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*On the Market for Data Networking Products**

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1. Introduction

In this paper we take a first look at several aspects of the prospective US market for data networking products, mostly from an economic point of view. The discussion includes three kinds of material: quantitative forecasts, theoretical analysis, and speculations (or questions).

Of course, the distinction between a voice network and a data network is somewhat arbitrary. At one extreme, one might say, is a voice conversation, at the other a late-night transmission of large quantities of data or code. But the mode of transmission may well be digital for all types of input (spoken words, written words, numbers, symbols, pictures). When we speak in this paper of "data networking" we shall usually have in mind local area networks (LANs) and wide area networks (WANs). We shall have occasion to discuss the similarities and contrasts between voice communication and data communication, and also between the past evolution of the voice network and the fledgling evolution of data networking.

The structure of the remainder of this paper is as follows: Section 2 contrasts certain features of voice traffic and transmission with data traffic and transmission. Section 3 deals with quantitative aspects of demand forecasting. Here we quote some preliminary numerical forecasts of the markets for LANs and WANs, and check the plausibility of these forecasts against certain aggregate considerations. Section 4 deals with qualitative aspects of demand forecasting, and examines in particular the relationship of the growth of demand to the establishment of standards. Section 5 treats certain pricing questions, and is mostly analytic in nature. We discuss the positive "network access externality", both positive and negative "call externalities", including one that has to do with information overload, and certain threshold effects, or discontinuities, that may plausibly arise in the

*The views expressed in this paper are the authors', not necessarily those of AT&T Bell Laboratories.

demand for data networks. Section 6 discusses industry structure. In Section 7, we depart from strictly market considerations, to talk about possible social effects of the increasing availability of data communication capabilities. In particular, we are interested in effects on management behaviour. We also raise a number of speculative questions about possible effects on the conduct of politics, science, etc. Finally, Section 8 offers some concluding remarks.

2. Data and Voice

There are several differences between voice traffic and data traffic and between the ways they must be handled, and these differences will persist even if both are eventually carried on the same universal network. At the risk of belabouring the obvious:

a) A voice conversation (but not Voice Message Service) generally involves almost instantaneous, two-way transmission, or at least a two-way open channel, permitting voice overlap. Data communication is generally one-way, or an alternation of one-way transmissions, and can tolerate some delay. Therefore, data messages can be broken into "packets", and transmitted on a store-and-forward basis.[1] Thus, in modelling terms, a voice network is a loss system, while a data network is a queuing system.

b) A data call may be multiply-addressed, while a voice conversation is typically between two points (but conference calls are an exception). (At present, however, multiply-addressed data calls are uncommon, especially in wide-area networks.)

c) A voice conversation can be satisfactorily conducted using an analogue channel four kilohertz wide. Digitally, a voice conversation is transmitted using 64 thousand baud (bits per second), although it is known how to reduce this to about 20 thousand baud, using more efficient coding. For many applications data transmission requires a much wider channel (and for some applications a narrower channel).

d) The intensity of data traffic is apt to be more "bursty" than in the voice case.

e) Community-of-interest effects ("affinity groups") are often stronger for data traffic.

It will be noted that none of these differences is hard and fast; all have to be qualified.

[1]Voice may also be digitized and transmitted as packets, provided the packets are transmitted without perceptible delay and are seamlessly reassembled.

Demand Forecasting — Quantitative Aspects

In this section, we begin by looking at short-term trends in the demand for LANs and WANs.

3.1. Demand for LANs

Demand forecasts for the local area network market have been assembled from market forecasts prepared by commercial information sources[2] and from trade journals.[3] Cross checks on demand estimates were made among the sources to reveal inconsistencies. We find, from our composite forecasts:

— The LAN market is growing very rapidly,
— is estimated to include 36 million installed connections in the US by 1992, and
— is growing even more rapidly in aggregate, outside the US, perhaps because it is at an earlier stage of growth.

In the longer term, most forecasts are for a decline to 10-15% compound annual growth rate by the mid 1990s.

In more detail:

— For the US, compound annual growth rates (CAGR) between 1988 and 1992 of 22% in revenues, 28% in shipments of nodes, and 46% in installed base. (Revenues will grow at a slower rate than shipments because of a decline in the average selling price of 4.3% over the five-year horizon.) But all these percentage growth rates are declining over the period.
— An installed base, for the US, of about 36 million LAN connections (to a terminal, a PC, or other computer) by 1992, with corresponding revenues of about $5.8B.
— Estimates of worldwide forecasts (excluding US) for the LAN market are 32% CAGR in shipments of nodes, and 23% CAGR in revenues, for the period 1988-1992. Notice that growth rates for the worldwide market are higher than for the US market.

We have also looked at a segmentation of the US LAN market into three broad categories, as follows:

- PC LANs: Local area networks that connect personal computers.

[2]Dataquest, Inc., International Data Corporation.
[3]*Computerworld, Data Communications, Telecommunications*. See references.

- System LANs: Local area networks that connect work-stations with servers.
- LAN Interconnect Equipment: used to interconnect LANs, such as gateways, bridges and routers.

This segmentation is on the basis of connection technologies used in the LANs, and the major suppliers in each of these segments are different. The marketing strategies and customer needs for each of the segments are also different. We find:

— Installed base CAGRs of 56% for PC LANs, 35% for System LANs, and 60% for interconnect equipment.
— Slightly slower growth worldwide of the PC LAN market, excluding the US, than for the US

One may try to check these forecasts for plausibility by various "back-of-the-envelope" aggregate calculations. For example, according to Statistical Abstracts of the US (1989), the number of establishments with at least 100 employees in 1986 was 120,000 (in all industries). (Note that an establishment is a single physical location, and that government employees and certain other categories are excluded.) Assuming a 5% annual growth rate, the number of such establishments in 1992 would be about 170,000. As an upper bound, suppose each of these has a LAN. Then, assuming 36 million connections, we get (as a lower bound) about 200 connections per average LAN, which is too high; the median number of connections on a LAN is probably about 15. So from this point of view, the estimate of 36 million connections by 1992 seems much too high.

We can approach this estimate in another way: According to US Statistical Abstracts, the number of employees in all industry, excluding government, in 1986 was 83+ million. Suppose that adding government and academia, and growing from '86 to '92, doubles this to 167 million. That would mean about 1 LAN connection per 5 employees. This again seems high. But we have not so far taken account of a social change that itself has been brought about by the ubiquitous availability of data links: The 83+ million employees cited excludes not only government but also self-employed people. The latter group is probably growing. Also, as is often pointed out, the availability of data-communications links has made it possible for certain types of corporate employee to work at home. Corporations also use many self-employed consultants; many other self-employed people — e.g. writers, editors, researchers — must be working at home, connected to the world by data-links, whether local or wide-area. Thus, our "estimate" of an upper bound for the data networking market should be increased. For the same reason, in counting "establishments", one should include those of all sizes, not just those with at least 100 employees. Even taking account of these considerations, however, the estimate of 36 million connections seems too high. Of course, slowed growth, or even saturation, in the number of connections by no means precludes growth in bandwidth per connection, nor growth in interconnection of LANs into MANs (Metropolitan Area Networks) and WANs.[4]

Beyond the mid '90s, any such forecasts are extremely suspect, because of the likelihood of qualitative changes in the technological situation.

3.2. Demand for WANs

We have derived from the same sources forecasts of the growth of WANs; data and forecasts in this area are more sparse, however, than for LANs. The US WAN market can be segmented into markets for public data networks and private data networks (generally owned by a corporation, but perhaps managed by a communications carrier). The *public* data network market is a service market, and includes no equipment sales. It is not so large as the LAN market. We find:

i. The total revenues from network services had a compound average growth rate over the period 1982-86 of 25.1%, but this growth was slowing.
ii. This growth rate over the period 1987-91 has been estimated at 5.2%.
iii. The revenues from this segment in 1991 have been estimated at about $500 million.
iv. We have also heard of growth rates in usage as high as 20% per month on research networks, which are costless to the user.

The greatest part of the private WAN market consists of bridges and routers; these manage the routing and alternate routing of packets.

i. The estimated growth rate of this segment over the period 1986-91 is 26%.
ii. The estimated revenue from this market in 1991 is about $671 million; thus it is forecasted to overtake, in sales, the public WAN market. Thus the total WAN market in 1991 is projected to be about one-fifth of the total LAN market in 1992.

A WAN requires a network management system. We have no projections for these, but the potential market is believed to be large.

4. Demand Forecasting — Qualitative Aspects

Further progress in forecasting the demand for data networking products, beyond the simple extrapolation of growth rates or changes in growth rates, requires a deeper understanding of many qualitative aspects of the market. We do not claim

[4]All the numbers quoted so far are for the U.S. In the near or middle-term future, it seems that world demand might be 3 times U.S. demand, roughly.

to have such an understanding at this point, but in this subsection we shall at least try to define the major issues. Broadly speaking, these issues relate to (1) the importance of "migration", i.e., the relative importance of current versus potential users of networking, (2) the variety of applications of data networking, both current and potential, and their relative importance in the market, (3) the interactions between demand and supply in the evolution of technology, and especially the evolution of standards and "gateways", and (4) the evolution of public policy, both at the national and international levels.

4.1. Migration

According to one view, the medium-term evolution of the data network market will be most heavily influenced by the demands of current users of local-area-networks and management-information-systems. Thus, in discussing the future of ISDN, David and Steinmueller (1989) write:

> Much of the current literature on ISDN is engaged with either the technical implementation of particular standards within the ISDN framework, or with national and private strategic positioning to take advantage of the first implementations of this international standard. Less frequently noticed is what ISDN will mean for user organizations that already are engaged in building LANs to serve their own local needs, and establishing more extensive connections with existing WANs. Our thesis in this paper is that user demands and vendor solutions developed in the course of prior experience will shape the emergence of specific ISDN implementations, and that these prior experiences and preferences will affect the success of the entire ISDN movement. (p. 4)

In the case of business users, do we envisage that most users of WANs will arrive at that point by "migrating up" from personal computers to LANs to WANs, or do we imagine that substantial numbers will jump directly from more primitive data-handling systems to large WANs that also supply some equivalent of LANs? Personally, we feel that — at least in the medium term — the first picture is more likely. On the other hand, large numbers of households, or even small businesses, may jump directly to the use of WANs without passing through intermediate stages, other than using a telephone or television set.

4.2. Applications

It would be useful to study in a detailed (yet speculative) way the variety of current and potential applications of data networking. Such a study would examine the functions that various entities (industrial, academic, and governmental) now perform using data networking. Examples might include:

— automatic teller machines,
— stock quotation systems,
— electronic ordering by manufacturing firms,
— power usage monitoring,
— electronic mail and other intra-corporate communications,
— and others.

The study would then try to predict the likely growth in those groups and functions. The next step beyond this would be to speculate about entirely new uses that might arise as a result of increased availability and capability of data networking.

More sophisticated forecasting would also have to forecast the demand for data networking and for data-terminals jointly. That is, for data networking, as for voice networking, terminal equipment and switching/transmission capability are complementary: the price of each must appear as a variable in determining the demand for the other.

Finally, we mention that in the longer run it may become inappropriate to study separately the demand for data networking products, as data communication becomes just one of a number of ways of using a universal digital network. However, it is by no means clear that this is the way the industry will develop, even in the longer run.

4.3. Compatibility and Connectivity: Standards and Gateways

It is often thought that the early development of national and international standards in data networking would hasten the spread of networking in an economically efficient manner. Thus this is the basic premise of the ISDN movement. However, at least two obstacles lie in the way of the smooth and early adoption of standards in this area. First, there are two alternative competitive strategies that providers of networking can adopt: (1) provide a range of equipment and/or service that is linked by company-specific standards and is difficult to "unbundle" by competing suppliers, in an attempt to "lock in" customers to one's own line; (2) design service and equipment that is compatible with complementary services and equipment provided by other (complementary) suppliers, in the hope of reaching a larger market. Successful adoption of the first strategy by providers with large market shares clearly impedes the evolution of common standards, unless a single successful provider achieves a near monopoly.

A second obstacle might be the proliferation of economical converters or interfaces to connect otherwise incompatible equipment and systems. David and Steinmueller (1989) call these "gateway technologies". Again discussing the ISDN movement, they write:

> There is another potential role for a gateway technology in the context of LANs, namely, permitting communications between local networks that have

> already been built around different "standards". Such connections open up the possibility of creating so-called "geodesic networks": more far-reaching information networks that can be formed through decentralized, sequential decisions to effect such connections where and when their value is recognized, rather than having to be centrally planned or coordinated ex ante among all the parties that ultimately would participate. ... Moreover, LANs are a major site for technological improvement and diversification. The specific software and hardware services developed for local use [need not be] limited by broad standards applicable to WANs such as ISDN. Instead, wherever there are specific opportunities ... to service user needs, the local area network provides a foothold for vendors to provide hardware and software, by omitting some technical specifications to make a product cheaper or by adding some nonstandard features to enhance performance. (p. 19)

Thus, in the shorter run, gateway technologies may accelerate the growth of WANs. However, as discussed in Farrell and Saloner (1989), the availability, or even the *anticipated* availability, of gateways may slow down the development and adoption of standards.

In thinking about the evolution of standards and gateways, it is tempting to rely on an analogy with the early days of the railroads and the telephone system. It seems absurd that, when coming to some European frontier, the contents of a train would have to be unloaded and then reloaded on another train, because of the difference in the gauges of the tracks. Nationwide standardization was once considered to be a significant benefit of the near-monopoly of AT&T in US telephone service. However, the data network situation is much more complex (and indeed the national telephone network has also become more complex). There are multiple levels of data networking, as well as a wide variety of functions and equipment served by data networks. Even without the obstacles to standardization that might be a consequence of the competitive strategies of providers with large market shares, the immense variety of function and technology supported by data networks suggests that rapid standardization may not be feasible, and even that it may have social costs as well as benefits. However, there seems to be some consensus that, at least in the long run, a significant degree of standardization will be desirable. Another consideration (the converse of the remark at the end of the preceding paragraph) is that the standards that are eventually adopted may well depend on the rate of standardization, because that rate will influence the development of gateway technologies and the spectrum of local information systems wanting to be served by wider networks. (See David and Steinmueller (1989) for a fuller discussion of this point.)

4.4. Public Policy

The preceding paragraphs suggested the possibility that the evolution of standards

might not be proceeding as rapidly as is socially desirable. If this is so, then some sort of public policy intervention might be called for. It seems clear to us that it is not a question of traditional regulation like that of telephony in the past. Indeed, since the market for data networking is already international — and will become increasingly so — some international coordination beyond what is being done currently on a voluntary basis may be desirable. However, a detailed discussion of this topic is beyond the scope of the present paper.

5. Pricing

5.1. Usage-Sensitive Pricing

In much of the preceding section, we have discussed demand as if it were independent of price, which it is not. When pricing is not usage-sensitive, or (as with academic WANs) service is perceived by the actual users to be free, one does not have much information about the demand function, and hence not much guidance about how to price. Perhaps a solution is to phase in gradually a traffic-sensitive component of the price. Questionnaires about reservation prices might help, despite the well-known infirmities of such questionnaires; local trials are also a possibility. In fact, the pricing situation is similar to that obtaining at the time of the introduction of usage-sensitive pricing of local telephone service ("local measured service") in the 1970's and 1980's. In pricing WANs, at least two kinds of externality must be considered.[5,6]

5.2. Network Access Externality

This is a positive externality: the greater the number of subscribers on the network, the more valuable the service for any one subscriber. Thus an individual's decision to purchase network access (join the network) confers a benefit not only on himself but on all "members". But a rational individual will join the network only if the price of access is less than the surplus (net benefit) he anticipates accumulating from usage. It follows that it may be desirable, from both an individual and an aggregate viewpoint, to subsidize access, that is to hold prices below costs so as to encourage the purchase of access. This is particularly the case when the network is small, and costs can be expected to be relatively high (i.e. before the benefits of economies of scale are realized). It may even be justified to reduce prices to zero,

[5]Much of the following discussion applies equally to a voice or a data network.
[6]The meaning of the term "externality" will become clearer in what follows. Roughly, it means an effect of an economic transaction on someone who is not a party to the transaction.

which has been the case (as far as the users perceive) with academic networks.[7] How and when to phase out this subsidy, without destroying the network, is a delicate matter; see Section 5.1, above.

For data networks, the access externality may appear most clearly in the case of electronic mail.

5.3. Call Externalities

A call often confers a benefit on its recipient, as well as on its originator, who pays for it.[8] This is a call externality, and is usually positive. (For a multiply-addressed data-call, however, the call externality is correspondingly multiplied.)

In a mature network the ideal price-structure is a two-part tariff, reflecting the fixed and usage-sensitive parts of the cost. To encourage a socially optimal amount of calling, in the presence of a positive call externality, one might consider reducing the usage-sensitive part of the price, i.e. to subsidize it by increasing the fixed (access) part.

However, not all call externalities are positive. Examples are the negative externalities associated with junk mail, junk electronic mail, and telemarketing, phenomena that will develop when the network has grown large enough to justify their fixed costs. Or, to take a perhaps more benign example: since technical papers have become cheap to reproduce and to send, they are sent without much pre-selection. The recipient rather than the sender must then do the work of selecting which to read, which to skim, and which to throw away. These are all examples of "information overload"; for a systematic treatment see VanZandt (1990). The negative externality works as follows: because I receive too many telemarketing calls, I am willing to listen to only a small selection of them. My selection has a strong random component. Under these circumstances, each vendor who calls me diminishes the probability that I will listen to the message of each other vendor. VanZandt shows that it may be not only socially preferable, but also actually preferred by the vendors, to impose a tax or negative subsidy, that is, to increase the usage sensitive component of the price, if it is sufficiently small to start with.

We are far from being able to estimate the net magnitude of the call externality, and thus the appropriate subsidy.

[7] Using game-theoretic language, when network access externalities are present, there may be multiple market equilibria. The subsidy can then be used to steer the situation to the more socially (and individually) desirable of these equilibria. Some of these ideas are explored further in Furman (1989).

[8] Except for 800 service and mobile radio, where (in the U.S.) the terminating party pays. In the case of 800 service, a vendor willingly accepts (in the interest of profit) this violation of the principle that one should not be billed for an action over which he has no control. With mobile radio, the recipient is billed for the last leg of the call because the rate is high, and the originator may not know he is calling a mobile phone; thus this principle of no involuntary liability is adhered to in this case.

5.4. Threshold Effects

Data networks are of two kinds, those in which every terminal communicates (or can communicate) with every other, and those in which every terminal communicates with a central processor. An example of the latter is the arrangement whereby a chain of retail stores communicates its sales, in real time or after working hours, to a central computer. A network of this type may have economies of scale (and then, presumably, at some sufficiently large scale, diseconomies of scale) in terms of the number of inputs.

Radner (1989) has considered such a network, in which m processors, arranged for example in the form of a tree, work together to summarize the inputs from N sources. In a simple model, the cost of the network is proportional to m: if a processor and its associated output link can be bought for a price p, then the total cost is

$$C = pm \tag{1}$$

The benefit curve he derives (where benefit is assumed proportional to N and several cost curves are shown qualitatively in Fig. 1; the cost curves are drawn for both high and low p, and also for a critical value of p, say p^*, whose geometrical definition is obvious. Note that the benefit, as a function of m, at first increases at an increasing rate, reflecting economies of scale, but at sufficiently large scale displays diseconomies.

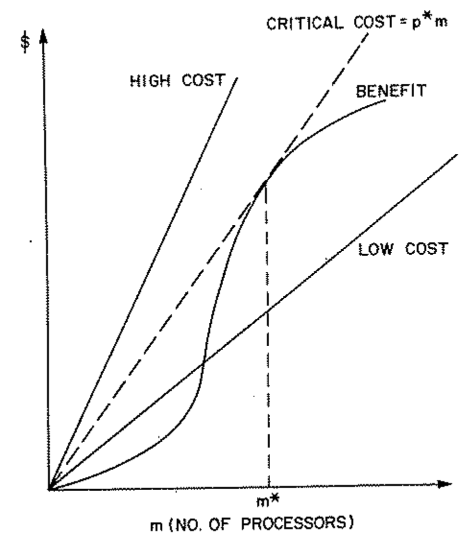

Figure 1. Discontinuity of demand

We see that for high p there will be no demand for such a network, but that as p drops to the value p^* — because of technological progress perhaps — there will suddenly be a demand for networks above a certain scale (namely that scale that efficiently utilizes m^* processors). As p continues to diminish, benefit will exceed cost for progressively smaller networks. (The threshold effect will, however, be smoothed out because of the heterogeneity of benefit curves among the potential subscribers.)

To the extent that such a model in fact captures the qualitative features of cost and benefit functions in certain real networking applications, one expects to see a relatively abrupt onset of demand as prices drop.

6. Industry Structure

The LAN market is still not very concentrated. Referring again to the sources cited in Section 3, we find 1988 LAN market shares falling off smoothly for the first 14 vendors from about 21% to about 2%, with 17% of the market accounted for by still smaller vendors. The PC LAN market in 1987 shows an almost equally diffuse distribution. However, Digital Equipment Corp. had 61% of the System LAN market in 1987. A striking feature of these data is the disparity among available estimates. For example, according to one source, Apple is the leading supplier in the PC LAN market with its *Localtalk* product, while according to another, the market leader is 3Com.

We cannot say whether the rather diffuse LAN market structure will "shake out" into an oligopolistic structure with a competitive fringe, resembling that in the long-distance voice market. (Note however, that the present structure of the long-distance voice market may be artificial, reflecting the asymmetric regulation of AT&T and the other carriers.)

For the public WAN market, the situation seems quite different, although we do not have recent data. As of 1986, two services — US Sprint's Telenet and McDonell Douglas' Tymnet — had between them 84% of the revenues in this market. In the *private* WAN market an intermediate degree of concentration prevailed, as of 1986: the top four suppliers combined had a 65% share of the packet nodes submarket.

We recall that one used to speak of the telephone voice network as a natural and necessary monopoly. Indeed this seemed obvious for many years, but we are no longer sure that it is so. Apparently, the existence of multiple facilities-based vendors of network services can be economically efficient, or at least economically feasible if (among other conditions) there is:

a. an inexpensive transmission medium,
b. the possibility of interconnection.

It should also be said that one may have (at least in the medium term) not only more than one network providing similar services, but also a multiplicity of networks providing a multiplicity of services. It is interesting to ask: For how long will national voice and data networks evolve separately? Will various types of data networks (e.g. dedicated private networks, ATM networks) continue to evolve separately?

7. Social Effects

In this section we discuss several possible social impacts of widely available data networks. The following subsections become successively more speculative.

7.1. Executive Behaviour

So far, the most dramatic effects of data networks on the conduct of business have been on the *operational* side (e.g. automatic teller machines in banking). Some had expected big effects on *management*; in fact surprise and disappointment are sometimes expressed at the fact that executives have not changed their behaviour more radically with the advent of data communications, i.e. that they do not spend more time conversing with computer terminals. Perhaps the expectation of such a change arose from a misunderstanding of the nature of managerial work. According to Henry Mintzberg (1973) the activity of executives — we might say their thinking — occurs in short bursts, and many of these are bursts of (two-way) communication.

Here are some data from Mintzberg, from his own survey and others:

- half the CEO's activities are shorter than 9 minutes. 90% are shorter than 1 hour.
- Foremen averaged one "activity" every 48 seconds.
- British middle and top managers worked for 1/2 hour or more without interruption only about once every 2 days.

Mintzberg finds that some executive activities are not only brief but ceremonial, many are face-to-face, few are of an analytic or (in the formal sense) planning nature.

Evidently such a pattern of activity does not lend itself to the perusal of large amounts of data. Indeed, it has been our observation that when executives use quantitative data they generally rely on a few useful facts, or "stylized facts", that they have learned from their subordinates, or from other executives, or from their reading. Managers are famously victims of information overload ("the inbox problem"). What they really need is a Thoreau filter: Thoreau said, approximately, on hearing of the completion of a telegraph line from Maine to Texas, "Mayhap Maine hath nothing of value to say to Texas". A Thoreau filter transmits only messages that have value (make sense). *Such a filter is a person.*

Nevertheless, perhaps there has been a change after all, but of a slightly different nature; perhaps it is the *staffs* of executives (not excluding their secretaries) who rely on data communications and access to computerized data sources, to keep their superiors informed. It would be interesting to look at this hypothesis more closely.

7.2. Teleconferencing

Broadband network communications should permit high-quality, low-cost teleconferencing (videoconferencing). One may speculate that with such teleconferencing, much travel would be eliminated. But teleconferencing, even of a technologically advanced nature, is very different from a face-to-face meeting. For example, teleconferencing is not apt to allow, in the near or middle future, the hand on the shoulder or the game of golf; these "kinaesthetic" things are felt to be very important in executive and sales environments. Again, teleconferencing technology would have to be advanced indeed in order to enable participants to pick up the changes in posture, expression, breathing that can be of great importance in negotiation.

Note also that transmission and switching are far from being all that is needed for teleconferencing. Terminal equipment and *control* of terminal equipment play a great role, and are very complex. Improvement of this technology at a "reasonable" price would open the market for the switching and transmission facets, where teleconferencing is desirable in spite of the limitations we have just mentioned.

7.3. Other Questions

Decentralization: What would be the effect of cheap broad-band data networking on centralization/decentralization of work and living?[9] There are competing effects:

- Data could cheaply be sent to a central processor, and results returned to the field. This would seem to be conducive to centralized processing.
- With cheap access to information from geographically dispersed sources, work could go on anywhere.

The present trend seems to be for continuing centralization of "front office" operations (e.g. bank headquarters), with decentralization of "back office" operations (e.g. bank data-processing). One must ask: Decentralization of what functions? Spatial or organizational decentralization? How about that kind of decentralization consisting of decision-making in the field when only local information is required?

Scientific Research: The intense flurry of communication among researchers at the peak of the excitement over the discovery of the new higher-temperature superconductors suggests that data communications may in some circumstances accelerate scientific research.

Bubbles: It seems plausible that the speed of evolution in both the growth and collapse of financial bubbles is increased by rapid global communication of data. Was this a factor in the stock-market crash of 1987?

Tyranny: It has been reported that "Fax" played a role in the growth of the student democratic movement in China. Have the invention of printing, the telegraph, the telephone, facsimile made tyranny more difficult?

[9]Working at home has been mentioned in Section 3, above.

8. Concluding Remarks

We are witnessing the spectacle of a new networking industry assembling itself from a variety of components, while undergoing rapid technical change. We have seen that data networking is as yet a smaller industry than voice telephone, by about two orders of magnitude (in terms of revenue), and that it is growing very rapidly. However, it is possible that data and voice will become, in the not very distant future, just two of the modes of using a more universal communications network.

The future structure of the data networking industry, i.e. its position on the competition/oligopoly/monopoly axis, cannot yet be predicted. Nonetheless, even in the absence of monopoly power, there may be a need for economic regulation. This is so because of the presence of externalities. These are of two kinds, network externalities and call externalities, and they may be positive or negative. (We have cited information overload as an example of a negative call externality.) This means that individually optimal choices by consumers — to subscribe to network service or to use it — may not be socially optimal unless elements of the rate structure receive a positive or negative subsidy (the latter is a tax). For a public WAN, the provision of such subsidies could be a regulatory function, or might be performed voluntarily be the providers. For a private WAN — say in a firm that makes use of transfer prices, and whose members therefore perceive decisions to use the network as, to some extent, economic decisions — such subsidies might be arranged by the network manager.

But economic regulation is not the only form of regulation. In the airline industry, economic regulation used to be the province of the Civil Aeronautics Board (before it was abolished), while safety regulation is the responsibility of the Federal Aviation Authority. For data networking, where the compatibility problem is more acute than for voice, there is a difficult and important question of whether technical standards to insure compatibility should be enforced by some governmental body, or whether — as at present — standards should be formulated by semi-official committees, compliance with whose standards will be voluntary. It is plausible that widespread standards compliance by LANs will promote the growth of WANs in the long run, but we have noted that the use of gateways may tend to accelerate the growth of WANs in the shorter run.

Finally, we have remarked that the social effects of more widely available, broader-band data networks may be unexpected. (We have cited as an example of an unexpected effect that the availability of data terminals has influenced the behaviour of executive staffs more than that of executives themselves.) Also, these social effects are likely to be profound. There are possibilities in the areas of decentralization of work and living, in the conduct of science, of finance, of government.

The challenge for economic analysis is to predict the structure of the maturing data networking industry on the basis of:

- its cost structure
- developing technology
- political considerations.

Everything we have said above is preliminary to this task.

References

Blumberg, P.A., 1988, Looking ahead: Network planning for the 1990s, Data Communications, 185-193.
David, Paul A. and W. Edward Steinmueller, 1989, The ISDN bandwagon is coming — who will be there to climb aboard? Centre for Economic Policy Research, publication no. 171, Stanford University.
Furman, D., 1989, Interdependent Preferences and Demand, AT&T Bell Laboratories Memorandum.
Farrell, Joseph and Garth Saloner, 1989, Converters, Compatibility and the Control of Interfaces, Working Paper Number 89-130, Department of Economics, University of California, Berkeley.
Huntington, J.A., 1989, OSI-based net management: Is it too early or too late? Data Communications, 111-129.
Mintzberg, H., 1973, "The Nature of Managerial Work." Harper and Row.
Mulqueen, J. T., 1988, 1988 market survey, Data Communications, 87-96.
Mulqueen, J. T., 1989, 1989 market survey, Data Communications, 95-102.
Pyykkonen, M., 1988, Local area network industry trends, Telecommunications 22(10), 21-29.
Radner, R. 1990, The Organization of Decentralized Information Processing, Mathematical Sciences Research Centre (AT&T Bell Laboratories).
Tewari, R., 1989, Local area network market-demand forecasts, Internal memorandum (AT&T Bell Laboratories).
US Bureau of the Census, 1989, "Statistical Abstract of the United States: 1989," (Washington, DC).
VanZandt, T.P., 1990, Information Overload in a Network of Targeted Communication, AT&T Bell Laboratories Memorandum.

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LEC Gateways

Provision of Audio, Video and Text Services in the US

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1. Introduction

"Gateways" are in fashion today. Judge Greene has permitted the Bell operating companies to offer gateway services lest the US fall further behind the Europeans. Various Regional Bell Operating Companies (RBOCs) are experimenting with audiotex and videotex gateways. The Information Industry Association commissioned a study of gateway navigational commands. NTIA's recent report on video services recommended that Bell companies be allowed to offer video programming on a gateway basis.

This paper discusses various aspects of gateway businesses in order to more clearly delineate the public policy issues associated with the operation of gateways by local telephone companies. It begins by reviewing the characteristics of "network externality products" (NEPs), the general class of products[1] which includes gateways and examines their significant differences from non-NEPs. The discussion then focuses on gateways — in particular, the gateways LECs offer today and might offer in the future, and the marketing and public policy problems faced by these enterprises.

2. Network Externality Products (NEPs)

Shopping centres do not get built until the developer has signed up one or two anchor tenants. Facsimile machines become more useful each year as more and more locations have them available.

Many businesses and products have characteristics similar to those of shopping centres and fax machines. Such products can be called "network externality products" or NEPs. We can define an NEP as:

[1]When I use the term products I use it in the broad sense which includes services.