Improving Rural Telecommunications Infrastructure

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TVA Rural Studies

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1. Introduction

Advanced (digital) telecommunications technology has the potential to dramatically improve the quality of life and the rate of economic development in rural America[1]. Public access to advanced telecommunications technology needn't imply that one has to be physically located in proximity to urban areas where most information and production is generated. But while technology adoption in communication networks continues at a very rapid pace, increased market competition among telephone network operators forces them to invest where the money is, in dense urban and suburban areas. Thus, while a modern and effective telecommunications infrastructure is crucial for rural economic development, its financing raises a multitude of difficult public policy issues.

The analysis herein examines the rural telecommunications infrastructure focusing on technological developments and the costs and financing of network modernization. While there has been considerable hype in the industry and trade press about digital information "superhighways" (as if we all can just sit back and wait for "it" to happen), a look at the facts would lead to a more pessimistic view, especially for rural areas of the country[2].

There are some recent technological developments which provide exciting prospects for new digital wireless technologies to come to the rescue for some rural services, however, the government needs to pay more attention to spectrum allocations for rural radio services in order for these to fulfill their promise[3]. Because the cost characteristics of such technologies are not nearly as sensitive to the physical distances involved, these technologies hold special promise for rural applications, but will likely not be deployed in rural areas until well after they appear in dense urban and suburban markets.

Much of rural America is served by small independent telephone companies. There are over 1300 local telephone companies in the US, the top 10 of which serve over 90% of all subscribers. The rest serve mostly rural areas with a relative handful of subscribers. Historically, financing for the modernization of rural company network facilities has come from a combination of the local tariff rates charged by the rural telco and cross subsidies derived from: 1) rural company charges to interconnecting toll carriers and, 2) other revenue sharing arrangements with larger local telephone carriers which serve relatively dense areas with lower cost (higher profit) subscribers. Increased competition has added considerable uncertainty to the traditional revenue flows derived from these sources.

Market competition is the natural enemy of cross subsidies. While direct competition for telephone subscribers may be long in coming to many rural areas, the competitive erosion of cross subsidies currently provided by toll calling, business and high profit residential market segments is surely going to proceed rapidly. Naturally, the political lobbies for competitive network operators do not want to provide any subsidies for rural development. At the same time however, small telephone companies want the government to assure that the rural network infrastructures and individual subscriber service in rural areas is affordable and equivalent to that available in urban and suburban areas[4]. The reality, of course, is that the outcome for the future will be similar to that of the past, namely, that rural network infrastructures will lag behind urban areas in terms of advanced service capability. In the new competitive environment, the risk (assuming the status quo of competitive entry with no proportional subsidy funding requirement from entrants) is that the disparity will become much worse.

In order to prevent the erosion of rural subsidies from newly competitive services, a number of federal and state initiatives are under way with the goal of preserving subsidy flows, usually under the rubric of so-called Universal Service Objectives. At the federal level, the FCC is investigating ways to better target subsidies to rural areas in need, and pending legislation in both houses of Congress contain provisions for maintaining subsidies for high cost areas[5].

Rural Network Technology

The following analysis indicates that now and in the future, fiber optics will continue to be the technology of choice for all shared network facilities where terrain permits. At times, local conditions may call for microwave radio trunk transmission lines instead of fiber. In the future, however, digital fiber optics will dominate local network trunking. For the dedicated subscriber loop plant, there are several alternatives depending on local terrain and the spatial distribution of individual subscribers, including coaxial cable, copper wire and digital radio. Due to significant variations in local demographics and topography, some of the overall analysis and conclusions may not apply in many specific rural areas although they are relevant for broad public policy considerations. For example, new digital satellite systems may be the only realistic way to get relatively low cost and high quality digital service to certain remote locations.

The most important conclusion of all is that technological solutions must be tailored to specific circumstances regarding topology, terrain, subscriber demand and spatial distribution. A "cookie cutter" approach to technology deployment, while easier from a network standards perspective, is usually not the least cost method to optimize the network for local supply and demand conditions or for planning future network upgrades[6]. Indeed, flexibility in network deployment strategies is the key to successful low cost investment. This means that flexible standards must be developed by both wireline and wireless network equipment manufacturers to allow efficient interconnection between networks and a high degree of connectivity between end users[7].

The cost of advanced rural communication network infrastructures is substantial. In a future competitive market environment, it may not be possible to finance its construction without significant increases in subscriber rates unless a new stable source of subsidy funding is adopted by regulators[8]. Assuming a construction interval of 10-20 years——a normal time span for turning over telephone plants——one estimate of the cost of digital service is about $1,000 per subscriber[9]. This would endow rural subscribers with digital communication capability comparable to narrowband ISDN service. While this may suffice for residential subscribers using home computers or other devices, such narrowband service capability may not meet the communication requirements of business customers. As subscriber needs develop, broadband services using fiber-optic technology or other suitable media may be necessary.

Achieving broadband communication capability in rural areas is a very costly proposition at about $4,000-$5,000 per rural subscriber[10]. Broadband communication facilities would allow consumers to enjoy high quality service, including entertainment video and multimedia applications where more than one communication activity may occur simultaneously. For example, with broadband telephony one may access an on-line database while viewing a movie, reading, or listening to the news. The cost of such capability is high because it requires new alternatives for the subscriber loop plant to replace traditional twisted-pair copper phone lines.

Where possible, existing coaxial cable television loops could be interconnected to a fiber backbone of shared network facilities to provide broadband capability. Elsewhere, fiber-to-the-home (or "near"-the-home) is required. Current satellite and microwave radio will not be the best option for most service applications because bandwidth limitations and delay times make these technologies unsuitable for a multimedia real-time environment. However, both radio and satellite are useful for infrastructure development in some applications. Satellites, for example, are preferred for delivery of distant video programming and may be interconnected to the wireline network infrastructure. But the use of satellites for voice service or other real-time two-way communications will likely be minimal[11]. This could change, however, with the future deployment of new Low and Medium Earth Orbit (LEO/MEO) digital satellite systems[12].

Microwave radio is useful and cost effective in many situations where fiber is not practical, such as over rough terrain or water. Much of the existing microwave facilities are useful for providing advanced telecommunications because they are already digital and may feature high bandwidth and capacity for new service applications. However, for distribution of basic local service, both satellite and microwave will generally be limited to relatively high cost applications. The FCC-approved Basic Exchange Telecommunications Radio Service (BETRS) is the primary application of microwave radio technology for local service. It is expected to be the preferred alternative when wireline service is not feasible, but as such cases are rare, rural radio service, as currently defined by the FCC, is not being widely deployed as an alternative to traditional wireline service in rural areas[13]. The FCC could change this if new spectrum assignments for high powered rural radio systems were made. High powered digital radio systems for fixed telephone service are cost effective in rural applications compared to wireline systems, but only if there is enough spectrum and only if system power restrictions allow for large ““macrocell”” radio coverage areas (e.g., 15-30 mile radius) featuring maximum sharing of available spectrum within single base station area. Foreign countries, especially those with nascent network infrastructures are deploying new digital wireless systems as an alternative to traditional wireline connections[14]. The US government’’s recent focus for radio spectrum policy has been on new convenient low power cellular and advanced paging and cordless telephone services which, while ideal for pedestrian and mobile applications in congested urban environments, is not cost effective or feasible in rural settings.

The best way to establish rural objectives for a network infrastructure is to begin at the state level. The reason: telecommunications depreciation policy, basic rates and economic development planning are set at the state level; each state determines its objectives, timetables and financing requirements. There is an important gap in telecommunications infrastructure planning in most states, especially regarding coordination with the important transportation and energy sectors. We find the synergies of telecommunication network providers and public power grid operators to be underutilized for fiber optic transmission and recommend more cooperation in this area. The same is true, but to a lesser degree, in the case of the transportation sector. The early beneficiaries of more cooperation between these sectors is rural education, health care and income growth.

2. What is Rural?

There is no standard definition of rural telecommunication subscribers; however, some general observations should be made. Government data indicates that about a third of all residence subscribers (some 30 million households) are in non urban areas of the U.S. (called Metropolitan Statistical Areas or MSAs). Non-metropolitan counties are those with no urban areas greater than 50,000 population, but there are many possibilities for classification errors. For example, there could be metropolitan areas close to the border of adjacent non-MSA counties, or there could be many towns of less than 50,000 people each. It is potentially misleading for policy makers to use such data for policy purposes without adjusting it for classification problems[15].

It is very important to distinguish "rural" from "remote" subscribers; The latter refers to those whose access to the telephone network is difficult due to physical "remoteness" caused by either extreme distance or terrain. While remote subscribers with no telephone service might represent a socially deserving segment of the general population, for public policy purposes they should be separated from the general body of rural subscribers. Public policy must be able to focus on upgrading communication infrastructures for those customers already hooked up to the network regardless of policies for reaching customers who are not only rural, but physically remote. Otherwise, policy debates over the subsidies required to provide service to remote non-subscribers can derail progress in technology adoption for the vast majority of rural subscribers. Furthermore, the available evidence is that remoteness is neither a particularly common problem nor one which requires much total subsidy to solve. Pockets of truly remote subscribers will be most economically served by new digital satellite communication networks.

There are few truly "remote" subscribers relative to the base of all rural subscribers. One estimate puts the number of remote customers at 183,000, or only about 1% of all rural subscribers[16]. Fortunately, a wealth of information exists for small independent telephone companies from industry trade groups such as United States Telephone Association (USTA), the National Telephone Cooperative Association (NTCA), and an agency of the United States Department of Agriculture which for many years was called the Rural Electrification Administration (REA). The REA’’s areas of responsibilities were recently combined with other areas and the new agency is called the Rural Utilities Service (RUS). RUS provides investment and financial data for almost 900 small telephone companies serving about 6M subscribers in very thin markets. Thus, for purposes herein, the RUS data will be representative of "rural" subscribers. While many other data sources will be used in this analysis, the basis for most statistics will be the RUS data[17]. Depending upon one’’s view as to the absolute number of rural telephone subscribers in the US, for broad policy analysis the per subscriber results based on RUS data may be increased by an appropriate factor to arrive at universal results.

Beyond the distinction of rural vs. remote, there is also an important distinction between existing and new customers. Costs of technology adoption may be very sensitive to the fact that the necessity of starting from scratch in some areas renders moot the issue of whether or not to use some of the existing facilities in a network upgrade. For most subscribers, a network upgrade must consider the embedded base of technology to ensure a cost effective construction decision. Keeping in mind the distinctions between rural vs. remote and existing vs. new subscribers, this analysis concentrates on the cost of network upgrades for existing subscribers——the vast majority. Remote and new subscribers will be considered separately.

3. Financial Profile for Rural Telephone Companies

There are over 1300 telephone companies in the US, about 900 of which are borrowers in the federal government RUS financial assistance program. The top 53 Local Exchange Carriers (LECs) which report annually to the FCC, account for about 90% of the approximately 150M access lines in the US[18]. The seven Regional Bell Operating Companies (RBOCs) alone account for about 70% of all telephone lines; adding GTE and Sprint accounts for nearly 85%. However, despite the huge differences in the scale and scope of the operations among US LECs, when comparing statistics for average per line financial results between large and small companies, the data are surprisingly similar. One reason for this is that, while the larger LECs may enjoy the low average per line costs of serving large metropolitan areas and spreading fixed network costs over a large subscriber base, they also serve a considerable number of rural service areas. Similarly, while small rural LECs may serve much less dense areas overall, they too serve relatively dense towns within those rural areas. Furthermore, larger LECs tend to have a scope of operations which is very different from that of smaller LECs including investments in regional toll service network facilities and specialized and business services.

Tables 1 and 2 provide financial benchmark data for key operating ratios, costs and revenues for large and small LECs.

3.1 Operations, Investment and Expenses

A comparison of the FCC and RUS data for large and small LECs indicates that large LECs enjoy substantial capital and labor productivity advantages due to their large scale of operations and dense subscriber base. For example, large LECs support on average about 30% more telephone lines per employee than small LECs.

Average annual expenses per line are $607 for small LECs and $446 for large LECs. However this includes annual depreciation charges per line which, due to the small LECs larger investment in physical plant per line, would be expected to cause annual capital related expenses to be higher. Since depreciation expense requires no cash outlay, operations expense net of depreciation provides a better measure of relative expense performance. Net of depreciation expense, small LECs annual expense per line is $450 and the large LEC is $330.

Even though small LECs have 40% more investment per subscriber line, the annual network related expense ($128) is almost the same as for large LECs ($120). Annual customer operations expense is $70 per line for small LECs and $84 for large LECs. Corporate operations expense (i.e., overhead) per line for small LECs is $120 and for large LECs is $70. This cursory analysis of average expense data reveals that small LECs are quite efficient relative to their larger LEC counterparts when considering the on-going network and business office operations. This is especially significant considering that conventional wisdom is that there are important production cost economies associated with larger scale and scope of network operations. Overhead expense performance for smaller LECs relative to larger LECs is not good. But, per line corporate overhead involves expenses which are more easily reduced by ““spreading”” them over more access lines.

3.2 Revenue and Operating Margins

Chart 1 portrays major sources of revenue and expense for small LECs in average percentage terms and Table 3 provides some indication of the variability of per subscriber revenue and expense among individual firms. The data presented earlier in Table 1 showed that annual revenue per line for small LECs is $799 per year or $66 per month and corresponding amounts for large LEC revenue is $605 per year or $50 per month. Basic local monthly service charges per line are similar for both large and small LECs at about $16 per month. Regulation continues to achieve the social objective of rate parity between rural and non-rural areas for Plain Old Telephone Service (POTS). The quality of POTS service is similar with RUS companies reporting that 98.5% of residential subscribers have single party service (the remainder have shared party line service).

These average revenue numbers reflect both business and residence lines. The FCC reports that 64% of access lines for large LECs are residential, while the RUS reports that small LECs have 82% residential lines. Throughout the US, business basic local service rates are higher than residential and therefore, the basic rates for residential service for rural subscribers is somewhat higher than that for large LECs once the higher ratio of business to residential lines is accounted for.

Table 1 shows operating margins per line for small LECs of 24% of revenue ($191.37 per year), for large LECs the corresponding margin is similar at 26%. So, for now, the cash flow performance is similar for both large and small LECs.

The most important difference in the revenue streams of small and large LECs is that a whopping 67% of small LEC revenue is derived from toll and toll carrier access services, while for large LECs the number is 45%. Per dollar of household income, rural telephone subscribers spend almost twice as much on toll service than urban customers. Relative to large LECs, small LECs provide very little toll service directly, but instead share in the use of the toll network facilities of interconnected large LECs and interexchange carriers (IXCs). This is a harbinger of future problems for small LECs who have little hope of increasing their toll operations. Large LECs on the other hand, especially the RBOCs, have much to gain when the government removes restrictions into the huge interLATA toll market. Carrier access charges and toll settlements paid from larger telephone companies to smaller ones increase the ratio of toll and carrier access revenues. As competition in the industry for toll and carrier access services escalates, this very important revenue support for small telephone companies is increasingly at risk. The fact that some very high cost rural telephone companies depend on toll subsidies for their very existence represents a special problem for the future. For such companies, average loop costs can easily run two to ten times the overall rural average.

3.3 Financial Trends

Whatever the prospects for the financial future of rural LECs, the trend for the last five years is certainly a healthy one. For the time period 1989 to 1993 RUS LECs achieved an 8% increase in per line revenue and operating margins. Basic service revenue for RUS LECs increased over the period by 8% and toll and network access revenue increased by 11%. This is impressive considering that the corresponding FCC data for large LECs indicates percentage reductions in revenue per line (-10%) and operating margins per line (-18%)[19].

Furthermore, investment in rural networks is proceeding apace. From 1989 to 1993 the per line investment for RUS LECs increased by 9%. The depreciation reserve ratio (an indicator of the rate of capital replacement) has steadily increased (albeit slowly 9%) from 38.1% to 41.6%. Large LECs have done somewhat better on average as depreciation reserve ratios rose considerably from about 34% to about 40% (an 18% increase). Thus, the rural LECs rate of capital recovery increased only one-half that of the large LECs over the last five years. However, the large LECs had started back in 1989 with a depreciation reserve percentage far below that of the rural LECs and are only now catching up.

That having been said, rural LECs are now at risk of stagnating and falling behind. Large LEC depreciation rates for 1993 were 7.1% compared to only 6.2% for the small LECs (about the same as it was for 1989). In 1993 the large LECs invested in capital additions at a rate of +7.5% of the total plant in service, indicating that almost all of the financing was generated internally from depreciation charges. No comparable estimate of total capital additions over time is available for RUS companies because the exact number of companies which borrow (and report) this data to RUS varies from year to year.

4. Rural Telephone Plant Characteristics and Costs

Based on RUS company cost characteristics, one broad gauge estimate of the total cost of providing rural telephone service in the US is $19B per year[20]. This total assumes that all 22M non-MSA subscriber lines are classified as rural and an average annual cost of $871.08 or $72.59 per month.

There are significant differences in the physical characteristics of rural vs. urban telephone plants. RUS companies' markets are very thin, averaging only 4 subscriber lines per square mile of area served and only 6 lines per route mile of telephone transmission plants. For large telephone companies the average density of subscriber lines is greater by an order of magnitude[21]. Large LECs have five times more lines per switching office and almost five times less transmission facilities per line than small LECs (measured by sheath meters of copper cable - Table 2). The average length of subscriber connections to the LEC exchange switch for large LECs is about 10,000 feet vs. double that for small LECs. However, the net result is that the average investment and expense per subscriber line is only about 40% higher for the small LECs (Table 2).

Chart 2 shows a breakdown of small LEC total capital expenditures by major category of plant. Eighty-five percent of small LEC capital investment is represented by switching plant (31%) and cable and wire facilities (54%). Large LECs have 82% of total investment in switching plant(38%) and cable and wire facilities (44%). For both large and small LECs the remainder of the investment is primarily in land, building and support assets.

The average loop length for RUS companies is 20,330 feet, which is significant considering that access lines longer than 18,000 feet usually require special treatment to insure high quality basic service. The main problem is the attenuation of the analog signal, which may require boosting, using repeaters and amplifiers, or passive reduction of attenuation losses by loading coils, or both. Such loops pose a problem for the narrowband digital and new broadband services that require relatively high quality circuits for error free digital transmission. However, the mode loop length is less than the average for RUS companies. Consequently, 55% of the loops are less than 18,000 feet. The majority of RUS company loops are actually non-loaded, but many still receive treatment of some kind to improve transmission and signal quality. In contrast, about 90% of RBOC loops are less than 18,000 feet, and a large majority of those are non-loaded with an average length of only 7,500 feet.

On average, there are about 7,400 access lines per telephone company exchange in the US. Bell companies (BOCs) have about 12,000 lines per exchange[22]. Non-Bell Independent Companies (ICOs) have only about 3,000 lines per exchange. For 1993, the RUS reports an average of only 1,223 lines per exchange.

Average statistics regarding costs and network operations can be very misleading when considering any individual LEC or specific geographic region and caution must be used before ascribing average statistics to any company or group of companies. An examination of the RUS data for individual companies indicates some highly skewed distributions. Charts 3-5 illustrate the high variability in small company network characteristics including the number of exchanges, the number of subscribers and the average exchange size. For example, Chart 3 shows that the average number of exchanges per small LEC is 6 while the standard deviation is 8.5 and by far, most companies have only 1. Chart 4 shows that the average number of subscribers per company is 6,341 with a standard deviation of 14,000 with most companies having under 1000. Chart 5 shows that most RUS companies have between 200—400 subscribers per exchange, while the average is 1,223 and the standard deviation is 1,499. There are a considerable number of companies with over 2,800 subscribers per exchange.

Indeed, even within a single rural exchange area there are substantial differences in the physical characteristics of subscriber connections. This means that it is not only misleading to ascribe average company or exchange statistics to individual companies or exchanges, but that it is also problematic to apply average loop characteristics of a single exchange to individual subscribers. This has enormous implications for public policies that are trying to accurately target funding assistance to those subscribers who are truly in need.

Figure 1 is a stylized example of a representative local exchange area for a rural telephone company. The average exchange is comprised of about 1,200 households with a relatively dense downtown area containing 65% of total lines in the exchange area and 35% considered to be in the rural surrounding area of the exchange. The ““typical”” rural exchange as shown in Figure 1 has 768 households in the downtown area at a density of 256 subscribers per square mile, and 440 rural households with an average density of 6 per square mile. This example of a ““typical”” exchange shows that it is the rule rather than the exception to expect very different costs for individual subscriber connections within the same exchange area.

To illustrate the impact of subscriber density on the average cost per subscriber for rural LECs, Chart 6 provides cost estimates for the average urban and rural subscriber in the stylized exchange presented in Figure 1. The overall average per subscriber cost is $2,200. For the urban zone of the exchange the average cost is $800 and for the rural zone it is $6,000. As expected, the difference in cost is due primarily to the placement of longer loops for the rural subscriber.

A further examination of the variability of rural loop costs among small LECs can be found in Table 4 which provides a breakdown of total investment per subscriber for three density bands 1—10 lines per kilometer (km), 10—100 lines, and 100—500 lines. The per subscriber cost in the lowest density band (0-10/km) is about one third higher than for the second (10-100/km) and three times higher than the highest density band 100-500/km, with the average investment being $2,055 per line. Even within each density band, however, it would be misleading to ascribe the average cost result to any one company. For example, there could be drastic differences in topology and terrain which would dramatically affect costs but which do not appear in this data. One company may serve a relatively flat area with sandy soil, while another might be hilly or mountainous featuring solid rock. The spatial distribution of subscribers in a single exchange area could be exactly the same for both companies and yet the per subscriber costs for each could vary by an order of magnitude or more. The bottom line is that local conditions matter a lot.

Table 5 provides further support for the need to consider local conditions when assessing average cost characteristics. This Table displays statistical correlations between key publicly available measures of subscriber distance and density and investment and expense costs per line actually observed for 886 RUS companies. The subscriber density measures which were correlated with average cost per line were subscribers per route mile of cable, subscribers per square mile of serving area, and subscriber lines per switch. The very low values of the standard correlation coefficients demonstrate that there is no significant relationship between density measures and costs. Yet, it is well known that local factors like terrain notwithstanding, the primary engineering cost driver in local telephone networks is the distance of subscribers from the exchange. The second set of correlation coefficients is based on positioning all of the observed values for each variable in rank order from highest to lowest and correlating the rank ordered vectors. The very high rank correlation coefficients do indicate significant relationships, but now they have no meaning for any given company since the ranking of variable values were made without regard to which company the values belonged.

Kentucky is considered one of the most rural states in the US and Table 6 shows how small LECs average costs and revenues may vary within any given state. There are 16 rural Kentucky LECs that borrowed from the RUS in 1993. Table 6 (2 pages) provides operating and financial statistics for each of them. The weighted average revenue and cost per line and network density for the combined Kentucky rural LECs (second last row of Table 6) are fairly close to those for the national averages which appear in the last row of Table 6.

Conventional wisdom (at least to the layperson) is that rural telephone companies serve sparsely populated regions with little or no urban areas. This is not true. The available data makes it clear that inferences for any given company based on the average statistics for the group could be grossly misleading. Similar data is available for small LEC revenues and expenses. This data provides an important message for policy makers and regulators which may be tempted to develop competition policies and rural subsidy requirements based upon average cost and revenue statistics. There is no such thing as an ““average”” rural company, and no such thing as a ““meaningful”” average measure of the subsidy requirement.

5. Network Modernization

Notwithstanding the differences in individual company costs, at a broad policy level, the average statistics for loop length, transmission electronics and investment are useful for evaluating the average and total cost of rural subscriber loop upgrades. There is a great disparity between the tasks confronting large and small LECs to upgrade their loop plant to ISDN compatibility. Although bridged taps limit the ability of loop plant to support new digital service, this is no longer a serious problem for RUS companies.

In terms of digital network switching and intelligent network (i.e., switches equipped for Signaling System 7 (SS7) facilities, small LECs compare favorably to large LECs. Table 6 provides recent data on digital network facilities for Bell, other large LECs and smaller independent companies.

As the economies of scale derived from digital and fiber optic technology continue to lower the incremental per subscriber costs for advanced telephone services, the total costs associated with converting subscriber lines to narrowband and broadband digital service remains high or even prohibitive. Digital subscriber lines will allow rural subscribers to take advantage of new information age services including on-line computing, database, information and transaction services, remote monitoring, advanced facsimile and data services. These are the primary near-term applications for advanced rural telecommunications that will enable subscribers to "telecommute" or improve their productivity in the office or the home. Eventually, broadband digital service will become possible, ultimately providing for bandwidth on demand for anything from still pictures and high speed graphics to video telephony and full motion entertainment video.

Basic narrowband digital service begins with upgrading rural network functionality. Initial upgrades will support only low speed data and voice service. Expanded network capability will support higher data rates from 56Kbs service up to 144Kbs full ISDN service. This is the same modernization scenario scheduled for urban and suburban network upgrades, except that rural areas face some special challenges due to longer loop lengths. In both urban and rural areas, business customers may require broadband services, while most residential customers will probably be satisfied with narrowband capability for advanced voice and data telephone services. If residential demand for integrated broadband services takes off, narrowband network upgrades could be ““leapfrogged”” by the provisioning of broadband network connections capable of simultaneously supporting traditional telephone and broadband services. This scenario is very expensive and particularly risky in light of the cost effective alternatives including terrestrial wireless and satellite networks. It is especially risky for rural LECs to deploy broadband subscriber connections due to the very high sunk costs involved in the face of uncertain demand and certain competition from technological alternatives.

Not only is the broadband network infrastructure expensive, but the additional subscriber premises equipment cost must be factored in. New terminal equipment is currently very expensive. Even the basic digital set top converter box which is used to manipulate and control telephone and digital television signals coming into the house is very expensive. Early production units will retail at around $500-$700 apiece.

A second major problem with narrowband digital service network upgrades (as with next generation broadband services) is that there are no significant demand drivers, primarily because network services, almost by definition, require two-way end-to-end connectivity. Yet, physical network upgrades are gradual processes where more and more customers obtain access to the new technology over a period of many years. It takes a long time to implement widely available interconnectivity——the factor that will provide the demand-pull for further technology adoption. What good is it to be able to have advanced telecommunications equipment in your home if the people you want to communicate with do not have similar capability.

Thus, developing and deploying advanced digital telecommunication networks is a difficult and costly proposition, even in dense urban and suburban areas. Narrowband digital service, in the form of ISDN, has been in the implementation stage for almost a decade now; and there is still no residential service and only very limited access to business service. With widely available residential ISDN service not expected until late this decade, it is clear that even more advanced network upgrades will be delayed for both physical and financial reasons.

5.1 Business Subscribers

The rapid development of an advanced communication infrastructure for rural America will depend on how easy it is for businesses to access the technology. Businesses consider telecommunications capability an important factor in their location decisions. To the extent that businesses will have advanced services available to them, rural areas may become more attractive locations. Furthermore, as telecommunications capability improves in rural areas, "demand-pull" will begin to stimulate further technology adoption as businesses and their various suppliers and customers make use of more efficient network facilities. However, exactly what constitutes advanced telecommunication for businesses is an unsettled issue.

Relatively large businesses in rural areas, whether in the service or manufacturing sector, often require broadband communications capability to maximize operating efficiency and compete with their urban and suburban counterparts. Broadband in this case refers to digital transmission speeds of 45 Mb/s and higher. At such speeds, high quality data services and video telephony are possible. These speeds are much greater than the narrowband ISDN service which is gradually being deployed. Broadband service generally requires coaxial or fiber optic cable for subscriber connections, while narrowband service may be provided over more traditional copper facilities. Microwave and fiber optic transmission technologies are nominally capable of supporting both narrowband and broadband services but, as already explained, fiber is expected to be the dominant medium for shared network facilities in the future——even in rural areas.

Since fiber optic and coaxial cable subscriber connections not only allow for future broadband telecommunications but also for simultaneously providing for high quality narrowband services, there is some question as to whether incurring the costs of narrowband ISDN on copper facilities is a good long term prospect. Some anaIysts believe early deployment of broadband facilities is the way to go, bypassing the deployment of narrowband digital service on copper. Rural economic development depends partially on attracting businesses that require efficient telecommunications. Therefore, the focus should be on getting fiber optics deployed in the public network as far downstream as possible, so that business customers have the option of accessing the network for high speed service applications, should the need arise. It will not be necessary to subsidize business access to the fiber optic public network but it is important that they have a cost effective option to build or lease their own access lines to a high speed digital public network, since this option usually exists in urban and suburban settings. The way to accomplish this is through an aggressive statewide plan for a fiber optic network infrastructure.

5.2 Residence Subscribers

The deployment of advanced rural telecommunication facilities for residence subscribers should be addressed/viewed in several stages. Dedicated coaxial and fiber optic access lines are generally not required to support the demands of residential customers for known services. Indeed, most of the copper loops in the ““downtown”” portion of rural exchanges, like that in the ““typical”” rural exchange described earlier, are short enough to cost effectively upgrade to narrowband digital service. The larger problem is that subscribers in the rural portion of the same "typical" exchange require that expensive loop rearrangements and improvements occur to reduce or eliminate loop electronics on longer loops.

Furthermore, since the late 1970s many rural LECs pursued a plan to upgrade rural loop transmission quality and achieve economies in loop provisioning by deploying remote terminals which were placed between the central exchange and the subscriber. This upgrade strategy was endorsed and encouraged by the REA's guidelines for borrowing companies. In effect, by investing in the deployment of remote terminals (RTs) at specified locations called serving area interfaces (SAI), the placement of subscriber loop carrier (SLC) systems allowed rural LECs to save on investment in loop transmission facilities dedicated to individual subscribers while improving loop transmission quality by making the subscriber connection shorter. But, as can often happen, saving in one generation of network upgrades may be costly in transitioning to the next generation.

It turns out that the deployment of new ISDN and broadband digital network capability is somewhat easier in an environment of dedicated subscriber connections. The placement of remote electronics makes it difficult to upgrade, on demand, any given subscriber's line to provide ISDN or broadband service. No smooth and cost effective migration from POTS to ISDN is possible in these situations, and ultimately this may result in the early retirement of remote terminals if future subscriber loop upgrades are to occur in a timely fashion. This situation is typical not just in rural areas of small LECs, but for many service areas of large LECs as well (which also deployed a number of remote terminals).

This discussion provides some measure of insight as to how to conduct sound fundamental network planning. Most experts agree that the future of telecommunications demand is that households will no longer be satisfied with POTS, desiring instead their own choices of service and their own choices of service suppliers. This means that networks must be designed flexibly enough to accommodate the mix of demand which will (or might) occur. In other words, not all households will want (or be able) to pay for ISDN or broadband service. At a minimum, not all households will want it all at the same time. Thus, a cash flow oriented fundamental network plan would try to accommodate the structure of future demand, meaning LECs must invest in network facilities which allow for differentiation of service capability to match the differentiation in consumer demand.

6. Network Upgrade Costs

Figure 2 provides an illustration of an advanced digital rural subscriber connection. The basic loop architecture is similar to today's average rural POTS loop except for a few features. Assuming that the basic POTS loop meets the maximum length for high quality digital service e.g. 12-l8 kft.) and that the serving C0 already houses a modern digital switch, the placement of sophisticated electronic equipment located in the three shaded boxes between the subscriber premises and the C0 enables the subscriber to use a range of new digital services.

Upgrading the loop plant of rural telephone subscribers for digital service presents a financial dilemma. A high percentage of existing subscriber loops cannot support an acceptable level of digital transmission, even for existing services. Regular voice telephone service requires much more bandwidth in digital form than in analog form. Most rural loops are engineered to support analog voice at 3—4 kHz, and very low speed data service up to 9.6 kb/s. To attempt more than this risks intolerable errors in transmission. Thus, the motivation to upgrade the rural loop plant is that current band-widths will not support the use of many new service applications.

It would be misleading to conclude from the data on rural company loop investment that the upgrade problem is simply solved over time by replacing investment through rapid depreciation. Increased cash flow from depreciation, an important source of funds for new loop plant, also implies rate increases for current subscribers, increased subsidies from others, or both. In addition, the new loop plant is nominally more expensive than the old, even with technological advances, because of inflation in prices.

Generally, the main problem with upgrading rural subscriber loops to digital service is the presence of loading coils. These must be removed by cutting out the coils and replacing the cable at the load coil point. Alternatively, loop carrier or remote switching terminal equipment may be installed. Normally, this is all that is required in the physical loop digital upgrade. However, some rural telephone companies still have old "non-filled" cable in their loop plant. This may not support high-quality digital service even at low speeds if moisture has penetrated the cable. Nevertheless, analog voice is generally acceptable on non-filled cable. The financial requirements for upgrading "gel-filled" cable rural loops for digital service are not too much of a burden for current telephone company construction budgets over a reasonable period of time. However, for "non-filled" cable loops, a costly and aggressive rehabilitation program may require external financing. The process of replacement will speed up since the remaining non-depreciated useful life of non-filled cable is relatively short (it was last installed in the early 1970s).

6.1 Narrowband Digital Service

Chart 6 presents the base case costs for current narrowband rural LEC loops. The estimated cost of upgrading existing rural loops to provide for ISDN service is only about $100 to $200 per subscriber (again assuming that the loop is qualified in terms of length and electronics) For non qualified loops (featuring load coils, non-filled cable, etc.), the average cost can be anywhere from $50—$2,000 per subscriber[23]. This only represents the average; some customer loops will be even more expensive to upgrade, such as where spatial distribution of subscribers was not conducive to sharing facilities. One goal of the upgrade, de-loading rural loops, could be very expensive when there is no cost justified possibility for shortening the dedicated portion of the subscriber loop through the use of a ISDN compatible remote subscriber terminal (RST) or digital loop carrier (DLC) system. The state-of-the-art loop architecture assumes that a fiber trunk connects an RST to a digital host CO (see Figure 2).

6.2 Broadband Digital Service

Based on a broad based analysis of existing (1992) RUS company cost structures, the monthly cost of deploying a rural broadband network is estimated to be between $92—$132 a month per line depending upon the period for deployment (10-20 years)[24].

Whereas rural network upgrades for narrowband digital service are based on maximum loop lengths of 18 kft. from the switching node, higher bandwidth and power requirements of switched broadband networks will require a smaller serving area featuring loops of only 6—12 kft. depending on the services contemplated and the specific network design. This raises costs considerably. For example, reducing a maximum serving area distance from 18 kft. to 6 kft. means that 9 network nodes are required vs. only one.

The digital loop diagram in Figure 2 indicates where electronics may be installed to allow subscribers to upgrade service for broadband capability like entertainment video service. Recalling that the downtown area of the rural exchange might well be within the 6 kft. limit, this situation certainly favors that area over the outlying rural area in any upgrade decision. Chart 7 provides an estimate of a rural LEC''s broadband loop upgrade using Hybrid Fiber Coax (HFC). Assuming that the maximum number of households served per HFC network node is 480, Chart 7 shows how per subscriber costs might be expected to vary as subscriber density varies (i.e., as one moves out from the downtown area toward the rural areas of the exchange). Subscriber access connections within the dense downtown area may be upgraded to broadband service for $1,000, while serving subscribers in the outlying rural areas of the exchange can cost up to $10,000. The illustrative costs in Chart 7 are for subscriber connections, and do not include the costs of upgrading other network and non-network functions including sophisticated broadband network system hardware and software and programming service. One estimate is that this could add another $400—$1,500 per subscriber.

Another possibility for providing broadband telecommunications to rural areas is through upgrading the existing rural coaxial cable systems with fiber optic trunk lines and interconnecting to the public switched telephone network. For a truly integrated broadband system, this usually generates per subscriber costs similar to those already discussed for telco network upgrades. There are other (even more sophisticated) methods of providing broadband services to the home, but the costs of these alternatives are generally equal to or higher than the HFC network upgrade.[25] Fiber to the Home systems are touted as being the ultimate in broadband telephony featuring high quality bandwidth on demand with capacity for any conceivable service. The costs of such systems for rural applications are currently so high as to not even be seriously considered by rural LECs, however, this conclusion in no way detracts from the great potential of fiber optic trunk network systems in rural settings. [26]

6.3 Wireless Alternatives

For situations where it is simply too expensive to use the recommended loop architecture, there are several alternative choices including satellite, point or multipoint radio, and cellular radio. These alternatives must be evaluated on a case-by-case basis, including an estimation of the cost of an efficient connection to the public wireline network.[27]

Digital wireless technology could potentially become a cost effective replacement for fixed wired telephone service for everything from POTS to broadband service. In particular, new digital wireless cable networks are already competing with traditional wired cable in urban areas and it is widely believed that the new digital cellular Personal Communication Networks (PCNs) will provide a cost effective alternative to both the fixed and mobile cellular telephone systems in service today, all at competitive prices.[28] However, rural areas pose a special problem for successful deployment of cellular systems for fixed telephone service. Furthermore, while PCN systems using small cells (microcells) are optimal for low power operation in urban settings (i.e., dense market areas), they are not cost effective in rural areas because of the sparse number of subscribers who can share a single base station in a small coverage area.

Due to the distances involved in a rural setting, the power levels for transceiver base stations needs to be much higher than in urban cellular markets or it is not possible to reach enough subscribers to make the investment worthwhile. Too many low power antennae sites would be required to cover rural areas in a cost effective manner. Current microwave radio systems for rural telecommunications (dubbed BETRS by the FCC) are very expensive to deploy and operate and tend to be cost effective only in the thinnest rural markets, or where terrain will not permit wired subscriber connections.[29]

Many recent articles have touted the virtues of using wireless access at a cost effective substitute for wired access in rural areas.[30] Hatfield, Paulraj and others show that in the thinnest markets (0—100 subscribers per square km), fixed microwave radio (i.e., BETRS) systems may be cost effective to deploy. Other authors show that cellular systems using large cells (macrocells) are also cost effective in many rural markets including downtown areas. Figure 3 provides a broad gauge look at the relative cost effectiveness of macrocell and microcell wireless access systems vs. wired access.

Raw cost efficiencies aside, much of the problem with deploying wireless networks in rural areas lies more with the long head start and continuing inertia of wired service and the ingrained preferences of telephone company managers and engineers for the old (well understood) way of doing things.[31] A second important problem to overcome is the current federal rules governing the provision of digital cellular service in rural areas and the limited radio spectrum frequency which has been licensed for use by rural radio systems.[32] Currently, rural cellular service must be provided under restrictive conditions imposed by the government on radio frequency use. Rural cellular providers must share radio frequencies with existing high power paging services, causing interference problems. Channelization schemes used by current urban area cellular radio licensees are not optimal for use in rural areas. Power restrictions are too low and the radio carrier channels are too narrow to allow for a single channel to be shared cost effectively in a rural setting.

If the government would allocate sufficient dedicated radio frequency spectrum (e.g., 20 MHz) and increase permitted power levels, then cellular equipment manufacturers and network operators could use state of the art digital access techniques such as TDMA and CDMA and wide carrier channels (e.g., spread spectrum). This would allow rural cellular service to become a cost effective replacement for expensive wired POTS access arrangements and could reduce the costs of broadband network upgrades.

For subscribers in rural areas which are truly remote (perhaps even unserved), new digital satellite systems offer the best hope of obtaining high quality digital telephone service. Beginning in l996, many new systems will be launched, providing coverage over the entire continental US. Initially prices for these systems will be very high and some subsidies may be required to make it available. One of the main reasons why satellite service has not been viewed as potentially competitive with wired service is the annoying (and heretofore unavoidable) delay time associated with voice transmission on the system uplink and downlink segments (250 milliseconds). Many new digital satellite systems have overcome this quality differential by using Low Earth Orbit (LEO) satellites which feature only a fraction of the delay time.[33]

The recent (and rapid) introduction of digital satellite television using Direct Broadcast Satellite (DBS) service demonstrates that rural areas will be able to benefit substantially. The cost of this technology is not distance sensitive and therefore rural subscribers can finally obtain equivalent service at equal prices in a market setting.[34]

7. Infrastructure Development

Now and in the foreseeable future, federal state and local governments play a key role in developing the rural telecommunications infrastructure. Indeed, regulators are largely responsible (along with the industry) for creating the current complex web of industry cross subsidies which are the very lifeblood of many rural systems and which allow rural POTS subscribers to enjoy a level of service and prices that are at par with urban and suburban subscribers.

As the industry transitions from a monopoly structure to a competitive one, rural subsidies are clearly at risk. The federal government remains concerned about rural issues and both major pieces of federal legislation aimed at furthering competition in the industry contain provisions to protect subsidies for universal service including both low income subscribers and rural high cost areas.[35]

7.1 RUS Guidelines for Borrower Companies

The RUS provides low interest loans for network upgrades to the majority of small rural LECs. As the primary source of public funding for rural telephone network upgrades, the RUS''s published guidelines for network upgrades has important national standing for infrastructure policy. The most recent guidelines were adopted on March 15, l995. Its major provisions are:[36]

. every State must have a modernization plan to improve the rural telecommunications network and must submit it for RUS approval (may be drafted by the State regulatory agency or the borrower companies themselves);

. the plan must provide for the elimination of party line service;

. the plan must provide for availability of services for improved business, educational, and medical services;

. the plan must encourage and improve computer and information highways for subscribers in rural areas;

. the plan must provide for rural subscribers to receive

  . conference calling

  . video

  . data rates of at least 1 Mb/s;

. uniform deployment schedules in rural and nonrural areas;

. expeditious deployment and integration of emerging technologies;

. affordable tariff rates for medical and educational services;

. reliable powering for POTS service including alternative power sources during electric utility power outages;

. in the "short term" all new telecom network facilities shall be constructed so that all single party service subscribers have access to

. lines capable of speed of at least 1 Mb/s

. switching equipment that supports custom calling features

. E9ll;

. in the *medium term* (6 years after plan approval) all new facilities must be capable of

. transmitting (motion) video signals

. E911;

. in the *long term* all plans should accomplish

. an elimination of party line service

. universal availability of digital voice and data service (56-164 kb/s)

. service at transmission speeds of no less than 1 Mb/s

. video service

Needless to say, the new RUS guidelines and the considerable network capabilities which are required have sparked equally considerable controversy.[37] Suffice it to say that while the RUS has laid out the rules for approving loan applications for network upgrades, it is far from clear that there is enough money available to pay for such substantial upgrades and it equally unclear whether or not non-borrower companies would otherwise plan to make such upgrades. A consistent state infrastructure upgrade policy would ideally be based on an industry consensus, but with the RUS setting the least common denominator at such a high level it may not be possible to reach an industry consensus. Keeping in mind that many large LECs serve rural areas too (in fact most rural areas of the US are served by large LECs), until the large LECs (which cannot borrow from the RUS) concur in the RUS proposals (not a likely proposition) it will not be possible for States to implement consistent network infrastructure upgrades plans.

It appears that the RUS rules were written for an era of continued monopoly provisioning of telephone service. This model is outdated in light of other federal and state initiatives promoting market entry. Large and small LECs, whether or not they are RUS borrowers, recognize that the future competitive environment means that local network upgrades involve considerable market risk, and there is no longer any good prospect of recovering all of the investment from tariff rates on captive customers. One obvious provision is lacking in the RUS's rules - that infrastructure investment plans meet the fundamental test of market viability (i.e., there is no business case called for).

This having been said, the RUS should be applauded for its vision, which, rather than a mandate, is a reasonable goal to strive for. The problem is that without large LEC concurrence it will never be implemented on a large scale. The RUS probably sensed this when they called for state PUCs, which regulate all LECs both large and small, to coordinate and submit their own infrastructure upgrade plans in accordance with RUS minimum requirements.

It will be up to the state and federal governments to try to coordinate their respective roles regarding telecommunications infrastructure policy. This is not an easy task and it has barely begun.[38]

7.2 Public Power Grid

The use of a dielectric transmission medium, such as fiber optics, provides an unprecedented opportunity for inexpensive infrastructure development by taking advantage of the new-found synergies of combining existing electric utility distribution infrastructures with those of telecommunications. Construction costs of fiber optic facilities may be substantially reduced by utilizing public power grid rights of way and pole or conduit facilities. Since optical transmission is not susceptible to the electromagnetic interference caused by power lines, fiber cables could use the distribution plant offered by the statewide power grid by purchasing or leasing facilities from rural electric utilities. Such inexpensive fiber deployment may even include lashing the fiber cable to the electric utility ground and phase wires, which often run along the tops of towers and poles. There are many possibilities. One new product on the market is a fiber cable which utilizes the metallic ground wire for strength. The ground wire in the cable supports the requirements of electric utilities, and the fiber communications capacity may be resold.

Power companies are heavy users of communication services, and many large utilities already operate major private communication networks. Smaller rural electric companies also require communications for load management, monitoring, internal communication and the like. Rural Electric Cooperatives serve geographically large and thin rural markets which often span many independent telephone company exchanges. Because they cannot justify "stand alone" internal communication networks, small electric utilities must rely on many rural telephone companies, and pay relatively high tariff rates. The sharing of power company facilities with local telephone companies can provide economies for both, providing a "win-win" situation.

In addition, some large businesses who choose to locate in rural areas are often able to get sufficient power, while advanced communications capability is lacking. If the shared infrastructure were available, businesses might be more likely to locate and expand in rural areas. Safety communications for fire and alarms are other new service applications which place only nominal bandwidth requirements on the communications infrastructure. There seems to be a natural synergy here for rural communication infrastructure development, but one that is under-exploited. The electric power industry tends to be very conservative, but many firms are now examining novel arrangements with communication service providers.

7.3 Toll Service

Rural telephone companies, long desiring direct entry into the lucrative toll market, could begin taking advantage of the revenue opportunities that a fiber optic infrastructure could provide, including the possibility of providing new data and video services. This is very important if the traditional large telephone company toll subsidies enjoyed by small rural telephone companies truly disappear due to increasing competition. Small rural telephone utilities may pool traffic and interconnect with the fiber optic backbone trunk network to efficiently, and profitably, provide high quality toll voice and data services. Fiber optic backbone networks may also allow rural subscribers to purchase digital services and access remote databases of enhanced service vendors.

7.4 State Planning

The process of rural telecommunication infrastructure development is an evolutionary one that will occur only gradually as advanced facilities become available. For this reason it is important that the process begin as soon as possible. State telecommunication planners must take on the role of coordinating network interconnection and development activities, exploiting potential synergies for the benefit of all subscribers In the early stages, such coordination will concentrate on surveying all of the communication facilities, public and private, and evaluating short and long term interconnection and compatibility potential. At first, microwave and satellite network facilities will be evaluated, along with existing coaxial cable network facilities, to determine interim infrastructure possibilities. The long term focus will be on migrating to a more efficient infrastructure based on digital fiber optics and radio technology; the goal will be to share network facilities whenever it is cost effective to do so, and guide the replacement of older network facilities with advanced facilities, stressing network compatibility along the way. Without compatibility, interconnection of communication networks will be inefficient or even impossible, and potential synergies are lost.

The rate of development for rural telecommunication infrastructures may depend largely on demand drivers. There are some logical ways to pursue network technology adoption, paying close attention to demand patterns in the current infrastructure. For example, secondary and tertiary schools, libraries, hospitals, and regional airports tend to be among the heaviest consumers of information and telecommunication services in rural areas. Public power utilities and other rural infrastructure firms, including occasional large manufacturing or service companies, also represent logical node points for rural networks. Existing telephone company switching offices, combined with the aforementioned, represent demand drivers and potential network hub sites, providing for efficient communication infrastructures. This set of candidates for network node (hub) points should generate a number of alternative deployment scenarios for state telecommunication planners to consider. Hubbing allows the economies of satellite, microwave, and fiber transmission to be used cost effectively in relatively thin markets, thereby maximizing the net present value of the rural construction program.

7.5 Regulatory Issues

Planning for an advanced rural telecommunication infrastructure raises many regulatory and public policy issues. Prominent among them is: Who should own and control the infrastructure and how should it be financed? There are obviously no "right" answers to such questions, but some general economic principles may guide the thinking on these issues First, private ownership and control is generally preferred to public ownership and control, for reasons of operating efficiency incentives that competition provides.[39] Second, government must have a pro-active role as an overseer, enabler, and planner. As discussed previously, private network development may help support infrastructure development in a "win-win" situation where net revenue opportunities accrue to both private and public network participants through efficient interconnection and compatibility. The role of state government may be most helpful in identifying where public and private communications network activities may complement one another and strengthen the overall infrastructure.

As a rule, an infrastructure approach does not imply centralized ownership or control. It does imply cooperation among the various players, however, and this is the enabling role of government bringing together the players and encouraging infrastructure development. Much more can be done than we observe today. Most states have not yet placed sufficient emphasis on telecommunication infrastructure and its role in economic development, even in rural areas. New technologies just beginning to be deployed have very low unit costs once demand thresholds are met, but have very high up front capital costs. For this reason, an infrastructure approach to planning, which maximizes capacity sharing through a "hubbing" network architecture, holds great promise for dealing with the problem of thin rural markets. For example, even in Kentucky, which is considered a rural state, there are many locations which could generate enough traffic demand to justify a fiber, radio or satellite hub, depending upon the specific demand application(s) required.[40] Eventually fiber hubbing would dominate as the technology of choice for most new shared network applications, while microwave radio, coaxial and copper cable will be used for dedicated short haul subscriber plant; with satellite and microwave radio utilized whenever wireline facilities cannot be deployed cost effectively, especially in physically remote applications.

Finally, there are a host of important pricing issues associated with recovering the costs of advanced telecommunications infrastructure development. Two primary issues, are broad toll rate averaging across the nation and toll-to-local service subsidies. Trends in both of these areas are troubling for rural telephone companies, and will no doubt become the subject of extensive public policy debates. A full discussion of these issues is beyond the scope of this paper but a few observations deserve brief discussion.

Increasing competition in toll services, and the absence of regulatory rules for retail tariffs of competitive toll carriers is slowly eroding the broad rate averaging rules which have been in effect for many years. The effect of rate averaging is to subsidize subscribers in thin rural markets relative to those in dense markets. New volume discounts for heavy toll users, especially business customers, have already been undermining traditional rate averaging. Regional rate de-averaging is likely to occur eventually. The toll subsidy which generally flows from larger telephone companies to smaller ones is also going to decrease as competition continues to drive prices down. The best solution here is probably to target subsidies more carefully toward only those companies who are most in need rather than toward entire classes of small companies as is currently the case.

7.6 Rural Telephone Service Subsidies

Using REA data as a representative proxy for high cost rural areas of the US, the total rural subsidy is estimated to be $5B per year based on revenues of $14B and costs of $19B.[41] This means that rural rates on average would have to rise about 35% in order to pat the full costs of providing rural POTS service. This means an increase in average monthly tariff rates of about $19.

But this is a broad average figure is substantially understated if open competition were allowed. Competitive entrants will tend to pursue only the profitable rural LEC subscribers, like those which reside in relatively dense downtown areas of the rural exchange, larger business subscribers, and those subscribers who purchase a lot of non-basic services. These subscribers also provide substantial contributions toward funding the high costs, and supporting the low average tariff rates for the high cost, low (or no) profit subscribers. Without individual subscriber data on costs and corresponding revenues it is not possible to estimate what the cross subsidy flows within the rural LEC exchanges would be, but it is well known that the most profitable subscribers who are responsible for generating the most revenue, provide an inordinate amount of funds to support the costs of the remaining majority. Thus it is easy to see that the rural subsidy to truly high cost unprofitable subscribers who need to be much more heavily subsidized, is at least two times or more than the $19 per month quoted earlier.

If competition and subsidies for small LECs are to coexist, then there are some general economic principles which should underlie the subsidy funding mechanism. The mechanism should be:

. fundamentally fair for consumers;

. competitively neutral for competitors; and,

. long term sustainable.

Furthermore, pursuant to a host of recent federal and state investigations of Universal Service it appears that almost all parties to the debate have agreed on certain aspects of various plans and proposals:

. All charges for telephone service should be cost compensatory except for a narrowly defined and highly targeted set of basic service subscribers (e.g., low income, high cost).

. Subsidy funding requirements should be shared by a broad base of market players and the funding mechanism should be administered by an independent third party.

Beyond the need to define exactly what constitutes the *benefited* service and subscriber group deserving of subsidies, there are some primary unresolved issues:

What is the cost of the current and future public service obligations (e.g., Universal Service Obligation (USO) and Carrier of Last Resort (COLR)) and how should the cost be determined?

. Exactly how should the subsidy funding mechanism work? (e. g., How to administer the subsidy fund? Who should administer the fund? How to collect and distribute funds within any given geographic area——local, regional or statewide.)

Assuming, for purposes of discussion, that subsidies should only apply to covering a portion of the costs of providing Plain Old Telephone Service (POTS) for certain residential PSTN subscribers (e.g., high cost/low income), and assuming also that all other subscribers should directly pay the cost of their POTS service, then it becomes clear that the proper cost ““object”” for quantifying a subsidy requirement for USO and COLR is the total PSTN investment and expense cost of the LEC minus the cost of the (hypothetical) PSTN if there were no such obligation to serve or be ready to serve. (Put it another way, had the LEC not had the social compact with the certification authority that it would be the only service provider and that it would be allowed to recover its total costs from tariff rates charged to its subscribers what would its investment and expense cost be.)

A cost study method must be developed which establishes both the historical and going forward costs of the USO. In particular, the total (or average per line) cost of the USO is simply the cost of providing POTS service to residential subscribers. When this cost is compared to POTS revenues, the difference is the net cost (subsidy requirement) of the obligation to serve.

In the current local monopoly environment, the funding of this subsidy amount comes from numerous sources, namely, mark ups of prices over costs (i. e., cross subsidies) for LEC business services and residential non-POTS services. In the new competitive environment, all carriers must be required, in a competitively neutral way, to share in the funding of the costs of public service obligations.

Historical Perspective

The reason that the historical cost of the LEC's public service obligations must be considered is that the monthly subscriber bills now and in the future simply represent the time payment plan that regulators (on behalf of PSTN subscribers) and the LECs agreed to under the pre-competitive regulatory regime. Thus, in the post-competitive regulatory environment, the LEC must still be enabled to reimburse its historical investors. Had the LEC and its investors known that the regulatory regime would change such that it would not have the future opportunity to compete at the margin and still recover the cost of its regulatorily imposed historical public service obligations, then the LEC would not have kept investing in network infrastructure to certain customers and locations which it viewed as too risky without good prospects for cost recovery.

Incremental Perspective

The definition of the going forward cost of a LEC's public service obligations is the same as the historical one except that the costs would be based on the total incremental cost of the obligation instead of the total historical cost. Thus, the cost calculations would reflect incremental instead of embedded technology and business practices.

LRSIC vs. Total (Average) Cost

Some parties to the subsidy debate have asserted that the cost and funding of LEC public service obligations should be based on the incremental cost of POTS, not the total or average cost. Unless the Long Run Service Incremental Cost (LRSIC) study methodology they espouse is carefully constructed to approximate the total cost of the obligation; then it is flawed. This is unjustifiable from an economic perspective. This theoretical and practical distinction is important since it is the total (average) cost of a business enterprise which must be covered by total (average) revenues for the firm to be sustainable. Open market entry and competition will, over time, force rates for all services to be driven toward their costs (unless subsidies are provided).

Thus, a subsidy system which relies on continued price cost margins on competitive services to fund a portion of the costs for residential POTS service is an inherently unsustainable system. Competition is the natural enemy of cross subsidies. Indeed, a

LEC, and, in turn, the LECs customers, which must incur the costs of regulatorily imposed public service obligations which are not similarly borne by market entrants (and their subscribers) will be disadvantaged in the market place The end result is a shift in consumer welfare from the LEC’’s customer base toward the entrant's subscribers.

To avoid such discrimination and inadvertent shifts of wealth between subscriber groups, regulators should adopt a consumer friendly and competitively neutral subsidy funding mechanism before competitive entry forces a de facto rate deaveraging where one group of subscribers must pay for regulatorily imposed obligations and one does not. Fundamentally, there are only two types of POTS subscribers: those low cost subscribers in relatively dense areas served by relatively short loops who have relatively low local calling rates (subsidizers); and those relatively high cost subscribers served by relatively long loops which have relatively high local calling rates (subsidizees). Of course, even in high cost (long loop) geographic locations there will almost always be highly profitable subscribers who purchase a lot of non-POTS services. For this reason, a proper cost analysis must be conducted at the individual customer level. In other words, classifying a particular subscriber as a net subsidizer or a net subsidizee requires monitoring individual subscriber characteristics. Obviously, this is not practical even though it is the only way to guarantee that subsidies flow to subscribers who would otherwise not be able to obtain POTS service (or at least that quality of POTS which "profitable" PSTN subscribers receive).

Because LECs were historically monopoly providers of residential POTS, it is straightforward to calculate the total cost of any given LEC’’s public service obligation by examining the embedded accounting cost data for PSTN investment and expense and converting it to an annual or monthly per subscriber amount.

In a historical context, LECs, as regulated common carrier monopoly providers of POTS, were obligated to serve (or be ready to serve) all subscribers on demand in a given service area at broadly averaged affordable POTS prices. Thus, the historical cost of the obligation to serve would be the cost a LEC would have incurred. The average subsidy requirement for rural telephone subscribers in the US was previously provided. Even this broad gauge level of analysis provides the regulators with a "ballpark" estimate of the total and average per subscriber subsidy. It is important to keep in mind, however, that this broad gauge estimate cannot be used to evaluate the cost (subsidy requirement) for any given subscriber or location because the available information is not sufficiently granular to make that determination. The average is the net total subsidy requirement from all POTS subscribers; the sum of those subscribers which are subsidizers and subsidizees. Nevertheless, the estimate does establish the total (average) amount of the subsidy funding requirement for the (as yet to be determined) subsidy recovery mechanism.

The total and average subsidy amounts determined in stage one of the costing process may begin to be deaveraged into density cells by examining the available data for a

LEC's POTS subscriber density characteristics. This Phase is made somewhat easier because it is also possible to examine the PSTN investment and expense costs of smaller rural (less dense) LECs and comparing that to the same embedded accounting data for larger (more dense) LECs (see Table 4). The results from density cell analysis may be further disaggregated down to customer specific analysis via a computerized cost "proxy" model which calculates the costs for each subscriber location.[42]

7.7 Funding Mechanism

The mechanism for collecting funds to pay the cost (subsidy requirement) of LEC public service obligations must be competitively neutral with respect to incumbent LECs, which have the obligations, and competitive entrants, which do not. In other words the contributions toward covering the subsidy costs should be shared equitably by all telecommunication service providers. In order to be sustainable, no service providers should be able to avoid payments via bypass of the LECs PSTN. Many such funding mechanisms have been proposed by industry groups and most involve a revenue surcharge mechanism.[43]

7.8 Financing Alternatives

The costs of the deployment of efficient communication infrastructures are high compared to any historical measure of the costs of technology adoption. The reason is that the technological trends are toward lower on-going usage costs, and higher up front capital costs. Digital network equipment has few moving parts and features very large scale capacity relative to older generation network equipment. As such, the new equipment is more cost efficient from a maintenance and repair expense perspective, but is more capital intensive and is typically purchased in greater "lumps", because it is well suited for large scale operations. The same tends to be true of fiber optic transmission equipment, although for many network applications fiber will soon be cost effective even relative to the older generation copper and coaxial cable costs. The bonus with fiber optics is not only its very high capacity, but also its high quality and reliable service as compared to metallic and radio technologies. Nevertheless, up front deployment costs for fiber optics are substantial, and every effort to cost it effectively is important.

Telephone rates are the obvious first choice for financing advanced rural network infrastructures. Indeed, most of the financing must come from this source. Fortunately, it appears likely that the internal capital flows of telephone utilities will fund much of infrastructure deployment costs. But as was pointed out previously, these traditional internal cash flows are at risk due to increasing competition and the advance of technological alternatives.

Borrowing is the next alternative to consider. The U.S. Department of Agriculture's Rural Utilities Service and others provide subsidized loans to rural telephone companies. Without government assistance these telephone companies would have to go to other capital markets that offer less attractive terms.

Unlike large telephone utilities, many rural companies are already highly leveraged. This is not bad in and of itself, but it does impact the propensity of lenders to approve more funds on favorable terms. Regulators may also become concerned about the level of business risk which leverage implies, even though ratepayers may benefit from the lower average cost of debt capital relative to equity finance.

The RUS and some other lender's practices are basically sound for financing advanced rural telecommunication infrastructures because they operate within an incentive structure which tends to signal borrowers to make good investments (not to mention the new aggressive network upgrade guidelines). The RUS uses "equity based" financing and loans that are usually ““self liquidating””. The proposed investments of borrowers must meet general technical guidelines for acceptable and approved equipment purchases. This system prevents speculation and abuse of government loan funds. Even though the RUS program is a loan subsidy program, only the interest rate discount is truly "subsidized””, and this is a relatively small portion of the entire loan and repayment sum. The loans are self liquidating from revenue and cash flow from telephone rates. Overall this approach seems socially efficient since it allows the private sector to determine the market requirements and opportunities for sound investment decisions, and requires the borrower to have a substantial equity stake. The only government role is to provide an inexpensive source of funds, technical support, and monitoring.

Direct subsidies, especially of the current untargeted variety, are much worse and are often not socially efficient. The current flow of toll-to-local subsidies from many large telephone companies to many smaller ones is generally inefficient because it is not based on need; instead, it is based simply on a grand formula for broad rate averaging and revenue sharing. In fact, some of the vast sums of money in the toll revenue pool now divided among telephone companies through the use of a broad formula could be used to increase the RUS’’s loan authority or could be distributed based on bonafide financial need Whenever subsidies are not targeted there are potentially wasted resources. The introduction of basic telephone ““lifeline" service based on a "need" (income) test is a good example; this has proven to be much more socially efficient than a blanket subsidy for all local service subscribers, many of whom can afford it. As the financial data provided earlier indicate, many small rural telephone companies have very healthy cash flow situations and do not really need subsidies.

Direct government subsidies for rural telecommunications should be discouraged since the investments funded will presumably generate some level of on going subscriber revenue and should therefore always be included in any loan repayment formula, even if the repayment is only a partial one.

8. Conclusions

Perhaps one of the most important policy conclusions from the analysis herein is a firm recognition that there is a notable difference between the costs of local network upgrades for the base of existing rural telephone subscribers, and the costs of serving brand new and physically remote subscribers. From a public policy perspective the latter group must be treated as special cases requiring significant cost subsidies, otherwise policy for the masses could fall victim to debates of subsidies for the few. Overall, the existing body of rural subscribers is currently being served cost effectively and profitably, and a timely digital network upgrade is a reasonable proposition without necessitating large rate increases.

The second important message is that small rural LECs cannot be classified according to average costs and subsidy requirements. There is just too much variability based on the local market conditions and geography, which presents a major problem for policy makers desiring to better target subsidies to those companies and subscribers who really need it. Average statistics just will not do. There is no such thing as an average rural LEC. This revelation has tremendous implications for state and federal government competition policy. If open market entry is allowed, existing subsidies will dry up——period. Therefore if the government is serious about having both competition and subsidies, the current system is in bad need of reform. The alternative is the natural market solution which is to drive out cross subsidies. This may not be bad since the subsidies may not all have been justified in the first place. Nevertheless, if it remains a public policy objective that rural areas of the US should be able to continue to obtain a comparable level of basic service (e.g., POTS however defined) at prices comparable to those in urban areas of the US, then the subsidy system must be reformed as soon as possible.

Third, the key to rapid adoption of advanced technology for rural subscribers is to take an infrastructure approach to the problem. This implies significant coordination and monitoring of public and private network investment and business activity, preferably at the state level. Specifically, in the current environment, there appear to be significant lost opportunities for the realization of public benefits and potential synergies from cooperation of the energy, transportation and telecommunication sectors.

The infrastructure approach could go a long way toward solving this problem and actually follows from the technology itself. First and foremost, new telecommunications technologies can be very efficient, but that efficiency depends on two critical factors which are often non-existent in rural areas of the country, economies of scale and end-to-end service capability. The first factor operates on the supply side of the equation and simply says that technologies such as digital fiber optics require relatively large scale operations to achieve the low unit costs which are ultimately available. End-to-end service operates on the demand side of the equation and simply says that unless advanced network functionality is adopted on a very wide scale, demand drivers will be unable to speed up the technology adoption process. It is no good to have ISDN service capability unless the other party to the call also has it. Thus, the critical issue for efficient technology adoption in rural telecommunications is sharing of network facilities, both to achieve scale economies and to stimulate demand drivers.

Fiber optics is generally the most cost effective technology for shared network service applications, and new digital wireless technology has tremendous potential for reducing the cost of dedicated subscriber connections. (Fiber is not cost effective for dedicated (non-shared) customer connections). Most businesses, especially large ones, share network facilities among a number of telephones and therefore may cost effectively adopt fiber technology before residential customers. However, both businesses and residences must share facilities as much as possible to take advantage of the superior economies of scale which fiber exhibits relative to competing technologies.

Another important advantage with fiber optics is that it can support new broadband services like video telephony, multimedia services, and very high speed data service. It is not necessary that demand for broadband services precede fiber optic technology adoption because fiber is also very cost efficient for simultaneously transmitting narrowband services. Sharing and multiplexing allow fiber to become cost effective even when only narrowband service applications are used.

An infrastructure approach to rural telecommunications technology adoption should maximize the possibilities for sharing, thereby stimulating investment in those technologies offering the greatest cost efficiencies. The bonus with adopting digital fiber optic technology early on is that the network will be robust with respect to almost any conceivable demand scenario that ultimately develops.

Footnotes

. For background reading on the relationship between rural development and telecommunications infrastructure see: E. B. Parker et al, Electronic Byways: State Policies For Rural Development Through Telecommunications, and Parker et al, Rural America in the Information Age: Telecommunications Policy for Rural Development, University Press, 1989. See also: Rural America at the Crossroads: Networking for the Future, and the many references therein, US Congress Office of Technology Assessment (OTA-TCT-471), April 1991.

. For a dose of healthy skepticism (or even cynicism) on the prospects for deployment of information superhighways in a competitive market place see: B. L. Egan, ““Building Value Through Telecommunications: Regulatory Roadblocks on the Information Superhighway””, Telecommunications Policy, 1994.

. "Economics of Wireless Communications Systems in the National Information Infrastructure," U.S. Congress Office of Technology Assessment, draft, November 1994 and the subcontractor report by B. L. Egan, "Economics of Wireless Communications Systems in the National Information Infrastructure," U.S. Congress Office of Technology Assessment, draft, November 1994.

. For a recent discussion of the goals and public policy concerns about continued subsidies of rural telephone companies see the testimony of Margot Smiley Humphrey on behalf of the National Rural Telecom Association before the U.S. Senate Commerce Science and Transportation Committee, May 19, 1994. See also: National Association of Development Organization (NADO) Research Foundation, ““Telecommunications and its Impact on Rural America””, April 1994.

. As part of its on-going investigation of Universal Service funding in CC Docket 80-286, on July 13, 1995 the FCC issued a Notice of Proposed Rulemaking (NPRM) which, by all accounts, is an attempt to reduce the broad subsidies flowing to high cost areas by "targeting" them to a smaller group of rural companies and subscribers.

. This is not to say that fundamental network planning should not pay very close attention to life-cycle costs of network equipment including all of its software dimensions. Planned and unanticipated network software upgrades for network switching, monitoring, control and service functions often represent a large share of total network costs and the cost savings associated with compatible or single-supplier purchases of software right-to-use fees must be considered.

. Of course, while non-proprietary flexible network software and interface devices may lower the costs for telephone companies which purchase from competing vendors, such standardization can reduce profits of vendors which make money on sales of proprietary hardware and software systems. When rural telcos are faced with purchasing in an environment of competing proprietary network systems, more often than not a least cost strategy is to select a single vendor of choice so that life cycle costs are minimized.

. This is contrary to the conclusions reached in my prior study of this issue nearly five years ago when the industry's regulatory regime was still based on monopoly supply and the threat to cross subsidies to rural areas was much smaller. See: B. L. Egan, "Bringing Advanced Telecommunications to Rural America: The Cost of Technology Adoption," Telecommunications Policy, February, 1992.

. This estimate is a broad average and depends heavily on embedded subscriber loop plant characteristics. For example, where digital switching is already available and the subscriber line is relatively short (< 18kft.) with no signal repeaters or amplifiers, the average cost of a digital upgrade is about one third this amount or $300. In older plant (about half of the embedded base), the per subscriber costs are much higher (about $2,500) due to digital switch replacement and rehabilitation of "non-filled" cable plant which generally will not support digital service.

. For a recent survey and discussion of the costs of residential broadband networks, see: B. L. Egan, supra at note 2.

. The round-trip transmission delay for two-way satellite service is 250 milliseconds which usually results in poor quality voice conversations, though some researchers believe this problem could be mitigated somewhat using advanced electronics. In cases like rural Alaska, where customers never had a high-quality wireline option for voice service, satellite is more readily acceptable. However the costs for voice satellite service in thin rural markets can be very high even when transponder capacity is leased from others (thereby removing up-front manufacturing and launch costs from the calculation). The delay does not present a serious problem for data transmissions.

. For more information on new digital satellite systems see: G. Gilder, ““Ethersphere,”” Forbes ASAP TELECOSM, October 10, 1994. The entire Gilder series of articles featured in Forbes ASAP sections over the last three years provides a thought provoking discussion of future telecommunications technology trends, especially regarding new digital wireless systems.

. For example, in a recent investigation of rural radio service, the Oregon Public Utility Commission concluded: ““BETRS is not now a viable system. There are too few BETRS systems in operation. No additional BETRS systems are planned for Oregon. BETRS appears to have significant drawbacks in terms of relatively high maintenance and investment costs. These drawbacks have resulted in low use of BETRS in Oregon.””, Oregon PUC Staff Discussion Paper, ““The Economics of Wireless and Wireline Telephone, draft, April 20, 1995.

. See: A. Paulraj, ““Wireless Local Loop for Developing Countries - A Technology Perspective””, 1994-95 Annual Review of Telecommunications, International Engineering Consortium, Chicago, 1995. Two North American manufacturers, Motorola and SR Telecom, are each deploying (or plan to deploy) many such systems, see: J. Gifford, ““Wireline Local Loop Applications in the Global Environment””, Telecommunications, July 1995; and, ““Rural Network Possibilities””, Interlink 2000, August 1992.

. For a more detailed discussion of the problem see: US Congress OTA (1991), supra at note 1, p. 36-38.

. See Parker et al, p. 67, supra note 1. This book classifies about 20M households as "rural" on a base of about 92M households in the U.S. Other estimates of remote subscribers appears in FCC Report No. DC-1066, CC Docket 86-495 "New Radio Service (BETRS) Established to Improve Rural Phone Service," December 10, 1987.

. The source of 1993 financial and investment data for small telephone companies is: REA "1994 Statistical Report, Rural Telephone Borrowers," US Department of Agriculture.

. Statistical data for non-RUS companies is based on the Federal Communications Commission

(FCC) ““Statistics of Communications Common Carriers””, 1993-1994 Edition, US Government Printing Office. LECs with annual revenues exceeding $100M are included in the report.

. Caution must be exercised when reporting trends in RUS data because annual data only applies to the companies which borrow money from the RUS, and this mix of companies changes from year to year. For example, from 1989 to 1993, the time period covered by this study, RUS borrower companies numbered 803, 897, 902, 899, and 883 respectively. Thus total and average per subscriber financial results are not directly comparable from year to year.

. C. Weinhaus, et al, ““Redefining Universal Service: The Cost of Mandating the Deployment of New Technology in Rural Areas””, 1994-95 Annual Review of Communications, International Engineering Consortium, Chicago, 1995.

. Detailed data for subscriber loop characteristics for both Bell and REA companies are available in Egan, ““Bringing Advanced Telecommunications to Rural America: The Cost of Technology Adoption," Columbia Institute for Tele-Information, Research Working Paper #393, Columbia Business School, October, 1990, Table 4.

. "Statistics of the Local Exchange Carriers 1994 - for the year 1993", USTA July 1994.

. It should be kept in mind that all of reported per line cost results make no assumptions about the demand side of the equation, if they did the costs would be higher. For example, the cost numbers presented do not include any costs associated with either customer premises equipment and terminals, so-called set top boxes, or network service software and programming services provided by the LEC or another vendor.

. Weinhaus et al, supra note 20

. For a discussion of such systems and what types of services they might be used for see: R. V. Henry, "Video and Broadband Services in Rural America", 1994-95 Annual Review of Communications, International Engineering Consortium, Chicago, 1995.

. D. W. J. Deutscher, "Rural Fiber Network in Service", 1994-95 Annual Review of Communications International Engineering Consortium, Chicago, 1995.

. Many case studies of alternative loop technologies are provided in Egan, supra note 21, Section 5.

. See B. L. Egan supra note 3

. See Oregon PUC (1995) supra note 13 and Egan supra note 3

. See: Hatfield associates, "The Cost of Basic Universal Service", draft, Boulder, July 1994; and Paulraj, supra note 14; and "Wireless Technologies and the National Information Infrastructure," US Congress Office of Technology Assessment, August 1995, p. 45-46, 95-98 and ch. 9

. For a detailed discussion and some rather piercing commentary on this problem see: G. Calhoun, *Digital Cellular Radio*, Artech House, Norwood MA, 1988; and, *Wireless Access and the Local Telephone Network*, Artech House, Norwood MA, 1992.

. See the discussion of the governments role in the OTA report supra, note 30 and the FCC's most recent decisions on rural radio service (BETRS)

. See Egan, supra note 3

. B. Murphy, "Rural Americans Want Their DirecTV", Satellite Communications, March 1995

. See draft legislation supra note 5.

. 7 CFR Part 1751, RUS Telecommunications System and Design Criteria, and Procedures.

. After the RUS released its proposed interim rules on December 20, 1993, there was an overwhelming response with concerns regarding the new requirements for State modernization plans. Over 39 parties commented and a good summary of these appears in the Federal Register Vol. 60 No. 29, 7 CFR Part 1751, February 13, 1995.

. This is also the conclusion reached in a recent Congressional Study, see US Congress OTA Report (1995) supra note 3, p. 45-46.

. Many rural electric utility cooperatives are very successful operations, thus publically owned and operated arrangements are not necessarily worse than strictly private ones.

. For a more detailed discussion of the existing Kentucky infrastructure for power, transportation, and telecommunications, see Egan supra note 21, Section 6 and the Appendix.

. Weinhaus et al. supra at note 20.

. Such a model was recently used by US West to calculate costs by US Census block groups, "Targeting High Cost Funding to High Cost Areas Using US Census Block Groups", draft US West, October 28, 1994.

. Such Mechanism vary in detail but all follow the general mechanism described in: B. L. Egan, and S. S. Wildman, "Funding the Public Telecommunications Infrastructure", Telematics and Informatics, Vol. 11, No. 3 1994 (with Steven S. Wildman), also see the references therein.