ACCESS CHARGES FOR PRIVATE NETWORKS INTERCONNECTING WITH PUBLIC SYSTEMS

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I Introduction

Private networks have proliferated since the advent of competition in telecommunications. Recent technological advances (especially in wireless technologies) and further regulatory changes (to permit if not promote interconnection of private systems with public systems) offer potential explosive growth in the reach of private networks.[1] No longer the exclusive domain of large companies, private networks are gaining the capability to attract significant numbers of smaller residential and business customers to their networks. This paper addresses the question of how to design access charges for interconnecting these private networks with public systems.

Private networks come in a variety of types and sizes ranging from CPE (including PBXs) and a variety of bypass technologies, to large network facilities serving many customers (e.g., General Motor's network is reported to serve 250,000 lines). Included are Metropolitan Area Networks (MANs) which offer network facilities to large business customers in densely populated areas. Such MANs may soon be able to offer services to public network customers at highly competitive rates, and the possibility of interconnection with the public network translates this capability into full competition with the public network. Interconnection would significantly increase the competitive appeal of MANs to ordinary telephone customers. It is the terms of this interconnection which will largely determine the market shares of private and public systems, and, to an extent, the size of the market itself. As Eli Noam has said, "Whoever controls the rules of interconnection controls the network system itself."[2]

Private networks develop for a diverse set of reasons, including the desire for control, reliability, new services capabilities, and the ability to cut costs. These can be classed into price and nonprice motivations. Nonprice motivations are largely efficiency enhancing and are part of the benefits of a more competitive environment. It is the cost-cutting motivations which are more ambiguous. Private solutions which require less resources than are needed by public systems are efficiency enhancing. Private solutions which simply allow users to avoid tariffs, with no rational basis in costs, of the regulated public

[1]The NERA analysis filed by Southwestern Bell Corporation (1991) before the FCC indicates that there are significant revenues at risk from customer connections with MAN facilities rather than local exchange facilities. The analysis shows that private networks and MANs are no longer only for large companies - regular customers can also be served by such facilities.

[2]Comments of Commissioner Eli M. Noam, New York State Public Service Commission in FCC CC Docket No. 88-2, Phase I.

systems, and which actually expend more resources to provide services, are inefficient. The task is to design tariffs which provide incentives for efficient private network development while keeping traffic and customers on the public network who can most efficiently be served by that network. We will not address the difficult question of how to set charges for interconnection of different private networks with each other. The assumption is that there is a network with special characteristics - the public network - with which private networks may wish to interconnect.

The paper proceeds as follows. Section II examines the present tariff structure and how it may provide for overdevelopment of, and oversubscription to, private networks. Overdevelopment is defined in terms of economic efficiency. Oversubscription may well be the more critical policy issue, since much of the private network capacity is already a sunk cost, regardless of its efficiency properites. Given the existing capacity of private networks (estimated to be sufficient for the current total volume of telecommunications traffic), do present tariff structures promote efficient subscription decisions? Section III sketches the possible scenarios for the public network of the future under existing tariffs. The public network has traditionally been the "carrier of last resort," in that it was required (in exchange for its franchised monopoly) to provide service to all that desired it, under regulatory oversight of tariffs. Will the public network become the "carrier of last resort," in that nobody will voluntarilly subscribe unless they have no alternative options? Section IV explores alternative tariff structures aimed at meeting the goals of maintaining the viability and function of the public network, as well as promoting the benefits of competition and interconnection.

II Private network development may be socially excessive

Determining the economically efficient level of private network development is difficult, if not impossible. Whether or not parts of the network possess natural monopoly characteristics is much open to debate, as well as which parts and for how much longer. The fact that private networks are not being discouraged, and perhaps even encouraged, indicates that telephone service is not generally considered a natural monopoly.

The most appealing theory to date for the formation and fragmentation of "the public network" is found in Noam (1990). The public network is viewed as a club, formed to take advantage of cost sharing. Eventually, the cost shares become redistributed to account for network externalities, and to accommodate the desires of a majority of subscribers to allocate increasing cost shares to the minority who value service the most. This leads to the demise of the single club, as coalitions break off forming their own clubs with their own sharing rules. Noam points out that the "universal service" goal is likely to be inefficient, as the network externalities are probably not sufficient to justify universality of access. The common public network disappears and is replaced by multiple interconnected subnetworks.

The efficiency of this transition is not clear. Subnetworks allow for heterogeneous demands of subscribers to be met more closely than by a common public network. Differentiated needs for quality, reliability, multiple services, and alternative cost sharing arrangements are promoted, but at the expense of some duplication of facilities and costs of the compatibility required for interconnection. The net result for efficiency is ambiguous. At the same time, NTIA (1991) calls for an expanded notion of universal service ("Advanced USA") which calls for a continued and upgraded public network. The optimal number of clubs, given a universal service constraint on one club, has not yet been modelled - nor has the ability of the constrained club to finance itself. Research on this important question is warranted and will impact the "optimal" rules for interconnection of clubs. However, we will not pursue this model here, since much of the private network development is already a sunk cost. Additionally, there appear to be a number of competing social goals, none of which our society is yet willing to abandon.

We take as our point of departure the assumption that continuance of the public network, with its attendant universal service obligations, is socially desired. Otherwise, there is no special status accorded to the public systems, nor to interconnection of private networks with it. Given the desire for continued "public systems" what can be said about the efficient development of private networks and the terms of interconnection?

Mueller (1988) provides an extreme view: "nonconnected networks will always offer access to different subscribers and hence will be more or less imperfect substitutes....once interconnected, networks behave more like complements than substitutes."[3] Accordingly, competition between networks is enhanced by banning interconnection. However, the costs of banning interconnection may well be too large. As Noam (1989) responds, "for states to fight the principle of open interconnection is to tilt at windmills."[4] The costs of duplication of facilities and/or the welfare losses associated with noninterconnected networks appear to us to be too large to seriously consider this prospect.[5] Hence we also assume that interconnection is a desired policy.

[3]Mueller (1988, pp.25-26).
[4]Noam (1989, p.91).
[5]These welfare losses are self-evident to any highway traveller in the northeastern United States. Toll highways do not interconnect easily with the free interstate highway system (this is particularly a problem with the Pennsylvania and New Jersey turnpikes). Consumers' needs often require universal coverage of both sets of highway systems. The result is that interconnection is accomplished, but with significant additional travel times and congestion.

We therefore wish to examine access charges for desirable interconnection of private networks with a public system which has a universal service obligation. We will assume that interconnection is technologically feasible and costless, and we examine the extent of private network development under current tariff structures. Forces which tend to promote inefficiently excessive private network development are isolated in this section, while the next section forecasts the resulting effects on public and private network evolution. Section IV addresses the question: can the terms of interconnection be modified to promote an efficient level of private sector development?

We proceed with a series of highly stylized models aimed at isolating the major inefficient forces in the existing tariff structure. Many institutional details of actual tariffs are omitted. We will return to these in section III, as the complexity of actual tariff and cost structures provide some mitigating factors for the inefficiencies identified in this section.

1. Option Values and Default Capacity

Originally identified as promoting inefficient levels of bypass, the carrier of last resort obligations imposed on public network suppliers also can lead to inefficient development of private networks more generally.[6] It is often the case that the users of private networks retain their original lines to the public network. This reveals that they are receiving value at least as large as the access tariffs associated with these lines. Given the growing importance of network reliability, the significance of the backup capability of the public network is not surprising.

Consider a private network subscriber paying P for access to the private network and a constant usage price/cost = p. Let the indirect utility function be $U(Y,p,I)$ where Y is income (if a business customer, then this could be profit) and I is an index indicating whether or not access to the public network is possible ($I=0$: no access; $I=1$: access). We assume that the decision maker is risk averse. There are $i=1,\ldots,n$ states of the world, each characterized by different utility functions and possibly different income levels. The associated probabilities for each state are π_i $(i=1,\ldots,n)$ with $\Sigma\pi_i=1$. Define option price, OP, to be the state independent maximum willingness to pay for access to the public network, and let CS_i be the state dependent compensating variation measure of consumer's surplus in state i. Then, CS_i is defined by

$$U_i(Y_i-P-CS_i,p,1) = U_i(Y_i-P,p,0) \quad i=1,\ldots,n$$

[6]For application to the case of bypass of the local exchange, see Weisman (1988) or Lehman and Weisman (1986). A rather different case for inefficient bypass, depending on unsustainability of a local exchange natural monopoly due to the different cost structure of bypass, is in Woroch (1987).

and OP is defined by

$$\sum_i \pi_i(Y_i-P-OP,p,1) = \sum_i \pi U_i(Y_i-P,p,0)$$

Option value, OV is defined as the difference between option price and expected consumer's surplus (ECS), i.e.,

$$OV = OP - \Sigma\pi_i CS_i.$$

It is well documented elsewhere (Bishop (1982), Freeman (1984), Schmalensee (1972), and Smith (1981)) that OV $\gtrless$ 0 depending on attitudes towards risk, the sources of uncertainty, and the opportunities available to protect against risk.

Some intuitive motivation for the nonequivalence of OP and ECS is useful. OP is a state independent measure of value ECS is the weighted sum of state contingent values. The sign of OV will depend on how dollars are valued in different states of nature, which, in turn, depends on both the sources of uncertainty and the individual's attitude towards risk. Risk averse individuals will prefer to make payments in states of nature with lower rather than higher marginal utilities of income. OP represents a certain payment, independent of the state of nature, but CS_i is a benefit measure derived in a particular state of nature. Risk averse individuals will generally be willing to pay a state independent premium beyond their expected consumer's surplus in order to resolve or reduce the source of uncertainty. Indeed, this is the principle behind the demand for insurance.

The possible sources of uncertainty are myriad, including but not limited to: tastes, income, prices, supply; and the opportunities to insure against such risks are similarly varied. Consequently, the sign of option value is not unambiguously positive, even for risk averse individuals. For instance, if I am uncertain as to my future demand because my future income is uncertain, then I may prefer state contingent payments to the state independent option price as the vehicle for expressing my valuation of a future option. Such contingent payments would provide the opportunity to minimize payments in states of nature where my income turns out to be relatively low.

Although OV is generally indeterminate in sign, results are available for specific sources of uncertainty and attitudes towards risk. The two cases most pertinent to private networks are (i) Risk aversion, demand certainty, and supply uncertainty of the form that the option guarantees the supply while lack of exercising the option leaves some nonzero probability of supply, and (ii) risk aversion with supply certainty and demand uncertainty arising from exogenous factors which do not affect the marginal utility of income across states of nature (strong seperability of the indirect utility function). Freeman (1986) has shown that both of these cases imply that OV > 0.

The first case is relevant to a private network which may retain access lines to the public network in case of system failure. The second case would apply to the option to resort to the public network in order to reach individuals not on the private network (it is assumed that the private network will connect the bulk of the subscriber's traffic, but that no attempt is made by the private network to carry occasional traffic to remote parts of the public network). In both cases, the insurance provided by access to the public network is worth something, and this value exceeds the expected consumer's surplus. This last observation means that attempts to extract this value through ex post usage payments will fall short of the full ex ante value of access. Private network users are receiving some benefits for which they are paying relatively little. This enhances the viability of private networks as well as generating less revenue for the public network than its value would indicate. Market failure is possible, wherein public network revenues are insufficient to maintain or upgrade the public network even under conditions where the social value exceeds these costs.

2. Public Network Usage Tariffs

We assume that the public network fixed costs = FC(S) so that default capacity retains the same fixed costs as regularly used capacity, i.e., that the fixed costs of the public network depend on the level of total traffic, S, and not only the traffic on the public network. This assumption is justified if the private network users retain access lines to the public network that were installed prior to the development of the private network. The public network incurs provisioning costs associated with the potential for these lines to generate traffic. Private network customers are not guaranteed that all of their default traffic will be accomodated on the public switched network, but it is likely that most such traffic will be provisioned for.

Default traffic may be blocked at any of three points in the network: these are the line-side connections to the central office, the central office switch, and the trunk-side connections to the remainder of the network. The need to adequately provision the public network reduces the last of these to negligible levels. The outside plant for the original number of lines remains regardless of whether the number of active lines is or is not reduced (this investment is not fungible). Central office switch capacity is more complicated, since it is engineered on the basis of line terminations and normal busy hour conditions. Depending on the fraction of line terminations from the private network customer, some switch capacity may be reduced. However, most switch capacity costs are generally recovered on a usage sensitive basis. Such costs are fixed (based on potential traffic), but are recovered from users. Since private networks are only occasional users of default capacity, they bear little of this cost burden. The access charge for the lines may or may not be compensatory, but it is clear that the option to use the line is worth its cost or these lines would be disconnected.

Assume that $FC'>0$ and $FC''>0$ and that the marginal cost for public network usage is constant = c. The private network incurs provisioning costs = P(Q), $P'>0$ and $P''>0$, and constant usage costs of $\hat{c}$. The efficient level of private traffic is determined by:

$$\min_Q \{FC(S) + P(Q) + c(S-Q) + \hat{c}(Q)\}.$$

The first order condition equates the marginal cost of provisioning the private network with the marginal cost savings of using the private network, i.e.,

$$P'(Q) = (c-\hat{c}).$$

Since networks have a risk of failure, let α be the probability of private system failure. The total cost function is now

$$FC(S) + (1-\alpha)c(S-Q) + \alpha cS + P(Q) + (1-\alpha)\hat{c}Q + \alpha Q\ 0.$$

This assumes that the public network will serve any default capacity from the private network when it is down. The first order conditions are given by:

$$P'(Q) = (1-\alpha)(c-\hat{c}).$$

Optimal private network traffic is smaller due to the possibility of network failure (of course, the public network can also fail, so that it is the difference in failure probabilities which is relevant - we ignore this, as we are interested in how the private network traffic will compare with this socially efficient level and not the absolute level itself).

The private network development decision is driven by private network costs relative to the public tariff. Assume the latter has an access charge of T and a marginal usage charge of t. A representative private network provdier will

$$\min_{\hat{Q}} \{T + \alpha t\hat{Q} + P(\hat{Q}) + \hat{c}\hat{Q}(1-\alpha)\}.$$

The first order condition is

$$P'(\hat{Q}) = (1-\alpha)(t-\hat{c}).$$

Private network traffic will exceed the efficient level if $t > c$, i.e., $\hat{Q} > (<)\ Q$ as $t > (<)\ c$. We assume that the public usage tariff is set to make the public network break even (in an expected value sense):

$$TN+t(S-\hat{Q})+\alpha t\hat{Q} = FC(S)+c(S-\hat{Q})+\alpha c\hat{Q},$$

where N is the number of public access lines. Rearranging and solving for the public usage price gives:

$$t = \frac{FC(S)-TN}{S-\hat{Q}+\alpha\hat{Q}} + \frac{c(S-\hat{Q}+\alpha\hat{Q})}{(S-\hat{Q}+\alpha\hat{Q})} = c + \frac{FC(S)-TN}{S-\hat{Q}(1-\alpha)}$$

Inefficiency of private network traffic depends on the term

$$\Delta = [FC(S)-TN]/[S-\hat{Q}(1-\alpha)].$$

Private network traffic will be inefficiently large provided that $FC(S) > TN$, i.e., if access line revenues do not cover the fixed costs of the network. Given the regulatory objective of universal and affordable access, access lines (in the aggregate) have been underpriced, and so this inequality is satisfied.[7]

Straightforward comparative static properties of Δ reveal that the inefficiency is larger: the more extensive the private networks ($\hat{Q}$), the more reliable private networks are (smaller α), the greater the divergence between fixed costs and access lines revenues ($FC(S)-TN$), the greater the fixed costs (FC), and the smaller the total number of access lines (N). Further, the private networks may be less reliable than efficiency would dictate, instead relying on the public network to provide reliability in the form of backup.[8]

In theory, this inefficiency can be removed by a "tax" = Δ.[9] Applying a charge of Δ to each unit of private network traffic is tantamount to charging such traffic for the expected loss in contribution payments to the public network. Such schemes are currently being considered and/or implemented, e.g., in New York State and in Switzerland.[10]

[7] We will briefly address the case of elastic demand. The first order condition for private network traffic will now include an additional term for the change in consumer's surplus resulting from the lower usage cost. Efficiency statements are more difficult, since any move in the direction of marginal cost is welfare enhancing, and the above inefficiency results from public usage prices which exceed marginal cost. Private network development will still be "inefficient" relative to the existing tariff, but possibly not in relation to the true cost structure.

[8] Lehman and Weisman (1986) investigate the possibility that bypass systems will be inefficiently unreliable due to underpriced option values. Similar reasoning applies here.

[9] Egan and Weisman (1986) discuss this option. Temin (1987, p.315) points out that there was a Congressional debate on taxing bypassers, which almost resulted in Congressional action in 1983.

[10] A 1/91 New York Telephone "actual collocation" tariff included a "Universal Service" rate element in which certain private line service components pay an access charge designed to offset the loss of contribution. this tariff was approved by the Public Service Commission in 5/91, the first of its kind in the country (NTIA(1991)). Switzerland has a similar tariff

It is important to note that this inefficiency results from the distorted public tariff structure and not the default use of the public network: i.e., even with $\alpha=0$ this inefficiency remains. So the inflated public usage tariff gives rise to inefficiently large private network development. Still, the default use of the public network is of interest, since the last discussion revealed that there is option value associated with the default use of the public network by private network users. It is worth asking whether or not the access tariff paid by the private network is compensatory - do access line revenues + occasional usage revenues cover the costs imposed by carrier of last resort obligations to serve these private networks in a default capacity?

To consider this question, we compute public network revenues (R) and costs (C) due to the private network being serviced under the carrier of last resort obligations. Let N_p be the number of access lines from the private network to the public network.

$$R = TN_p + \alpha tQ \quad \text{and} \quad C = (N_p/N)FC(S) + \alpha cQ.$$

We have assumed that the fixed costs attributable to private network lines are proportional to the fraction of total lines which service the private network. Such lines may be less costly than average due to their relative proximity to central offices, but this must be weighed against the heavier pre-private network usage on such lines for which the public network was already provisioned. The net contribution of the private network as public network customer is given by (substituting the value for t from above):

$$R-C = TN_p+\alpha cQ+\alpha Q[FC(S)-TN]/[S-Q(1-\alpha)]-FC(S)(N_p/N)-\alpha cQ$$

$$= [FC(S)-TN][\alpha Q/(S-Q(1-\alpha))] + [TN_p-FC(S)(N_p/N)]$$

$$= [FC(S)-TN] \left[\frac{aQ}{S-Q(1-\alpha)} - \frac{N_p}{N} \right]$$

The first term is positive since we have assumed that aggregate access line revenues do not cover all nontraffic sensitive costs. The second term depends on the relative fractions of traffic and lines represented by the private network. Due to the occasional use of the public network (whether derived from private network failure or from default to the public network to reach lightly called and/or distant subscribers), we assume that Q is small relative to S compared with the ratio N_p/N. Under these conditions the revenue contribution of private networks will fall short of the costs of providing default capacity. The earlier discussion also reveals that this revenue is likely to fall short of the total value of private access to the public network. This provides a ripe ground for market failure and/or inequitable cross subsidies from regular public subscribers to private networks defaulting to the public network.

It may be argued that from a network perspective, this default traffic of the private network appears no different than the infrequent usage of an occasional user of telephone service who is a public subscriber. While this may be technically correct, the similarity in kind is surely dominated by the difference in degree. Usage patterns resulting from innate customer characteristics would also appear to call for different treatment than those resulting from a change in customer behavior due to distorted tariff structures.

Without formally defining a measure of equity, the large business customer who consciously designs a private network so as to utilize the public switched network on a default basis without compensatory payment is surely different in society's eyes from an individual whose infrequent use of their telephone results in a degree of cross subsidization. Pre-competition, the former situation could not arise and the latter was simply a de facto social transfer. Post-competition, the former situation is economically ineffecent and the latter may be as well. But from a socially equitable position, we are hard pressed to argue that these situations are one and the same.

This section suggests that the desire to underprice access results in overpricing usage which gives rise to inefficient private network development. This might suggest that cost based pricing which removes this cross-subsidy will remove the inefficiency. However, the next discussion reveals that there is a further distortion which will still cause ineffecent private network development, even if aggregate access tariffs cover the fixed costs of the public network.

3. Geographical Averaging of Access Tariffs

Usage tariffs would probably be geographically averaged to some degree in a competitive world (current long-distance tariffs seem to support this). Transactions costs and customer satisfaction may well require a degree of averaging. However, it is unlikely that access tariffs would be averaged to a similar degree. Different subscribers impose quite different fixed costs on network infrastructures. Farther removed and low density routes are far more costly to serve than dense routes located near central offices. As Sharkey (1982) observes, "we see that it is the network configuration rather than the network size that is relevant in the determination of natural monopoly charactistics in the industry."[11] Yet part of the carrier of last resort obligation imposed on the public network is that it average the access tariff across customers, at least to a greater degree than the variation in costs.

It is not necessary that the cost structure depend not only on the size of the network, but on the identity of its subscribers.

[11] Sharkey (1982, p.23).

We assume that there are two types of fixed network costs: those that are independent of the subscriber set, F, and those that are individual to each subscriber, F_i (i=1,...,n). The former may be thought of as switching and transmission costs, while the latter are trunking costs. Trunking costs will increase with distance from the central office due to the costs of installing additional plant, as well as the need for signal repeaters (roughly proportional to distance). The marginal cost of usage is assumed to be constant, c, and usage is assumed to be fixed and constant per subscriber, Q. We will relax these assumptions later.

Assume that the customer specific costs are ordered so that $F_i < F_j$ whenever i<j. We will partition the total set of subscribers, N, into two groups - those on the private network, m, and those remaining on the public network, N-m. We assume that the private network will choose those customers with the lowest connection costs, leaving the remaining higher cost customers for the public network to serve. As Mueller (1988) has observed, "Current policy, in contrast, fosters competition in high-density business routes only, where markets are undersupplied or overpriced due to rate overaging. Increasingly open interconnection policies allow new companies to leave the task of providing universal service to the established network, thereby making it highly unlikely that the benfits of competition will ever reach the bulk of the population."[12]

Assume that the private network has a parallel cost structure, with fixed costs = P, subscriber specific fixed costs = P_i (i=1,...,n), and constant marginal usage cost = $\hat{c}$. We partition the total subscriber base into public and private subscribers, on the assumption that there is some real cost advantage enjoyed by the private network (otherwise private network development would never be efficient). The condition which describes efficient partitioning is given by:

$$F_i - P_i > Q(c-\hat{c}) \quad \text{(for all } i=1,\ldots m^*)$$
$$F_i - P_i \leq Q(c-\hat{c}) \quad \text{(for all } i=m^*+1,\ldots,n).$$

The left hand side is the connection cost savings for the private network relative to the public network. The right hand side is the per subscriber usage cost savings on the private network. This inequality states that the private network never include subscribers for whom the connection cost savings are less than the usage cost savings. m* is the efficient coverage of the private network.

The private tariff structure will charge each subscriber an equal share of the common fixed cost, P/m, and the customer specific connection charge, P_i. We assume the private market is sufficiently competitive that the usage price = $\hat{c}$. The public network is assumed to average its access tariff across its subscribers. To isolate the effects of access tariff averaging,

[12]Mueller (1988, p.31).

we will assume there is no cross subsidy from usage to access in this model. In other words, the public access tariff is a two part tariff = T+tQ, where

$$t = c$$

$$T = \frac{F + \sum_{i=m+1}^{N} F_i}{N-m}$$

Individual subscribers will join the private network as long as

$$T+tQ > P/m + P_i + \hat{c}Q.$$

The equilibrium marginal subscriber, $\bar{m}$, is defined by

$$T+cQ > P/\bar{m} + P_{\bar{m}} + \hat{c}Q \quad \text{and } T+cQ < P/\bar{m}+1 + P_{\bar{m}+1} + \hat{c}Q.$$

Assuming that the number of subscribers is great enough that the optimal conditions hold with equality, $\bar{m}$ is given by:

$$T - (P/\bar{m} + P_m) = Q(c-\hat{c}), \text{ i.e.,}$$

$$\left[\frac{F}{N-\bar{m}} - \frac{P}{m}\right] \left[\frac{\sum_{i=\bar{m}+1}^{N} F_i}{N-\bar{m}} - P_{\bar{m}}\right] = Q(c-\hat{c}).$$

The right hand side is the same as in the determination of the efficient m*. The second term on the left hand side is larger than (F_m-P_m) due to the access tariff averaging. So, private network coverage will exceed the efficient level, provided that the first term on the left hand side is positive (or sufficiently small, if negative). Of course, this must be the case for the private network to be viable. The only cost premium potentially attributable to the private network is that its size may not be sufficient to enable cost sharing to make it cheaper than the public network. This is related to the concept of "critical mass" found in Noam (1990). We will assume that the private network has reached critical mass. Then, the above analysis reveals that it will grow beyond the efficient level, i.e., $\bar{m}$>m*.

Note that excessive private network growth is not assured. The private network must gain sufficient size to overcome the cost disadvantage of its smaller sharing group. At the same time, there are a number of considerations which will tend to reinforce the tendency to overgrow. If we allow usage to vary between customers and for elastic demand, the private network becomes more attractive. In fact, it is likely that the covariance between connection cost and subscriber usage will be negative, meaning that a relatively small number of subscribers stand to gain a lot by private network subscription. This is further enhanced by the analysis of the last section, wherein the tendency for the public network to underprice access in the aggregate also contributes to private network over-growth. The option values inherent in public network access would only exacerbate this picture.

III Public networks may be unsustainable under current tariffs

We have identified 3 major factors which interact to cause excessive private network growth from the point of view of efficiency. These are:

(1) option values for connection to the public network for default in the case of private network failure and/or extending the reach of the private network to the universe of subscribers, many of whom will only occasionally be accessed - such option values tend to be priced lower than their value, and perhaps even lower than their provisioning costs;

(2) inflated public network usage charges resulting from the social goal of decreasing the cost of access - these inflated usage charges provide incentives for heavy users to flee the public network in favor of private networks with more cost based pricing; and

(3) geographically averaged public network access tariffs - this provides an incentive for subscribers with lower than average connection costs to seek alternatives with more customer specific pricing.

In additon, the three sets of customers to which these incentives apply have significant overlaps. In this section we put these factors together to forecast the evolution of the public network vis a vis private networks which interconnect with it. To simplify matters, we will assume that the private network has precisely the same cost structure as the public network - this eliminates any truly efficient reason for private network development (we are ignoring the nonprice motivations for private networks here). Any remaining incentive to flee public network subscription in favor of private networks can then be regarded as inefficient.

Subscribers are heterogeneous and their differences are important to our story. We distinguish between subscribers in two critical dimensions: their usage level, and their connection cost to the network. We seek to describe the set of public subscribers who would prefer to join private networks ("defectors") despite the identical underlying cost structures for both networks.

Figure 1 provides a framework with which to examine the defector potential. The first quadrant is the scatterplot of the universe of public network subscribers, shown in terms of their two basic attributes: usage level and connection cost. The third quadrant shows the critical level of cost savings required for

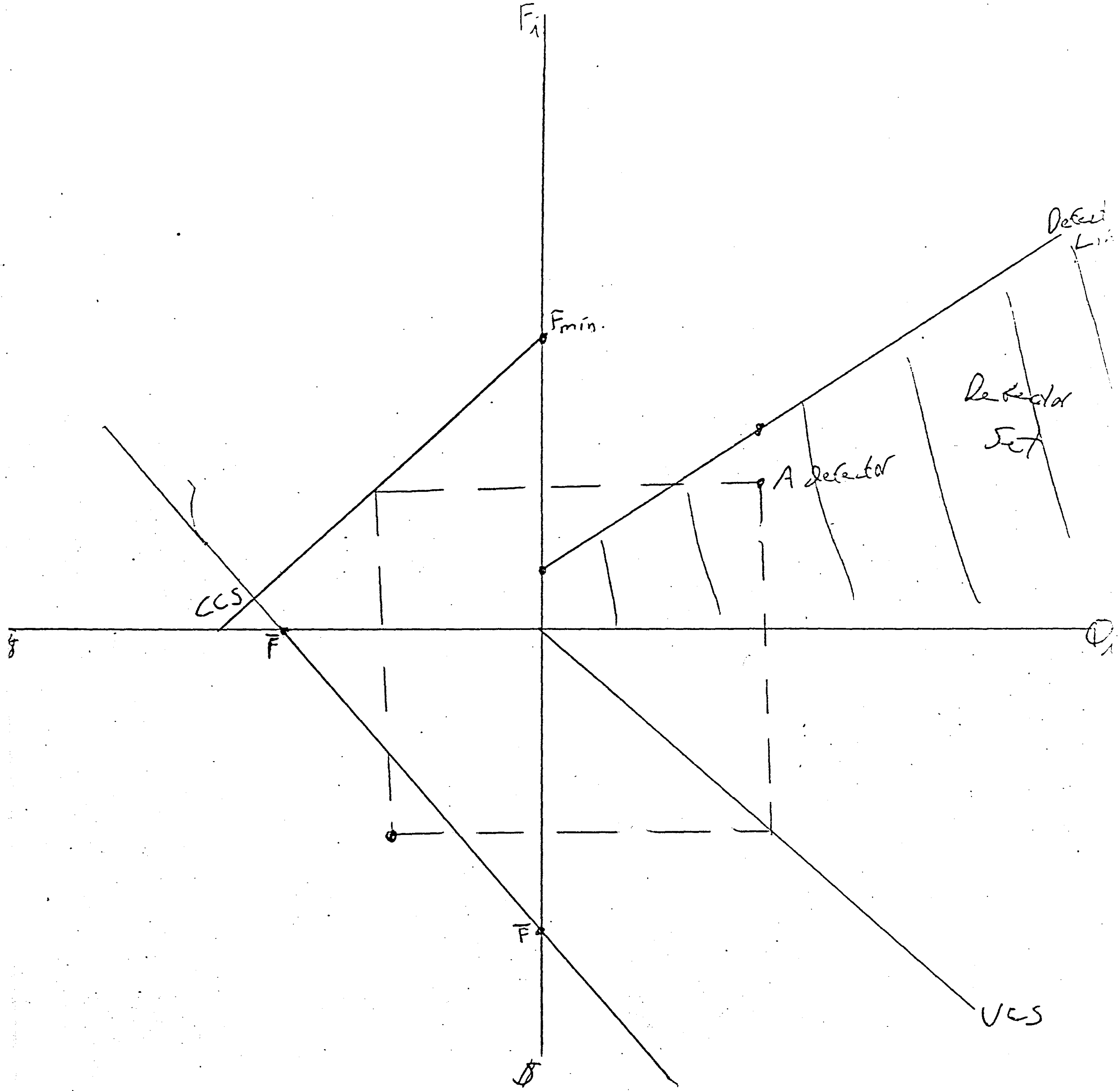

Figure 1

subscription to the private network rather than the public network. This critical level of cost savings is given by:

$$\bar{F} = [F/(N-m) - (F/m)].$$

This represents the cost disadvantage of a smaller sharing group on the private network. Of course, once the private network has sufficient size, this term could become negative. The most relevant case at present is that usage and access cost savings must be sufficient to overcome the disadvantage of the smaller sharing group. If there were additional fixed costs of enabling connection to the private network and/or costs associated with achieving compatibility with the public network, then these costs would be added to $\bar{F}$. Note that the critical level of cost savings in quadrant III extends into quadrants II and IV, as only the total cost savings count in predicting defection. Any cost savings combination that lie to the southwest of the $\bar{F}$ line are sufficient for defection.

The connection cost savings (CCS) and usage cost savings (UCS) are shown in quadrants II and IV, respectively. Usage cost savings result from avoiding inflated public network usage tariffs. Connection cost savings result from avoiding the geographically averaged public network access tariffs. Each of these varies across subscribers according to their attributes, and are given by:

$$CCS = T - (F/m) - F_i$$
$$UCS = Q_i(t-c).$$

We have assumed that the private network charges each subscriber their true connection charge and not a geographically averaged access tariff. Since the private network will need to connect to the public network on behalf of their subscribers, it would be expected that the geographically averaged public access tariffs would be passed on to private network subscribers. However, the private network need not maintain a connection line to the public network on behalf of *each* of their subscribers, since they can concentrate traffic that would flow onto the public network. It is expected, for example, that MANs would meet the heavier traffic needs of their customers, needing far fewer lines to the public network than their number of subscribers in order to achieve universal connection capabilities. These cost savings are assumed to allow the private network to charge individualized connection costs to its subscribers.

We constrain the public tariff structure to allow the public network to just break even:

$$T(N-m) + t\bar{Q}(N-m) = F + \sum_{i=m+1}^{N} F_i + c\bar{Q}(N-m).$$

To simplify the analytics, we ignore default use of the public network and we assume that $\bar{Q}$ represents the average usage level for public subscribers.

In constructing Figure 1, consider the initial case where t=c so that UCS = 0. Define F_{min} as the value of F_i which gives CCS=$\overline{F}$. All customers with $F_i<F_{min}$ will defect, but none with higher connection costs will. Consequently, the defection line in quadrant one is horizontal.

Now consider t>c. The UCS line is shown in quadrant IV. The breakeven constraint requires that T be lower than before, so that F_{min} will be lower than before (CCS are decreased). The combinations of (Q_i,F_i) which yield defections are now given by the upward sloping line in the first quadrant. Higher usage levels will induce defection, but for low usage levels, defection will require lower real connection costs than previously.

"Dynamics"

We mention only a few of the dynamic properties of Figure 1. The critical story is the evolution as private network subscribership increases. It is easily shown that F_{min} increases, since the remaining public subscribers are the higher connection cost individuals. The required cost savings for defection, $\overline{F}$, will decrease as the sharing group on the private (public) network increases (decreases). These are the effects if we assume that t is not adjusted in relation to c. The result is that the defector region is increased as private network subscribership increases.

Any attempt to lower t in response will serve to increase CCS, since T will be raised. Attempts to lower T will increase UCS, since t must be raised. Consideration of elastic demands and uncertainty will only exacerbate the problems. Elastic demands are tantamount to increasing UCS beyond what is shown, since we would add increased consumer's surplus to the cost savings. Option values are not related to actual usage levels, so the UCS line, if it included option values, would become an irregular surface including some (Q_i,F_i) combinations previously not showing savings when option values were not considered.

The dynamic story would seem to indicate a dissolution of the public network, even in the face of assuming away any real resource savings in private networks. There are mitigating factors. Actual tariff and cost structures are quite complicated. Some business line access tariffs are compensatory, although the aggregate access tariffs almost certainly do not cover aggregate nontraffic sensitive costs. Actual connection arrangements to the public network for private network subscribers may vary considerably, only yielding connection cost savings in particular cases. Usage cost savings depend not only on usage levels, but on the entire usage structure. Time of day, distance, volume, etc. all matter. While the resulting pattern of defection is complex and requires empirical verification, we believe that the basic forces we have outlined will remain.

This paper has presented an extreme form of the forces for inefficient public network defection inherent in existing public tariff structures. There are mitigating considerations, but the forces will tend to force the public network towards a minimal network, truly the "carrier of last resort." Existing tariffs provide incentives for private networks to pick off the more lucrative public subscribers, leaving only the more "undesireable," i.e., costly, subscribers for the public network to serve. The ability of technology to take advantage of these incentives will only increase with time. The situation will be exacerbated if the public network is to upgrade its infrastructure, incurring the modernization costs with no committment on the part of its customers to repay these costs with public network subscription or usage.

This picture may seem extremist and/or unrealistic, but we hasten to point out that it already has a precedent in the health care industry. As documented in Leyerle (1984), Blue Cross - Blue Shield (BC/BS) was granted tax exempt status in exchange for carrier of last resort obligations. It's "community ratings" were required to equalize rates across people, regardless of health status (i.e., costs). Commercial companies (e.g., HMOs) had no such tax advantages but utilized "experience ratings" which geared rates to the individual's actual experience (i.e., costs). The result was that the BC/BS market share of 61% in 1945 had dropped to 37% by 1969. In fact, BC/BS was forced to offer experience rating plans in competition with others. The community rating plans increased continually in price. The viability of BC/BS was further bolstered by a variety of government contracts (e.g., VA contracts). But the general policy of community ratings was abandoned in favor of experience ratings. Whatever community rating plans that remain are prohibitively expensive.

The health care industry presently has 37 million uncovered individuals. We doubt that universal telephone service will suffer the same fate where subscribership drops to some 75% of the households in the U.S. The cost structure for telecommunications is one of declining real costs, not rapidly rising real costs as in health care. However, we believe there is a real danger of just such an outcome if we look at advanced telecommunications services. Indeed, we already are experiencing less than universal service for advanced services. The present tariff structure paints a bleak picture for the ability of the public network to offer advanced services on a universal basis in the face of significant competition from interconnected private networks.

We also raise the possibility that the current "infrastructure movement" may result be socially excessive and/or biased. It may result in expensive modernization of the public network with little benefit to the mass of subscribers and facilities which are of value to a relatively small group - precisely those with private network alternaitves. With no committment of the subscribers to pay its costs, i.e. no restrictions on exit, private networks need bear little of the costs of experimenting with new capabilities in the public network. Significant option values may be associated with such experimentation, but a free exit policy will allow private networks to realize the benefits of these experiments with no obligation to bear their share of the costs.

IV "Solutions"

We believe that the current set of social constraints on the evolution of telecommunications markets is untenable: the desire for public systems with universal service obligations; the desire for a degree of access charge averaging geographically; the desire to burden the heavier users of the public network with more than their share of its costs; the desire to significantly upgrade the technology of the public systems; and, the desire to foster private network development and competition. As Crandall points out:

"The lessons we have learned from the past two decades of reductions of regulatory barriers to entry into telecommunications are quite clear. Entry has proceeded much more rapidly than anyone would have expected from simply watching the new OCCs. The enormous rise in private communications systems ought to suggest to regulators either that there are diseconomies of scale and scope among the regulated telephone companies, that regulated institutions have created little incentive for efficiency among these telephone companies, or that regulated rates are substantially distorted. None of these possibilities would argue for a restoration of the satus quo ante."[13]

We agree that all of these suggestions are true to an extent, but our focus has been on the last of these - the significant distortions in regulated rates. We have encouraged a vast social experiment with competition in telecommunications which has yielded, and should continue to yield, huge social benefits. However, as we seek to upgrade our infrastructure and continue to maintain universal service as a social goal, sitting on the fence between competition and regulated monopoly becomes increasingly precarious. It is critical that we enter the information age with an appropriate set of incentives in place, and not the vestiges of earlier regulatory structures.

Accordingly, we should outline what an efficient set of incentives for private network interconnection with public systems might look like. Unfortunately, it is far easier to state what efficient incentives *do not* resemble. We propose the following guidelines for public network tariffs:

[13] Crandall (1989, pp. 64-65).

1. Eliminate as many cross subsidies in the current structure as possible. We view the dangers of distorting usage tariffs as more serious than distortions in access tariffs, so we should continue to move in the direction of lowering marginal usage prices. In fact, the flat rate usage tariff has much to recommend it, especially as the network becomes fully digitalized. The desire to keep access universally affordable is better funded out of general tax revenues or some other more efficiency neutral device (this mirrors the suggestions of NTIA (1991)).

2. Actual usage is rapidly diminishing as a meaningful base for assessing charges. Most network costs are associated with access and *potential* usage, rather than actual ex post usage. We believe that option values are rising in significance and these cannot be recovered efficiently through ex post usage charges. Means need to be devised to recover costs (particularly the costs of new technology) through potential rather than actual usage.

This would mirror the changes in the information structure of the industry. In the franchised monopoly era, the firm had better information than customers about usage patterns and was in a better position to forecast demand. Public networks bore this risk in the form of a usage dependent revenue structure. Private networks have shifted the information advantage towards the customer. Accordingly, users should now bear more of the risks associated with uncertain demand - payments should shift in the direction of independence from the state of nature.

3. Given the large incentives for private networks to develop, *even in the absence of real cost efficiencies*, under existing tariff structures, we would recommend assessing some type of exit cost from the public systems. Compensation payments for lost revenues to the public systems could fulfill this, as being used in Switzerland or New York. Setting these compensation payments will be difficult and we would recommend erring on the low side rather than the high side. The payments could be adjusted according to the actual experience of public/private network evolution. The critical first step is recognition that such payments are appropriate in light of current market forces.

4. We believe there is much to be gained from sharing of private and public networks. Efficiency would seem to call for sharing of such capacity jointly (i.e., bidirectional interconnection rather than unidirectional interconnection). Capacity at different times and in different places could be traded. In fact, carrier of last resort obligations of the public systems could be traded for excess capacity on private networks. The pricing recommendations above would facilitate such trades. Achieving the potential of bidirectional interconnection will require considerable compatibility between networks and resolution of difficult network control problems. Regulators have a key role to play in these areas. LECs may be in the ideal positions to be clearinghouses or brokers for excess capacity.

5. A volume discount tariff structure might effectively collect the option values associated with public network access. The first price tier would have a high charge, with declining blocks thereafter. To regular public network users this would look like a two part tariff. For occasional users, it assesses high charges, as they would pay only when they use the public network. The advantage of this approach is that only a single tariff structure needs to be offered to all customers. There would be no need to differentiate between different classes of customers. The drawback would be that such charges on *all* occasional users may be inequitable.

6. A final alternative is to tax some other input to telecommunications services which is used regardless of which network is subscribed to - e.g., CPE. This is the approach used to fund maintenance of the highway infrastructure. The primary revenue source is gasoline taxes. These taxes are levied on fuel without respect to what type of highway is traveled.

The above changes can ameliorate some of the potential dissolution of public systems posed by existing tariff structures. They would also send from regulators that private networks will not escape regulatory oversight. Part of the advantage of private network development is currently the ability to circumvent the regulatory process. The current regulatory paradigm regulates on the basis of the identity of the supplier, not on the basis of the service being supplied.[14] Public welfare, on the other hand, derives more from the service than from the identity of the firm supplying it.

We are less optimistic that tariffs can be designed efficiently on the basis of existing knowledge and data. For instance, even if we accept that option values are significant and should be tariffed, we know of no adequate basis on which to determine the efficient levels for such tariffs. Elimination of all cross subsidies would go a long way towards providing efficient incentives, but we wonder about the political feasibility of the result. The transition to competition is frought with such problems, and asymmetric regulation during the transition only compounds these. We can recommend the above alternatives in order to buy time and prevent some of the grossest inefficiencies that might result from current market forces. However, we are concerned that we are headed towards a system of "managed competition." This system did not work well for the airline industry and tends to result in fixed market shares. In the rapidly changing telecommunications environment, fixed market

[14] Goldberg (1976) maintains that evaluation of regulation must begin with the nature of the service, or it will result in comparing imperfect regulation with perfect market environments. The reality is that the nature of the service being regulated often requires comparisons between two imperfect systems.

shares does not strike us as a very efficient outcome.

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