Procuring Universal Telephone Service

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Introduction

One of the hallmarks of modern society is its pervasive reliance on telecommunications. Progress in telecommunications has deeply changed the nature of social relations, politics and commerce. Individuals and communities with limited access to modern communications are disadvantaged in their efforts to keep abreast of current news, to participate in public debates, and to make their opinions known to the rest of the world. Business firms need electronic communications to integrate their far-flung operations. Much more than in the past, firms can now depend on distant suppliers to be well enough informed to react quickly to their changing needs. Combining rapid communications with flexible manufacturing technologies enables firms to make customized products that respond to individual customers' changing demands (Milgrom and Roberts, 1987).

When a geographic area is cut off from modern communications, that creates a tear in the social fabric, separating the residents from the rest of society. That is perhaps the most compelling reason for a democratic society to seek universal access to modern telecommunications. There are also good economic reasons as well to ensure widespread access by *individual* members of communities to the communications networks, particularly the telephone network. For example, public emergency services—police hospital and fire service—can be delivered more quickly and effectively and at lower cost when households have quick and easy access to telephone services. In addition, there are *network externalities*, meaning that broadening the communications network helps not only the newcomers but also those already on the network by enlarging the circle of people with whom they can communicate. For all these reasons, many countries have set near-universal access to telecommunications services as a policy goal.

Achieving such widespread access to telephone service is expensive for two reasons. First, some customers have such low incomes that even modest telephone charges are unaffordable. In the United States, programs designed to subsidize telephone service to low income customers are called "lifeline service" programs. Second, the fixed cost per customer of installing access lines to remote areas with low population density is very high. For example, establishing service to customers living on farms and ranches in rural areas typically requires running long wires through difficult terrain even though only a small group of telephone subscribers is served. Even within urban areas, the costs of connecting different customers to the telephone network can vary among customers by a factor of ten. Programs designed to pay part of the cost of providing service to high cost areas are called "universal service" programs.

In practice, implementing a program of universal, affordable access to basic telephone service involves first establishing what is to be included in the "basic telephone service."

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What options should be available? What level of quality should be maintained? Second, an affordable price must be established. Third, a service provider or providers must be identified, and a means must be found of footing the bill.

In the United States, universal service has been implicitly subsidized both through reduced prices for basic telephone service supported by higher prices for other telecommunications services and through the use of uniform telephone rates over wide areas. In California, for example, even today, anyone in the area serviced by the largest telephone company, Pacific Bell, can purchase basic telephone service for $11.25 per month. This price is the same for hillside dwellers in remote mountain communities as for residents of large apartment buildings in downtown Los Angeles, even for apartments that are just a block away from the main telephone switch. The phone company's cost per phone line of hooking the apartment and its residents into the system, though, is much lower than for the mountain dwellers, because a single short high capacity wire can be used to provide service to all of the large building's residents. The implicit subsidies in the system are enormous: one estimate for the subsidy to rural service alone is about $5 billion per year[2] and the estimated size of all rural and urban subsidies is higher still.

So long as local telephone service is provided by monopolies that are free from competitive market constraints, this system can be sustained. In recent years, however, the local telephone monopolies have come under siege. New phone companies have sprung up to offer services in places like Manhattan (initially for business customers), where the high density of telephone lines makes the average cost of service quite low. In the US, the passage of the Telecommunications Act of 1996, which aims to reduce regulation and increase competition in telecommunications, is destroying the monopolies at the foundation of a system of uniform local service prices for all customers. The Act provides for the establishment of a fund to subsidize service to customers in high-cost-of-service areas. The Act also requires that the subsidy levels in each area be adequate to cover the universal service provider's costs.

It is now the task of regulators to decide how to implement the Act's provisions, keeping in mind the two main goals of encouraging competition in the provision of telecommunications services and keeping down the cost of subsidies (and the taxes needed to support them), as well as subsidiary goals like reducing the need for ongoing regulation.

With these goals in mind, two main kinds of policy options have been discussed. The first calls for the use of an auction in which bidders name the price they require to accept a universal service obligation in a service area. This means that the selected suppliers stand ready to offer a prescribed basic service package at a prescribed "affordable price." The advantage of this option is that competition among would-be universal service providers could drive down the necessary level of subsidies. Also, once auctions are conducted, there would be no further need for cost studies to determine appropriate levels of subsidy to a monopoly telephone supplier. Nevertheless, this option is often regarded as unsatisfactory because it results in a single provider in each service area. With neither competition nor regulation to discipline the single provider, there would be little pressure on it to introduce

[2] *What Price Universal Service?: Impact of Deleveraging Nationwide Urban/Rural Rates,* Telecommunications Industries Analysis Project, Cambridge, MA., 1993.

new services and maintain high standards of quality. Also, new telephone providers may be able to bring valuable new services, like cheaper long-distance calling, or packages including telephone service with wireless or cable television services. Having a single provider denies these potential new services to customers.

The second option calls for estimating the costs of providing basic service in each area and then making that level of subsidy available to any company that is willing to accept a universal service obligation for the area. This makes competitive entry relatively easy, with all the advantages that competition entails. However, it has two big disadvantages. First, because it bases subsidies on the existing wireline technology and ignores the revenues from new services that might be delivered over the telephone network, it locks in the subsidies at an unnecessarily high level. Second, it requires ongoing regulatory intervention in the form of both cost studies (to meet the legal and practical requirement that subsidy levels are adequate) and coercive service requirements on the incumbent telephone company at the established subsidy levels.

Each of these options has advantages and disadvantages. Across the United States, the conditions of entry vary as well, with some areas already home to local telephone competition and others where the prospect of competition seems distant. These combined facts raise some obvious questions: Is it possible to tailor the regulatory system to the local conditions? Is there a system that does that automatically, without the need for an omniscient regulator to choose the proper regulatory intervention? Is there a mechanism that is demonstrably optimal for the universal service problem in such varied environments?

An Optimal Auction Mechanism for Universal Telephone Service

In the process of answering these questions, our analysis introduces an important new alternative into the policy debate. This is an alternative in which the number and identities of the competitors is determined by the market process itself, rather than being set by fiat as in traditional auction proposals. In particular, the new mechanism promotes different market structures in different geographic regions, as is certain to be appropriate given the very different cost conditions that prevail in different areas. Compared to the older proposals, the new alternative is more balanced in encouraging competition both "in the market" after the auction, to promote better service and more variety, and competition "for the market" in the auction, to reduce the level of subsidies that need to be paid.[3]

Because the actual situation in supplying universal telephone is so complex, the theoretical analysis advanced here aims only to capture a few of the most important features of the real situation. We begin by specifying the objective of the whole exercise, which is to maximize a "total welfare" criterion or objective consisting of three terms:

Expected Benefits to Consumers
+ Expected Profits Enjoyed by Service Providers
– α *Expected Subsidies Paid to Providers*

The first term is the benefits enjoyed by the consumers in an area, which depends on the level of competition in the local telephone market. More competitors vying for customers

[3] See Dana and Spier (1994) for a closely related analysis.

can lead to various benefits for consumers, including more variety, better service offerings, and more responsive service. More competitors may lead to lower prices, too, if splitting the market does not increase costs too much. To account for the interests of telephone company shareholders, we add the firm's profits to the social objective.

These two initial terms, however, do not include all the economic benefits and costs. The taxes or surcharges used to pay universal service subsidies distort choices made in the economy and result in a loss of welfare. For example, if universal service were funded by a tax on long-distance calls, that could result in fewer such calls being made–calls that would be made if the price of long-distance calling were not made artificially high by the additional tax. The welfare loss from such distortions is approximately proportional to the total subsidies paid; it is captured by the third term in the formal objective.

To simplify the problem for this presentation, we make a number of assumptions whose significance we discuss briefly at the end of this lecture. We focus on the case where there is a single region in which universal service is to be provided and where all subsidies are paid in the form of a lump sum. There are assumed to be N bidders indexed as i=1,...,N.

Each of the bidders has a cost "type" θ_i that determines its cost of providing service to some or all of the customers in the service area. We may think of lower values of θ_i as corresponding to lower total and marginal costs for firm i allowing it to earn greater profits in any particular competitive situation. Let θ denote the N-tuple $(\theta_1,...,\theta_N)$. Let $\pi^i(\theta,S)$ denote the profit earned by firm i when the set of firms receiving subsidies to accept the universal service obligation is S and let $B(\theta,S)$ denote the benefits enjoyed by consumers. We assume that (1) both consumer benefits $B(\theta,S)$ and each firm's operating profits $\pi^i(\theta,S)$ are independent of the types $(\theta_i, i\notin S)$ of the firms not actually present and providing telephone service, (2) a firm can earn profits only if it is authorized to supply subsidized service, that is, $\pi^i(\theta,S)=0$ if $i\notin S$, (3) $\pi^i(\theta,S)$ is continuously differentiable in θ_i, and (4) for all θ and all $i\in S$, profits are decreasing in θ_i: $\pi_i^i(\theta,S) \equiv \frac{\partial\pi}{\partial\theta_i} < 0$ and non-increasing in the set of competitors S.

The auction that is implemented, including the rules for the kinds of bids that can be made and the way firms behave in the auction game, determines which firms will receive subsidies in exchange for bearing the universal service obligation and what subsidy payments they will receive. The actual outcome of the auction cannot be predicted in advance because it depends, of course, on the cost types θ. One can describe the likely outcomes by a set of functions which express the probabilities $p_S(\theta)$ that S will be the set of firms selected to be suppliers when the cost types are given by θ and the corresponding expected levels of subsidy payments $x_i(\theta)$ to each firm i. With the outcomes described in this way, the corresponding expected level of welfare, given θ, is:

$$\sum_S p_S(\theta)B(\theta,S) + \sum_S p_S(\theta)\sum_{i\in S}\pi^i(\theta,S) - \alpha\sum_{i=1}^N x_i(\theta)\,.$$

The three terms in this objective correspond to the consumer benefits, profits and burden of taxation term in the welfare calculation.

The expected value of the welfare measure is to be maximized by choosing functions $p_S(\theta)$ and $x_i(\theta)$ (i=1,...,N) corresponding to a feasible auction and associated bidding behavior. For the expected value calculation, we assume that the θ_is are independent and distributed according to distribution functions F_i with corresponding densities f_i, i=1,...,N. Thus, expected welfare is:

$$\int\left[\sum_S p_S(\theta)\left(B(\theta,S)+\sum_{i\in S}\pi^i(\theta,S)\right)-\alpha\sum_{i=1}^N x_i(\theta)\right]f(\theta)d\theta$$

In order to characterize the maximum in this problem, one first must characterize the constraints on the p_S and x_i functions that are implied by our postulates concerning how the bidders will behave. We assume that the bidders will play the Nash equilibrium strategies of whatever auction game we may design and, if there are multiple equilibria, that the bidders will play the equilibrium selected by the mechanism designer. To solve the maximization problem, we utilize techniques first developed in the Roger Myerson's 1981 analysis of auctions that maximize the seller's expected revenues.

The full details of the mathematical analysis will not be reported here. What Myerson's analysis demonstrates is that the p_S functions combined with the avoidance of unnecessary subsidies to losing bidders combine to determine uniquely the necessary expected subsidy levels $E[x_i(\theta)|\theta_i]$. This allows one to substitute for x_i in the objective function, rewriting it as the expectation of the following alternative objective function:

$$\sum_S p_S(\theta)V(S,\theta)$$

where

$$V(S,\theta)=B(\theta,S)+\sum_{i\in S}\left((1+\alpha)\pi^i(\theta,S)+\alpha\pi_i^i(\theta,S)\frac{F_i(\theta_i)}{f_i(\theta_i)}\right).$$

The function $V(S,\theta)$ is called the "*virtual welfare*" function. We limit attention here to what we may call the "regular case," which is characterized by two assumptions about the function $V(S,\theta)$. The first is that it is more attractive to add low-cost types θ_i than high cost types. We write this as a "decreasing differences" condition: $V(S\cup\{i\},\theta)-V(S,\theta)$ is decreasing in θ_i. The second condition is that firms and types may be ranked by an index such that V-maximizing collection of firms consists of some number of firms with the highest index values. Various particular assumptions may be made which imply this structure. The upshot of the analysis is the following:

Proposition. In the regular case, an auction design is optimal if and only if it results in outcomes in which (1) for almost every θ, $p_s(\theta)=1$ for the S maximizes $V(S,\theta)$ and (2) the expected net profits (gross profit plus subsidy) of the highest cost types are zero.

A striking aspect of the optimal auction is that it calls for the market structure to be *endogenous*. This means that the *number* of firms participating in the market may depend on the firms' cost characteristics, which are the private information of the various firms. If there are several independent regions in which universal service is to be supplied, the result is that different numbers of competitors may be present in each, according to the privately known cost information of the firms.

In determining the optimal set of firms to include in the market, the profits of the firms are given extra weight in the virtual welfare function compared to the original social objective: it is multiplied by $1+\alpha$. In addition, $V(S,\theta)$ includes terms (F_j/f_j) to account for the bidding incentives of the firms. Awarding universal service subsidies to many firms tends to reduce the incentive of each firm to bid aggressively, since even a less aggressive bid is more likely to result in a reward. Therefore, unless there are diseconomies of scale (which is unlikely in practice), one consequence of designing an auction to allow multiple universal service providers is higher average subsidies. An optimal auction design takes that effect into account, typically reducing the number of firms both to increase pre-subsidy industry profits and to increase the intensity of competition "for the market."

Although the first part of the Proposition identifies quite specifically the criterion for who the winners in an optimal auction should be, the Proposition does not specify a unique rule for how payments should be made. Rather, the second part of the Proposition specifies only that high cost types should expect zero profits, that is, that no unnecessary subsidies should be paid.

The multiplicity of optimal payment rules means that there is scope for using the payment rule to pursue secondary objectives. One such objective is to arrange that each bidder has a *dominant strategy*. The advantages of dominant strategies were first identified by Vickrey (1961), who emphasize that these simplify the bidders problem, avoiding potentially costly errors and providing no incentive for bidders to make wasteful expenditures trying to guess each other's bids. The basic rule for making truthful reporting of cost data a dominant strategy is also one that Vickrey (1961) had identified. One achieves that by "paying each seller for his supply an amount equal to what he could extract as a perfectly price discriminating monopolist [against the residual demand curve]." In this case, the analogous rule is as follows: For each θ, pay firm j a subsidy that makes its post-subsidy profit equal to the increase in the maximal value of the virtual welfare function, $V(S,\theta)$, that results from expanding the set of available firms $N\backslash\{j\}$ to N. This rule implements the allocation identified in the Proposition, and makes truthful reporting a dominant strategy.

Another possible secondary objective is to pay uniform subsidies to all subsidized universal service suppliers. There may be legal reasons to prefer uniform subsidies. Uniform per subscriber subsidies may also be desired because they avoid advantaging any particular competitor when the competition for customers begins. Although uniform subsidies are possible, it is not possible to achieve both uniform subsidies and dominant strategy implementation of the optimal auction.

Limitations and Possible Extensions

The foregoing analysis is a preliminary one that is valuable because it introduces a new option. However, the recommended solution is only as good as the underlying model. The model itself has several limitations.

One of the most important assumptions of the model is that subsidies are paid in the form of a lump sum, regardless of the number of subscribers served. In reality, lump sum subsidies have some undesirable incentive properties. Bidders have weaker incentives to provide good service if the subsidies are independent of the number of customers served. Indeed, because subsidies are needed only for high-cost customers for whom service is unremunerative, it is necessarily wrong to suppose that service would be provided at all, let alone at the same level, if subsidy levels were low. To put the point more generally, the level of subsidies is likely to affect the intensity of competition among suppliers, and the existing model fails to account for that.

A second potentially important omission concerns variations in costs among customers in the area of universal service. If the cost variations are large across the service area, firms may be tempted to offer service only to the customers in the lowest cost segments of the service area. That problem could be resolved by running auctions for smaller, more homogenous areas, and indeed such a proposal has been made in the United States. However, if small service areas are specified for the auction, it may be inappropriate to consider the costs of service separately for each area, because there could be important shared costs among them. As of the date of this lecture, the importance of such shared costs for universal service remains an open question.

A third point concerns how the auction will operate when some of the service providers purchase some of their inputs from an incumbent telephone company. In the United States, the law governing local competition requires the incumbent to provide unbundled network elements at regulated prices, which confounds the question of whether the auction can help to identify the low-cost providers.

Fourth is the need to account for possible dependencies among areas in designing the auction. One significant possibility is that the cost of serving a set of adjacent areas is significantly reduced when a single firm serves them all. In that case, there are two practical approaches possible. The first approach treats the several areas as a single unit. That works tolerably well when the same groupings are appropriate for all the bidders. The second approach is more complicated but also more flexible. It involves allowing bidders to specify bids for combinations of areas and then selecting winners to take account of these economies of scope. Auction designs like that are still novel and unproved, but some promising designs are currently being tested for other applications.

Finally, during the transition to competitive provision of local telephone service in the United States, the incumbent local exchange carriers continue to have a special obligation to offer service. The analysis suggested here has been vague about the details of how the transition will be made. The timing of auctions in different service areas could be important, as could issues about the relation of the auction rules to other local competition rules. All of these details need to be worked out carefully if universal service auctions are to be successfully implemented.

Conclusion

Competition in providing local service has made obsolete the old model of a monopoly providing service at a uniform rate over wide service areas. Yet, for a wide variety of political, social and economic reasons, it is desirable to have affordable service even to relatively remote communities. Up to now, the ways of achieving that goal have either involved continued regulation or an auction that preserves monopoly supply status for some firm.

Our new proposal combines the advantages of an auction scheme, in which bidding keeps burdensome subsidies low and avoids the need for detailed price regulation, with those of a fixed price free entry scheme, in which the number of entering firms depends on market conditions. Although many details remain to be specified, this approach offers the promise of a mechanism that can be applied flexibly to balance the several conflicting objectives in establishing a universal service plan.

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