandate for the 1990s. The agency has successfully opened telecommunications to competition, and should continue to do so. But
as the internal cohesion of the old AT&T gives way to a more centrifugal system, the FCC must provide some of the glue to hold the system together. This is a gradual process, in which we are all learning — government, carriers, users, and independent experts. The FCC has already made progress in this process, and your hearings will further encourage it.