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# Bringing Advanced Telecommunications to Rural America: The Cost of Technology Adoption

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# EXECUTIVE SUMMARY

Technology adoption in telecommunications occurs at a very rapid pace, but in today's competitive marketplace significant advances are concentrated in specialized private applications and dense urban areas. Not wanting to be left behind, regulated telephone utilities actively deploy new technology in dense markets to compete with private carriers. This leaves many Americans at a technological disadvantage in an information-oriented society; a situation that raises the specter of "information gaps", the communications counterpart of the oft-mentioned income gaps between the poor and rural and the wealthy and urban social strata.

Though an efficient communications infrastructure is necessary for rural economic development, it is invariably an expensive proposition which raises a multitude of socio-political issues about financing. Endless arguments arise from various interest groups regarding subsidies to promote rural development. Such conflicts emphasize economic issues of costs and financing options of various technologies for advanced rural communications.

The results of this study indicate that fiber-optics is the technology of choice for all shared network facilities where terrain permits. For dedicated subscriber loop plant, there are several other viable alternatives including coaxial cable, copper wire and digital radio service. Because of significant variations in local demographics and topography, the analysis and conclusions may not apply in many specific rural areas; however, they will still meet the requirements of broad public policy considerations.

While the cost of an advanced rural communications network infrastructure is substantial, financing its construction given the existing customer base appears feasible *without* significant subscriber rate increases. Assuming a construction interval of 10-20 years -- a normal time span for turning over telephone plant -- one estimate of the cost of high quality narrowband digital service using traditional copper access lines is about $1000 per subscriber. This investment would endow residential subscribers with digital communication capability comparable to narrowband ISDN service. Such narrowband service capability may not meet the communication requirements of business customers where broadband service is preferred using fiber-optics or other suitable media.

Though broadband communications capability is a costly proposition, at over $5000 per rural subscriber, it could be managed over a reasonable construction interval of 2-10 years for access by business subscribers and 10-20 years for residential users.

The best way to establish rural objectives for a network infrastructure is at the state level. Telecommunications depreciation policy, basic rates and economic

development planning are set at the state level; each state determines its objectives, timetables and financing requirements. The infrastructure approach implies significant coordination and monitoring of public and private network investment and business activity. The reason for such an approach follows from the technology itself. First and foremost, new telecommunications technologies can be very efficient, but that efficiency depends on two critical factors which often do not exist in rural areas of the country: economies of scale and end-to-end service capability. The first factor, economies of scale, operates on the supply side of the equation and simply means that technologies, such as digital fiber-optics, require relatively large scale operations to achieve the low unit costs which are ultimately available. The second factor, end-to-end service, is on the demand side of the equation and shows that unless advanced network functionality is adopted on a very wide scale, demand drivers will not be able to speed up the technology adoption process. It is worthless to have ISDN service capability unless both the calling and called parties have it. *Thus, the critical issue for efficient technology adoption in rural telecommunications is the 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. Fiber is not cost-effective for dedicated (non-shared) customer facilities, like residential loops. Most businesses (certainly large ones) typically share network facilities among a number of telephones and therefore may cost-effectively adopt fiber technology long before residential customers. However, both businesses and residences must share facilities as much as possible in order to take advantage of fiber's superior economies of scale relative to those of competing technologies.

Another important advantage of fiber-optic technology is its ability to support new broadband services like video telephony, multi-media services and very-high-speed data service. However, it is not always necessary that demand for broadband services precede fiber-optic technology adoption because fiber is 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. Thus, an infrastructure approach to rural telecommunications technology adoption will maximize the possibilities for sharing, thereby stimulating investment in those technologies offering the greatest cost-efficiencies. The bonus of the early adoption of digital fiber-optic technology will be the network's resulting ability to handle almost any conceivable demand scenario.

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## 1.0 Introduction

Technology adoption in communication networks occurs at a very rapid pace, but in today's competitive marketplace the significant advances are concentrated in specialized private applications and dense urban areas. Not wanting to be left behind, regulated telephone utilities actively deploy new technology in dense markets to compete with private carriers. Thus, many Americans are left at a technological disadvantage in an information-oriented society, raising the specter of "information gaps". Some evidence of the level of social concern regarding rural telecommunications appeared in a New York Times article (Nov. 5, 1989), suggesting that the rapid introduction of new digital and fiber-optic technology in private markets may lead to the formation of a "communications elite."

While an efficient communications infrastructure is necessary for rural economic development, its financing raises a multitude of socio-political issues.[1] There are endless arguments among various interest groups regarding subsidies to promote rural development. Much of rural America is served by small independent telephone companies. Historically, financing for the modernization of rural network facilities has come from local rates and toll settlement payments received for providing network facilities to long-distance telephone companies and their toll service customers. Increased competition has added an element of uncertainty to the expected revenues derived from these sources. Meanwhile, lower toll rates have resulted in an increase in calling volume. The end result is a higher net toll income for rural companies. The greater danger to rural companies lies in the "deaveraging" of toll rates, whereby a call of equivalent distance would cost more on a low volume rural route than would a call on a high volume urban route. In this case, long distance rural calling would diminish along with toll income of the rural telephone companies. Large business customers and telephone companies also wish to reduce toll settlement payments to small telephone companies. These events may not only hinder rural network modernization and service quality, but may threaten the very survival of many rural telephone companies.

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[1] A recent discussion of these and other issues appears in Edwin B. Parker et al, Rural America in the Information Age, University Press, Inc., Lanham, MA, 1989. Some cost/benefit analysis appears in an earlier paper, Edwin B. Parker, "Economic and Social Benefits of the REA Telephone Loan Program," draft, Stanford University, March 24, 1981.

The discussion in this paper will: illuminate economic issues by evaluating the costs and financing options of various technologies for advanced rural communication networks; examine trends in telecommunication technology and the cost of technology adoption in a rural setting; consider transmission media including copper wire, coaxial cable, microwave radio, fixed station radio (BETRS), cellular, fiber optics and satellite, for both digital and analog applications; and study hybrid arrangements where advanced networks can rely on a combination of technologies.

While specific demand and institutional factors are very important, they are beyond the scope of this study. The analysis assumes that the current institutional environment will continue, featuring common carrier regulation of telephone utilities. To what extent certain features of the existing environment are hindering or enabling factors for an advanced rural telecommunication infrastructure will be identified. Prices and demand are assumed to remain at today's levels, although new service capabilities that advanced networks can offer will increase demand, perhaps substantially. Thus, the analysis herein is considered quite conservative in that it concentrates on the cost side of the equation and does not impute substantial new revenues to the profit picture.[2]

The results of this study indicate that fiber-optics is the technology of choice for all shared network facilities where terrain permits. For dedicated subscriber loop plant, there are several viable alternatives: coaxial cable, copper wire and digital radio service for example. Microwave is also preferred for some applications of shared plant. In the future, however, digital fiber-optics will dominate. Due to significant variations in local demographics and topography, the analysis and conclusions may not apply in many specific rural areas although they are relevant for broad public policy considerations.

The cost of advanced rural communication network infrastructures is substantial; however, it may be possible to finance its construction given the existing customer base, *without* significantly increasing subscriber rates. Assuming a construction interval of 10-20 years -- a normal time span for turning over telephone plant -- one estimate of the cost of digital service is about $1,000 per subscriber.[3] This would endow rural

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[2] For a discussion of new services and public benefits see Mary Gardiner Jones, "The Consumer Interest in Telecommunications Infrastructure Modernization," Consumer Interest Research Institute, January, 1990.

[3] This estimate is a broad average and depends heavily on embedded loop plant characteristics. For example, where digital switching is already available and digital loop carrier or remote switching exists, the average cost of a digital upgrade is about half this amount or $500. In older plant (about half of the embedded base), the per

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 become necessary.

Though achieving broadband communication capability is a costly proposition, at over $5000 per rural subscriber, it could still be managed over a construction interval of 10-20 years.[4] Broadband communication facilities would allow customers to enjoy high-quality service, including entertainment video, and multi-media 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 electronic news. The cost of such capability is high because it requires new alternatives for 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. 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 multi-media 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. The round-trip transmission delay for two-way satellite service is 250

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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 description of rural telephone plant characteristics see Gerald S. Schrage, Chief, Systems Engineering Branch, Rural Electrification Administration, "Rural Subscriber Loop Performance," TE&M, January 15, 1988. Many of the cost estimates in this article are based on formal and informal private correspondence between the author and various experts. Hastad Engineering Company in Minneapolis performs network upgrades for small telephone companies and provided some useful cost estimates.

[4] For some discussion of the cost of residential broadband networks see Bruce Egan and Lester Taylor, "Capital Budgeting and Technology Adoption in Telecommunications: The Case of Fiber," Center for Telecommunications and Information Studies, Research Working Paper #336, September, 1989; also Bruce Egan and Douglas Conn, "Capital Budgeting Alternatives for Residential Broadband Networks," Center for Telecommunications and Information Studies, Research Working Paper #353, October, 1989, Columbia Business School.

milliseconds which usually results in poor quality voice conversations, though this problem could be mitigated somewhat using advanced electronics. Furthermore, the delay may not present a problem for data transmission. In cases like rural Alaska, where customers never had a high-quality wireline option for voice service, satellite is more readily acceptable. 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).

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 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 and is expected to be the preferred alternative when wireline service is not feasible.

The best way to establish rural objectives for a network infrastructure is to begin at the state level. Telecommunications depreciation policy, basic rates and economic development planning are set at the state level; each state determines its objectives, timetables and financing requirements. As an example, a high-level infrastructure analysis is presented for Kentucky in Section 6.

## 2.0 Rural Network Profile

### 2.1 What is Rural?

There is no standard definition of rural telecommunication subscribers; however, some general observations should be made. "Rural" customers must be distinguished from "remote" customers. Customers whose access to the telephone network is non-existent for any acceptable level of cost are definitely "rural". These potential customers are so expensive to serve because of their physical remoteness that 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 also physically remote. Remote customers pose a special problem and should be examined carefully.

There are few truly "remote" subscribers relative to the base of all rural subscribers. One recent estimate puts the number of remote customers at 183,000, or only about 1% of all rural subscribers.[5] Many analysts designate the population outside of government-defined Metropolitan Statistical Area, or "non-MSA," as the rural population since the government is a convenient data source. Government statistics for non-MSA counties put the number of non-MSA subscribers at about 30M which represents a third of total telephone subscribers. 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 each.

Fortunately, for actual telephone statistics and data on rural subscribers, a wealth of information exists for small independent telephone companies from industry trade groups such as United States Telephone Association (USTA), National Telephone Cooperative Association (NTCA), and an agency of the United States Department of Agriculture, the Rural Electrification Administration (REA). Specifically, REA provides investment and financial data for over 900 small telephone companies serving over 5M customers in very thin markets. Thus, for purposes herein, the REA data will be representative of "rural" subscribers. While many other data sources will be used in this analysis, the basis for most per subscriber results will be the REA data. Depending on any definition of the size of the rural subscriber base, the per subscriber results may simply be increased by an appropriate factor to arrive at universe 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.[6] 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.

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[5] 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.

[6] Ref., Egan and Taylor, supra note 4.

## 2.2 Financial Profile for Rural Telephone Companies

There are over 1300 telephone companies in the U.S., over 900 of which are borrowers in the federal government REA financial assistance program. The top 25 local exchange carriers constitute over 90% of the total 130M access lines.[7] All other telephone companies are quite small by comparison. Table 1 gives financial data for over 900 REA companies juxtaposed with data for the top 25 large companies; Table 2 gives investment data for both; and Table 3 provides investment per access line for purposes of comparison. Despite the great differences in physical plant characteristics between large and small companies, the financial and investment data are surprisingly similar when comparing average statistics.

On average there are about 6,000 access lines per telephone company central office. Bell Telephone companies have about 10,000 lines per central office and serve about 80% of the market with about 50% of all central offices.[8] Independent companies, on the other hand, have only 2,350 lines per central office. REA borrowers, considered very small independents, average only 2,500 lines per central office. In 1988, REA companies served 5.3M access lines, approximately 4% of the total industry (for all 913 borrowing companies). Large telephone companies have average subscriber loop (access line) lengths that are about half that of REA companies, (10,787 feet vs. 20,330 feet).[9] Finally, while Bell Telephone companies average almost 130 subscribers per route mile of outside plant, REA companies average just six.[10]

Even with such striking differences in physical plant parameters, REA company investment per access line is only about 20% higher than for large telephone companies. The exact reasons for this are not known. However, the ratio indicates a significant cost efficiency relative to large companies with their short-loop, high-density plant. Overhead, toll operations and other specialized plant costs represent proportionally more of large companies' total cost, partially explaining the surprising

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[7] Bruce L. Egan and Leonard Waverman, "The State of Competition in US Telecommunications," Center for Telecommunications and Information Studies, Research Working Paper #350, Columbia Business School, September, 1989.

[8] "Telephone Statistics for the Year 1987," USTA, Volume 1.

[9] Gerald S. Schrage, supra note 3.

[10] Source: REA Bulletin #300-4, "1988 Statistical Report, Rural Telephone Borrowers," US Department of Agriculture; and NTCA, 1989.

investment and expense data.

Total book cost per line is $2,288 for REA companies and $1,881 for the top 25 local companies. Interestingly, REA companies have depreciation reserve percentages somewhat higher than the top 25 local carriers and their net plant cost per access line is only 14% higher. Relationships in rates of capital spending and total investment per subscriber for large and small telephone companies have remained fairly constant since divestiture, which represents an aggressive network upgrade period for both. Another interesting category for comparison is annual expense per subscriber line. REA companies' expenses average $522 each year, while large companies' expenses average $558.[11]

Overall, REA companies' greater efficiency (despite the abilities of lower-cost large companies to take advantage of economies of scale in the network) has significant implications for the ability of small rural telephone companies to finance network upgrades to meet the requirements of an advanced network infrastructure. Of course, some reasons for these relatively low costs of REA companies are the low-costs of REA financing and the savings from arrangements to share large-company toll facilities and traffic and billing systems. In other words, some small company operations may be treated as operating expenses while the same activity for a large company may require capital outlays. Nevertheless, even operation and maintenance expenses per line are consistently and significantly lower for smaller companies.[12] Large companies may incur relatively more costs due to the mobility of the access line base (access line inward and outward movement, or "churn") and the tendency for service quality to be higher on large company loops (but which are also shorter implying lower costs). Churn alone may not completely explain the difference in expense per line. Labor costs for both craft and management functions are much smaller for rural telephone companies. However, the fact that loop costs depend heavily on resource costs, presumably favors large telephone companies with volume purchasing economies.

Table 1 shows key financial results after 1984 for large and small telephone companies, including revenues, cash flow, debt ratios, and rates of return. These data are valuable for assessing the companies' capability to finance network upgrades. The data indicate very good financial health, providing strong support for aggressive modernization programs, if regulators allow this situation to continue. While total revenue growth is sluggish, about 5% per year, cash flow (net income plus depreciation) remains high and growing. In fact, cash flow for REA companies is 36%

[11] Source: REA Bulletin #300-4, "1988 Statistical Report, Rural Telephone Borrowers," US Department of Agriculture; and USTA Statistics, 1988.

[12] USTA Statistics, 1988, volume 2.

of total revenues compared with 29% of the industry average for large local telephone companies. During the post-divestiture period, both large and small telephone companies had high cash flow due to significant increases in depreciation rates and large tax reductions. Debt ratios for telephone companies have been falling, increasing their ability to use debt financing for new construction. Rate of return on net capital (calculated here as net income divided by total invested capital) continues to be high relative to historical rates. Figure 1 illustrates revenue by category of service and cash flow for both REA and large companies for 1988.

Revenues per line for small companies is $682 per year or $56 per month. Comparably, large companies are $757 per year or $63 per month (see Table 2). The difference can be attributed to the large companies' higher proportion of business access lines, which generate proportionally more revenue than residential lines. Thus, average monthly charges for residential customers are similar for both large and small companies.[13] Both REA and Bell companies obtain about 10% of their revenues from non-network activities. One significant difference is that 56% of all independent telephone company revenues (64% for REA companies) is derived from toll and access charges, compared with only 46% for Bell companies.

Rural customers tend to spend proportionally more on toll service than urban customers. Access charges and toll settlements paid from larger telephone companies to smaller ones increase the ratio of access and toll revenues. As competition in the industry for toll and 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 interstate toll subsidies for their existence represents a special problem for the future. For such companies, average loop costs can easily run three times the overall rural average.[14] Of course this also implies that some other companies operate well below the average.

### 2.3 Rural Telephone Plant Characteristics

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[13] For detailed data and discussion on post-divestiture trends in rural telephone subscriber rates and costs see Joseph P. Fuhr, "The Effects of the Divestiture of AT&T," and "Rural Telephony Since Divestiture," draft, Widener Univ., 1990.

[14] For a description of a very high-cost rural company's experience and how it is dependent on toll settlement subsidies see "RTC -- Pioneer in Today's West," Rural Telecommunications, Winter, 1989. For some data on high cost rural telephone plant and subsidies see Joseph Fuhr, supra note 13.

TABLE 1

## TOP 25 LOCAL EXCHANGE CARRIERS ($M)

| YEAR | REVS | OCF | NI | DEPR | DIVS | ADDS | DBTRAT | ROR | LINES (000) | REVS/LN |
|---|---|---|---|---|---|---|---|---|---|---|
| 1984 | 75157.0 | 23085.5 | 8770.8 | 11906.5 | 6691.2 | 18206.6 | 43.2 | 7.4 | 113089 | 665 |
| 1985 | 82547.7 | 25789.3 | 9778.4 | 13672.5 | 5984.3 | 20386.1 | 42.2 | 6.8 | 116334 | 710 |
| 1986 | 88247.3 | 26980.8 | 10545.6 | 15396.0 | 6484.0 | 21035.1 | 41.4 | 8.0 | 119360 | 739 |
| 1987 | 92168.2 | 26920.0 | 10788.5 | 17806.3 | 6958.2 | 20311.7 | 41.7 | 7.8 | 123257 | 748 |
| 1988 | 96668.4 | 28039.3 | 11387.6 | 18767.4 | 7153.1 | 20806.3 | 41.0 | 8.0 | 127624 | 757 |

Source: Company Reports

## RURAL TELEPHONE BORROWERS ($M)

| YEAR | REVS | OCF | NI | DEPR | DIVS | ADDS | DBTRAT | ROR | LINES | REVS/LN |
|---|---|---|---|---|---|---|---|---|---|---|
| 1984 | 2910.19 | 1049.66 | 445.75 | 603.91 | 133.76 | 985.88 | 65.44 | 6.28 | 4616810 | 604.17 |
| 1985 | 3108.22 | 1115.23 | 487.68 | 627.55 | 164.58 | 780.16 | 63.43 | 6.72 | 4913146 | 632.63 |
| 1986 | 3180.79 | 1145.30 | 503.18 | 642.12 | 139.68 | 1249.47 | 62.09 | 6.90 | 4963542 | 640.83 |
| 1987 | 3339.43 | 1264.73 | 569.74 | 694.99 | 171.55 | 1031.34 | 59.71 | 7.47 | 5170751 | 645.83 |
| 1988 | 3598.29 | 1305.85 | 554.64 | 751.21 | 279.31 | 1031.34 | 56.84 | 7.14 | 5275096 | 682.13 |

Source: REA Statistical Bulletin

Notes: All amounts in millions except DBTRAT, ROR, LINES and REVS/LN
REVS: Revenues
OCF: Operating Cash Flow
NI: Net Income
DEPR: Depreciation Expense
DIVS: Dividends
ADDS: Capital Expenditures
DBTRAT: Debt Ratio
ROR: Rate of Return
REVS/LN: Revenues per line
OCF=NI+DEPR
DBTRAT=((Long term debt)/(Long term debt + Shareholder's Equity))*100
ROR=Net Income/NPIS

TABLE 2

## TOP 25 LECS

| YEAR | GPIS | NPIS | DR(%) | DE(%) | RETS | ADDS |
|---|---|---|---|---|---|---|
| 1984 | 190696.19 | 146208.3 | 23.33 | 6.24 | 6617.03 | 18266.56 |
| 1985 | 205847.40 | 153834.5 | 25.27 | 6.64 | 7399.26 | 20448.08 |
| 1986 | 219818.04 | 159656.3 | 27.37 | 7.00 | 7788.67 | 21203.13 |
| 1987 | 229661.33 | 163229.6 | 28.93 | 7.75 | 8927.85 | 20447.71 |
| 1988 | 240092.68 | 164615.1 | 31.44 | 7.82 | 8310.59 | 20806.34 |

## RURAL TELEPHONE BORROWERS

| YEAR | GPIS | NPIS | DR(%) | DE(%) | RETS | ADDS |
|---|---|---|---|---|---|---|
| 1984 | 10194.74 | 7102.29 | 30.33 | 5.92 | 509.74 | 985.88 |
| 1985 | 10670.88 | 7256.42 | 32.00 | 5.88 | 533.54 | 780.16 |
| 1986 | 10917.50 | 7289.23 | 33.23 | 5.88 | 545.88 | 1249.47 |
| 1987 | 11621.09 | 7630.74 | 34.34 | 5.98 | 581.05 | 1249.47 |
| 1988 | 12071.38 | 7772.85 | 35.61 | 6.22 | 603.57 | 1031.34 |

Notes: all amounts in millions except ratios (including per mile and per sub), miles, lines and subscribers (for all tables).

Rural ADDS for 1984 n/a; estimated from growth rates of subsequent years.

GPIS: Gross Plant in Service

NPIS: Net Plant in Service

RETS: Retirements

ADDS: Capital Expenditures

ADDS(t)=GPIS(t+1)-GPIS(t)+(5%)(GPIS(t))

RETS(t)=(5%)(GPIS(t))

DR(%)=Accumulated Depreciation/GPIS

DE(%)=Depreciation Expense/GPIS

TABLE 3

## TOP 25 LECS

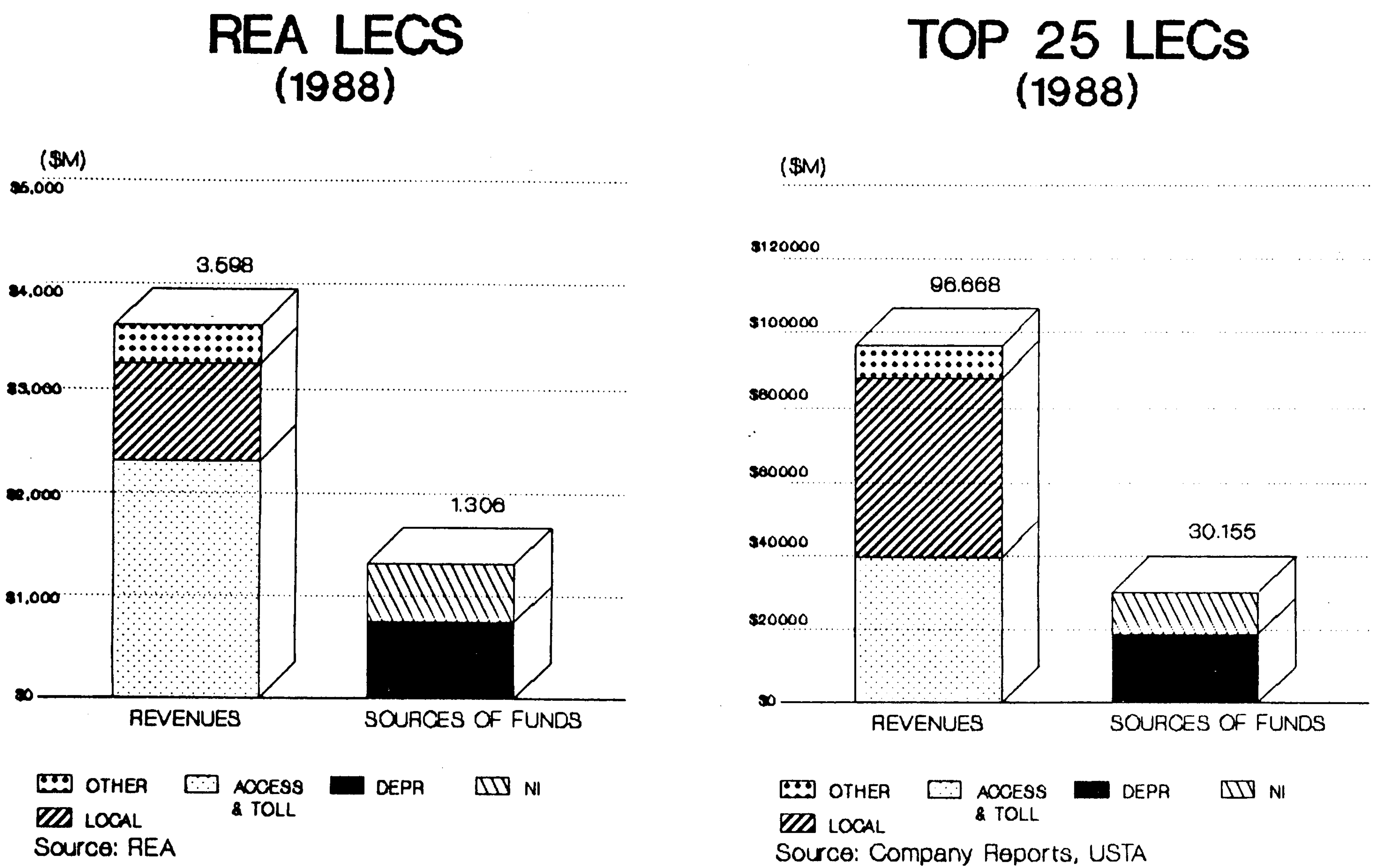
| YEAR | GPIS/LN | NPIS/LN | LN/RTM | LN/SQMI |
|---|---|---|---|---|
| 1984 | 1686 | 1293 | | |
| 1985 | 1769 | 1322 | | |
| 1986 | 1842 | 1338 | | |
| 1987 | 1863 | 1324 | | |
| 1988 | 1881 | 1290 | 130 | |

## RURAL TELEPHONE BORROWERS

| YEAR | GPIS/LN | NPIS/LN | LN/RTMI | LN/SQMI |
|---|---|---|---|---|
| 1984 | 2116 | 1474 | 5.55 | 3.86 |
| 1985 | 2172 | 1477 | 5.64 | 3.85 |
| 1986 | 2200 | 1469 | 5.71 | 3.96 |
| 1987 | 2247 | 1476 | 5.89 | 3.96 |
| 1988 | 2288 | 1473 | 5.89 | 4.03 |

Notes: GPIS/LN: GPIS per line
NPIS/LN: NPIS per line
LN/RTMI: Lines per route mile
LN/SQMI: Lines per square mile

FIGURE 1


REA LECS
(1988)
($M)
$5,000
$4,000
$3,000
$2,000
$1,000
$0
3.598
1.306
REVENUES
SOURCES OF FUNDS
OTHER
LOCAL
ACCESS & TOLL
DEPR
NI
Source: REA
TOP 25 LECs
(1988)
($M)
$120000
$100000
$80000
$60000
$40000
$20000
$0
96.668
30.155
REVENUES
SOURCES OF FUNDS
OTHER
LOCAL
ACCESS & TOLL
DEPR
NI
Source: Company Reports, USTA

There are significant differences in the physical characteristics of rural vs. urban telephone plant. REA 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 plant. For large telephone companies the density of subscriber lines is usually greater by at least an order of magnitude. Table 4 gives subscriber loop characteristics for both Bell and REA companies. Bell has significantly more business access lines with an average line length much shorter than for residential lines. Bell loop lengths average about half that of REA companies. The average loop length for REA 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 are generally a problem for the new ISDN services that require relatively high-quality circuits for error-free digital transmission. However, the mode loop length is less than the average for REA companies. Consequently, 55% of loops are less than 18,000 feet. Sixty percent of all REA loops are actually non-loaded, but many still receive treatment of some kind to improve transmission and signal quality.[15] In contrast, 88% of Bell loops are less than 18,000 feet, and 76% are non-loaded with an average length of only 7,500 feet.

Both large and small telephone companies have very long-tailed distributions for loop length and the averages are sometimes misleading. Nevertheless, the average statistics for loop length, transmission electronics and investment are important for evaluating the average cost of loop upgrades. There is a great disparity between the tasks confronting Bell Companies and REA companies 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 REA companies.

Figure 2 shows the breakdown of telephone plant in service for REA companies and the top 25 local telephone companies. As expected, the investment in loop transmission facilities is in relatively higher proportion for REA companies. Figure 3 gives switching plant characteristics for REA companies. Interestingly, REA companies -- while serving proportionally more of their subscribers with old Step-by-Step mechanical switching technology -- have a higher proportion of lines served with advanced digital technology (45%) compared to Bell companies (30%) and the 10 largest independents (41%).[16] This has important implications for network upgrade decisions. On the average, Step-by-Step switches are much older than the stored program control 1AESS and cross-bar electromechanical switches which serve many of

[15] Schrage, supra note 3.

[16] Parker et al., p. 79, supra note 1.

TABLE 4

## SUBSRIBER LOOP CHARACTERISTICS *

**BELL** (2290 pairs sampled in 1983)

| | | |
|---|---|---|
| Residence | 1553 | 68% |
| Business | 737 | 32% |

| | | | | |
|---|---|---|---|---|
| Avg. Loop length | 10,787' | Min. 186' | Max. 114,103' | s.d. 188' |
| Avg. Feeder length | 10,448' | Min. 100' | Max. 102,293' | s.d. 217' |
| Avg. Dist. length | 1,299' | Min. 0' | Max. 23,177' | s.d. 63' |

88% < 18kft. **
76% non-loaded at avg. length 7,535'
avg. loaded loop 21,249'

**REA** (984 pairs sampled in 1986)

| | | | | |
|---|---|---|---|---|
| Residence | 909 | 91%) | (91% 1-party) | (66% dial, 34% tone) |
| Business | 85 | 9% ) | | |

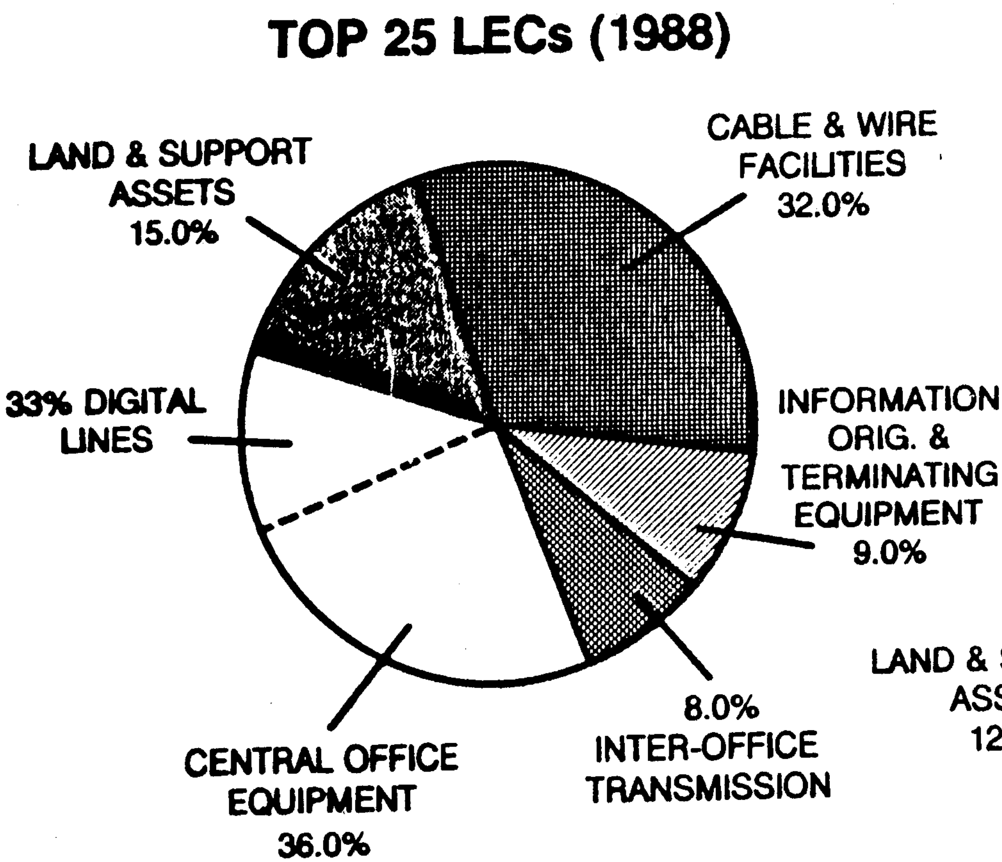
Avg. Loop length 20,330'
Avg. Feeder Length
Avg. Dist. Length

55% < 18kft.
60% non-loaded

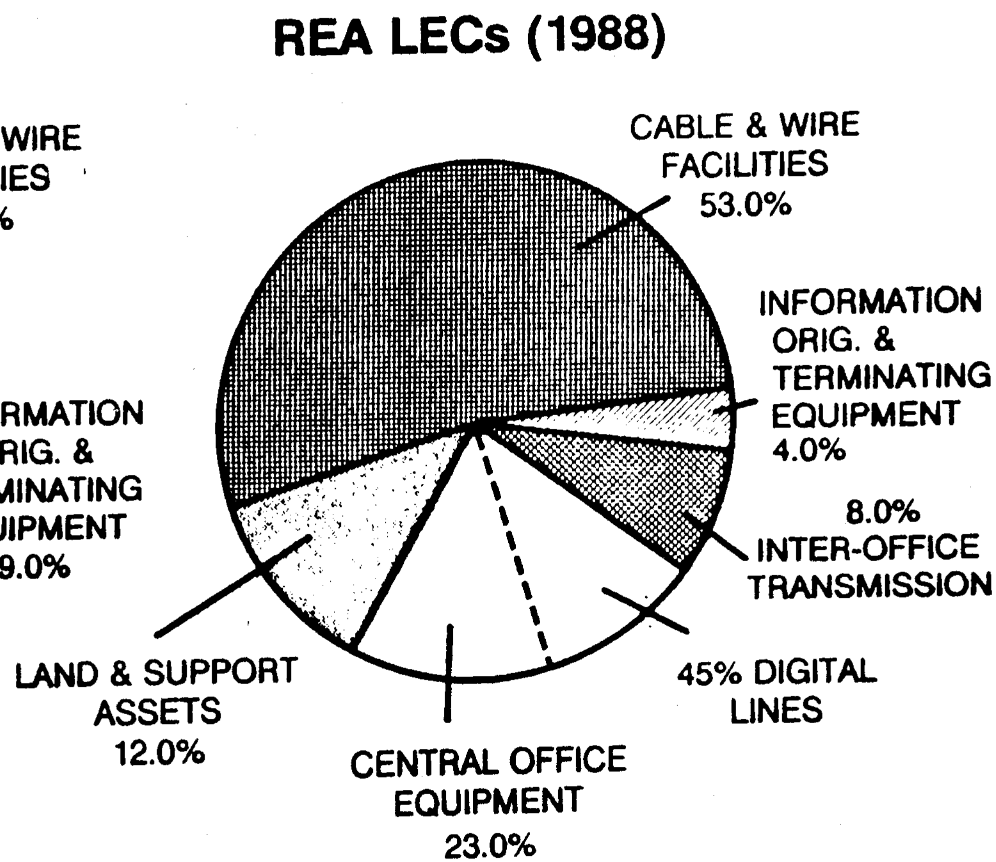
* = working pair
** = load coils recommended over 18 kft.

FIGURE 2

# *Plant Investment*



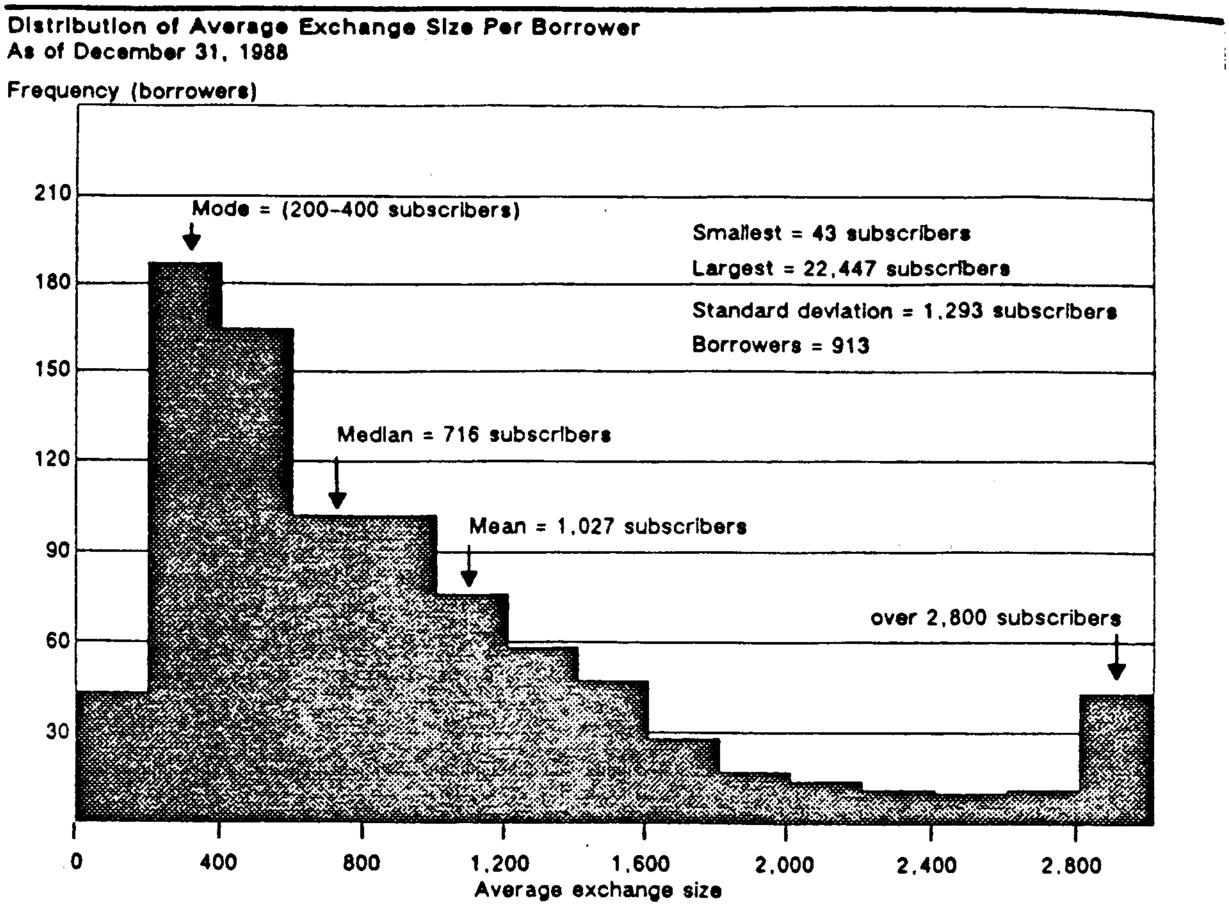

Source: Company Reports

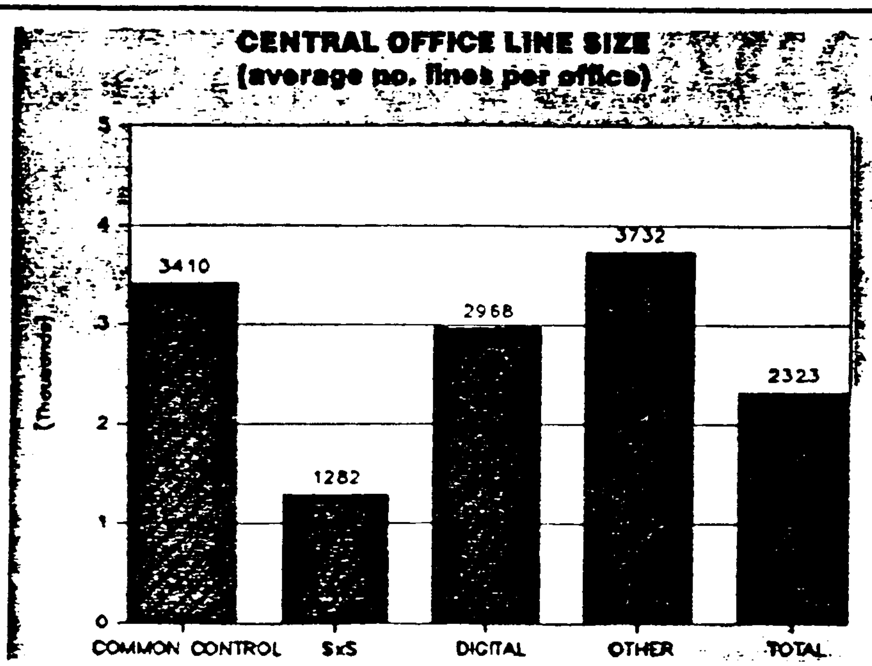



Source: REA Statistical Bulletin

FIGURE 3

REA CENTRAL OFFICE SWITCHING CHARACTERISTICS




* average exchange size - approx. 1000 subscribers
45% subscriber lines served by digital switching but represents only about a third of exchanges

SOURCE: REA

the Bell access lines; therefore the Step-by-Step switches of smaller companies are closer to economic retirement and should be converted to digital in any upgrade situation. Consequently, small companies may have an advantage over large telephone companies who must consider the financial effects of early retirements of their embedded base of electronic analog and electromechanical switching plant.

The situation is quite the reverse for loop and transmission plant. Over one-quarter of transmission plant for small companies utilizes buried "non-filled" cable that may not support ISDN. Although this type of cable may be nearing retirement age,[17] per subscriber costs for replacement is quite high.

### 2.3.1 Existing vs. New Subscriber Plant

For decades, dramatic advances in network technology for providing toll service have lowered unit costs substantially. In the last decade, some significant advances have been achieved in loop plant technology. Before divestiture the investment per access line for both large and small telephone companies was rising substantially; since divestiture, it has been more stable. In the previous two decades there was significant inflation in materials and labor costs and access line growth was relatively high. This explains some of the recent stabilization in recent loop plant costs. However, the relatively low real costs for access lines is mostly due to the introduction of the serving area concept in current plant designs. The serving area design concept was introduced by the Bell System and adapted for use in rural areas by REA companies in the mid-1970s. This design concept arranged logical groupings of subscribers who would be served by relatively short and large pair-size distribution cables from an intermediate field location called a Serving Area Interface (SAI) point. Relatively long feeder cables connect the SAI to the central office switch. Subscriber circuits are created by cross-connecting pairs from the feeder and distribution cables at the SAI points. Two significant developments in loop technology -- the introduction of loop carrier systems and digital remote electronics and switching technology -- helped implement this design concept. Loop carrier systems concentrate access lines by combining many customers' lines into one or more shared trunks. Previously, each customer had required a dedicated (non-shared) loop.

The introduction of digital switching reduced the amount of dedicated loop plant by allowing remote nodes to be connected to the host digital switch. Because of further advances in loop technology and other impending developments, real costs of rural telephone loops will decrease over the next decade. Significant advances in loop

[17] See Schrage, supra note 3.

electronics and fiber-optics are essential for future cost economies. Also, system growth is expected to decrease because of continual improvements in telephone penetration rates. This does not imply that serious pockets of unserved rural areas are not a problem, but that the outlook on the cost side for the majority of subscribers is favorable due to advancing technology.

There is a notable difference between the costs of loop upgrades for existing subscribers using advanced digital, fiber-optic and radio technologies, and the costs of serving brand new and physically remote subscribers. From a public policy perspective, these groups should be treated as special cases requiring significant cost subsidies. Overall, the existing body of rural subscribers is being served cost effectively and profitably.

Based on the average loop and digital central office plant parameters presented previously -- roughly four miles in length with 2,500 subscribers per digital central office -- the average cost of a new rural access line is estimated to be $2,500. Digital remote terminals utilizing fiber-optic feeder trunks connected to the host CO are assumed. The remaining subscriber distribution plant is normal twisted-pair copper. A stylized view of the average subscriber line appears in Figure 4. This stylized loop could support narrowband digital services (56 Kbs to 144 Kbs).

### 2.3.2 Rural vs. Remote Subscriber Plant

Physically remote subscriber loops create special problems for engineering. Vast differences in topology for any given subscriber mean there is no least common denominator. The possibilities are countless, preventing the adoption of a standard loop architecture. Engineering for high-quality service is on a case-by-case basis. The suitability of various technologies for remote applications are covered in the next section on technology, followed by some specific case studies.

## 3.0 Technology Costs, Trends and Service Applications

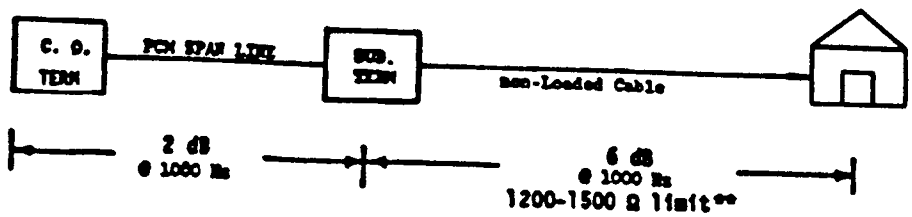
### 3.1 Digital Switching and Transmission

Much progress has been made in digital telecommunications technology for rural

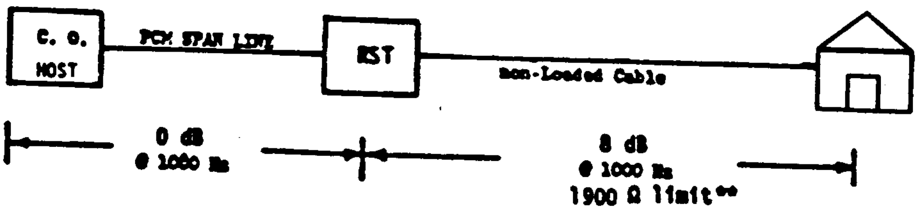
FIGURE 4

STYLIZED RURAL TELEPHONE LOOPS

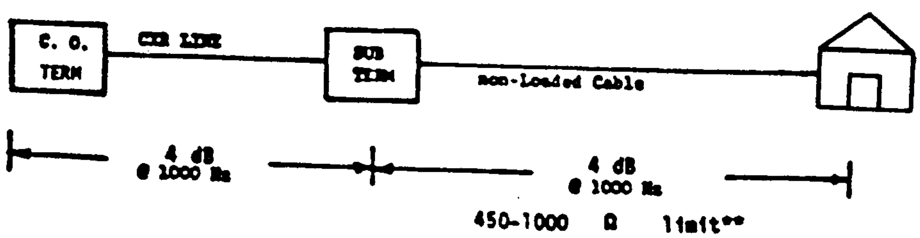
PCM SUBSCRIBER CARRIER/CONCENTRATOR




REMOTE SWITCHING TERMINAL




STATION CARRIER




* IF LESS THAN 0.4 LOAD SECTION, BUILD OUT TO ½ LOAD SECTION.
** OHM LIMITS SPECIFIED INCLUDE TELEPHONE SET.

Source: REA

applications. As the economies of scale from this technology are used more efficiently, per subscriber costs for digital switching are beginning to fall. This technology, more than any other, 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 for anything from still pictures and high-speed graphics to 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 migration scenario scheduled for urban networks. In both urban and rural areas, business customers may require broadband services while residential customers will probably be satisfied with narrowband capability.

## 3.2 Fiber-Optics

Fiber-optics, the next paradigm in telecommunications transmission technology, is undoubtedly the lowest cost technology for future high-capacity network applications. It is already the preferred technology for most telephone company interoffice plant, both toll and local. Unit costs continue to decline rapidly, making fiber viable in loop plant for feeder applications connecting host digital central offices with remote subscriber terminals. Already most major cities in the U.S. have excess fiber-optic capacity for intercity connections; by the time fiber-optics becomes widely used in feeder plant applications there will be no bottlenecks in the connections of long-haul fiber routes. Ultimately, service demand drivers for end-to-end digital service capability will gain momentum, pushing this technology even further out toward the subscriber premises.

Because fiber-optics involve lightwave transmission instead of the electron transmissions in traditional copper networks, it is not sensitive to electromagnetic interference; a major problem with existing electronic transmission techniques. In general, fiber-optics provide more capacity, reliability, flexibility, and functionality than existing metallic facilities. Due to its high-capacity per physical fiber circuit, fiber cable is much smaller than copper and coaxial cable. Because of declines in fiber costs and recent increases in the strength of the fiber cable itself, installation costs are equal to or less than installation costs for copper and coaxial cable based on engineering first costs. Splicing fiber cable, more than with copper, significantly increases the cost of deployment. The remaining expense categories -- lasers, opto-electronic signal converters, and other optical devices -- make fiber costs unattractive in many current loop applications. However, the costs of fiber components, devices, and splicing procedures continue to decrease, and the expectation is that total installation costs of "lit" (operational) fiber cable will be cost-competitive with copper in several years. Despite fiber's relatively high initial engineering costs, it may be currently preferable for new plant construction because fiber's service life and net revenue stream may be greater than copper's.

Though fiber is just beginning to be deployed in local exchange plant, its use will increase as engineers become more familiar and comfortable with it. Already, REA has issued engineering guidelines for the use of fiber in rural feeder routes and between host and remote central office facilities.[18]

Because of its high capacity and interference-free transmission characteristics, fiber offers unique advantages over alternative technologies for advanced rural communication services. Fiber's dielectric properties can reduce deployment costs; it may be lashed onto existing metallic facilities or carried on electric power distribution facilities without transmission interference that occurs with both copper and radio facilities. Fiber's low signal attenuation properties enable repeaterless transmission lines to work for relatively long distances within a rural exchange. The relatively large signal attenuation and propagation of copper and radio transmission facilities are significant and costly considerations. Fiber can be used to support stereo audio, video, and, as an important new revenue source, cable TV transmissions. Large telephone companies are currently barred from direct participation in many mass-media activities while small/rural ones are not.

Though fiber-optic technology has capacity in excess of the needs of most individual subscribers, it provides cost-effective, high-quality narrowband services when shared subscriber use is possible through multiplexing. Only when a fiber circuit is dedicated to one or few subscribers is it clearly at a cost disadvantage compared with other technologies. For this reason, fiber may not be viable for subscriber access lines for many years to come. Most of the current fiber-to-the-home trials address this sharing problem by testing time or wavelength division multiplexing techniques at various points in loop distribution facilities. Meanwhile, many business customers already share access lines; therefore, fiber access facilities may be cost-justified based on demand conditions.

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[18] "1989 REA Telecommunications Engineering and Management Seminars", Section C: Lightwave, US Department of Agriculture.

## 3.3 Microwave

Microwave has long been a mainstay in telecommunications network technology. Historically, its primary use (like fiber-optics today) was high capacity, long-haul toll service. It also has been the technology of choice for private long-haul networks, and will remain a primary player in such markets for some time to come. Recent technological advances in microwave, as well as increases in the useable spectrum for telecommunications, have made it a popular technology for high-capacity short-haul applications. Microwave is used for both digital and analog services. One of microwave's advantages is its relatively low construction costs for certain rural applications compared with other technologies. Rooftops, hills and mountains can often provide an inexpensive base for microwave towers, although buildings, hills and mountains, like trees, are often more of a problem than a benefit. Perhaps microwave's main advantage is that, unlike terrestrial wireline technologies, it does not require placement of physical cable plant which is usually the highest component of deployment costs. Microwave requires line-of-sight on the transmission path and is subject to electromagnetic interference, but this is often a small problem compared to costs of right-of-way routes for wireline technologies.

Unit costs of microwave service continue to fall as more high-powered systems expand the useable spectrum. Very small capacity systems are also available, with only a handful of circuits. As an over-the-air technology, microwave has inherent security and privacy disadvantages compared with wireline technologies, though signal encryption and encoding can mitigate this factor. Microwave plant features flexibility and mobility--favorable aspects that far exceed those of wireline technologies and assure its future use in many situations and service applications. Because reliability and signal propagation are less of a problem, fiber is expected to dominate many network applications currently served by microwave; however, for rural service, microwave is especially useful for niche applications where rough terrain or water must be crossed.

## 3.4 Radio

Radio technology, like microwave, relies on the electromagnetic spectrum and has long been used in various forms for telecommunications and broadcasting services. Its use in basic rural telecommunications has only recently been formally approved as a primary service by the federal regulators, who must approve all private uses of radio spectrum.[19] This technology is sometimes referred to as the "wireless loop," and its immediate advantages in terms of speed and ease of installation are clear since there is no requirement for placing physical transmission plant. The term "radio" in this case refers to certain frequencies assigned to the service which are distinct from those frequencies assigned microwave toll service. Cellular and satellite frequencies are also distinct and will be discussed below. As an over-the-air technology, radio service supports both analog and digital applications and has the same relative advantages and disadvantages as those listed for microwave. Unlike microwave, rural radio provides short-haul telecommunications and requires different power, performance, transmission and reception capabilities and devices.

Clearly, the most advantageous feature of radio technology is its low cost in rural service applications not suited for wireline service (because of topology and remoteness). In a recent FCC proceeding it was estimated that basic rural radio service may be cost effective for serving about 900,000 subscribers who do not have service at all, or whose service upgrades using other technologies are not cost-effective. However, there are many lower estimates.[20] Some case studies of this technology will be presented in Section 5.

Finally, there is another important development on the horizon in digital radio technology -- personal portable communications. In the very early stages of development in urban areas, this technology is sometimes referred to as "micro-cellular." It will be initially introduced as a low-powered cellular service, a cross between current cordless telephones and mobile cellular service. Some analysts predict that this type of telephone service will soon exceed growth of normal cellular and fiber-optics, which are currently the highest growth telecommunications markets. It is not yet clear how this network infrastructure will develop because it requires spectrum space which regulators must allocate. If this service is made available, it will become a major player in local telecommunications. Truly personal and portable communications would enable one to send and receive communications anywhere, which is easier than depending on a phone hooked up to copper or fiber.

If normal cellular phones are any indication, the cost of micro-cellular base stations and subscriber equipment will likely decrease very rapidly. For rural applications where the spectrum is less crowded, this technology could revolutionize communications. However, because infrastructure deployment will take years, personal portable communications will not become a significant factor before the end of the

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[19] Documents filed in FCC CC Docket #86-495 (BETRS) provide detailed information on this service.

[20] See FCC CC Docket # 86-495 Report and Order, December 10, 1987.

decade.

## 3.5 Cellular

Cellular radio service is the fastest growing telecommunications service in America. Today there are approximately 4.5 million subscribers, a substantial increase from 50,000 in 1984. Cellular radio has the same properties as microwave radio service except that it operates at low power on a grid of "cells." The pattern of alternating cells is such that the same frequency from non-adjacent cells may be re-used. Cells interconnect to a Mobile Telephone System Office (MTSO) which provides the system switching and interface to the public telephone network. This service is not currently offered in many rural areas, even for mobile users. A recent FCC order ruled that cellular spectrum would be made available on a "co-primary" basis with private radio in rural areas, defined to be within a 100 mile radius from the top 54 Standard Metropolitan Statistical Areas (MSAs).[21] Standard cellular service is offered in all MSAs in the U.S. and is beginning to be offered in rural areas (RSAs).[22] New digital cellular technology will soon be deployed, significantly increasing the capacity of congested analog urban systems. The FCC recently turned down requests to assign dedicated frequencies for fixed cellular BETRS service as an alternative to basic telephone service in rural and remote areas. This is seen as a positive step to promote its use for Rural Radio Service. Though unknown, cellular's viability for rural fixed service is probably extremely costly. Current technology, involving very high up-front construction costs, can only be justified with a sufficiently large subscriber base. A large base could be established by using cellular radios for both fixed and mobile rural service.[23]

## 3.6 Satellite

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[21] FCC CC Docket #86-495 Memorandum Opinion Order on Reconsideration, June 1989.

[22] For some information on the market for rural cellular service see, Parker et al, pp. 83-85, supra note 1; and "FCC Gives Green Light to Rural Cellular Service", Jerome K. Blask, Roundtable, summer, 1988; and "A Cellular Plan You Can Bank On", Paul Shultz, Rural Telecommunications, summer, 1989.

[23] Parker et al., p. 83 supra note 1 provides some discussion of rural cellular service.

The profitability of satellite technology for rural telecommunications is ambiguous. In rare cases satellite is used to provide basic telephone service, though by and large it is used in specialized applications for toll, data and video transmission. The technology is cost effective for one-way transmissions of high-bandwidth services such as video; it is most useful for very long-haul service applications because distance barely affects satellite costs. However, a large base of customers is necessary for satellite service to be cost effective for providing "plain old telephone service" (POTS) because of the large up-front manufacturing and launch costs. Most satellites are launched by large companies that lease transponder capacity to others in order to achieve an efficient level of demand.

There are two basic types of satellite service, depending on the power and frequency of the satellite system: C-Band and Ku-Band. The long-used C-Band birds, efficient for point-to-multipoint transmissions of video services, are also used for international toll service for voice and data traffic. The relatively new Ku-Band satellite service allows for Direct Broadcast Satellite (DBS) service of many video channels which, as an alternative to cable television, has received much attention in the communications industry trade press.[24] Ku-band birds use higher frequencies and require more power for transmission, but have an advantage for the end user because smaller receiving dishes may be used. The potential use of satellites for communication services revolves around the higher frequency birds because they circumvent a major impediment in the adoption of satellite technology by significantly reducing not only the size but the cost of customer reception devices. Currently, C-Band reception dishes are about six feet in diameter, while Ku-Band dishes are less than a meter -- the latest models measuring only 18 inches. Aesthetically desirable, flat phase-array receivers are also on the drawing board, and some early models are already on the market.

The greatest inherent disadvantage of satellite service is the transmission delay time of 250 milliseconds for round trip communications (125 milliseconds uplink and 125 downlink). As a result, satellites are most suitable for one-way transmissions, such as video and data services, and in situations where delay times are not an issue for customer acceptance. Though satellites presently carry little local voice traffic in the continental U.S., there is a C-Band network in Alaska that serves some extremely remote subscribers. Many developing foreign countries use satellite technology for toll services, as does the U.S. In the U.S., however, satellites are not likely to become a significant technology in the telecommunications infrastructure. Instead, they will continue to be important for certain applications such as video and other mass media services, as well as point-to-multipoint data. Thus, from a public policy perspective, it will be essential to promote efficient interconnection of satellite network facilities with

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[24] Catherine Stratton, "High-Power DBS May Be On Its Way," Multichannel News, February 26, 1990.

the rest of the public telecommunications network infrastructure. This issue will be addressed in Section 6.

### 3.7 Coaxial Cable

Coaxial cable has long been used in traditional telecommunications applications. In the public telephone network it has been used primarily for high-capacity trunk applications like T1 digital interoffice transmission. Since the inception of cable television, coaxial cable has been the standard for video signal distribution. Coaxial cable has certain advantages for rural telecommunications: it has very high bandwidth capacity and well known physical properties; field engineers may feel as comfortable with it as they do with traditional copper telephone lines; it already exists and may be useful to support advanced telecommunications services, especially those requiring bandwidth beyond that which twisted-pair copper phone lines can support. Yet this technology, in current cable television networks, cannot support new high-quality two-way services without significant costs. Under the current tree-and-branch cable network architecture, capacity is fully utilized by existing television channels.

Cable networks are engineered for efficient one-way transmission. Adding two-way services, even narrowband ones, would cause interference and reduce service quality. The newer cable network architectures can support advanced two-way communications services by upgrading the cable trunk network with fiber and microwave links.[25] The trend of cable network upgrades is clear -- with fiber-optic backbone trunk facilities, cable service quality and reliability increase and new services may be added at minimum cost.

### 3.8 Electric Power Grid

A novel technology which exists in only a few applications is the electric power subcarrier. The electromagnetic field on electric power lines may sometimes be used for carrying low speed data using a sub-carrier frequency. However, it is currently impractical for two-way voice and data services because of interference and the high cost of electronics. Consequently, many large electric utilities have installed their own private telecommunications networks to meet internal communications needs on their rights-of-ways on poles and towers and in conduit. The utility may also sell spare

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[25] Ref. Egan and Conn, supra note 4; and Gary Kim, "Evolution of CATV Networks into Integrated Broadband Networks," Multichannel News, Draft, 1989.

network capacity, as in several recent cases where interexchange carriers utilize some of the electric utility infrastructure for providing toll services on high-capacity routes.

The public power grid has not been used for local or intraLATA toll services to any great extent. However there is some active consideration on expanding the use of electric power facilities for telecommunications. The Tennessee Valley Authority, Electric Power Research Institute and others are expanding research on sharing electric public power grid facilities and rights-of-way to provide telecommunication services. For now, small rural electric utilities generally do not have their own telecommunication facilities and instead must rely on the public networks of rural toll and local telephone companies.

**4.0 Advanced Rural Networks**

Developing and deploying advanced 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 several years now; however, there is still no residential service and very limited access to business service.[26] With widely available residential ISDN service not expected until late this decade, it is clear that advanced network upgrades will be delayed for both physical and financial reasons.

A 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 only gradual processes where more and more customers obtain access to the new technology over many years. It takes a long time to implement widely available interconnectivity, the factor that will provide the demand-pull for further technology adoption.[27]

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[26] "ISDN: What's Holding Up Implementation?", Center for Telecommunications and Information Studies Monthly Seminar Series, Columbia University, September, 1988.

[27] David Allen discusses the problem of reaching a demand-pull threshold in his article "Network Externalities and Critical Mass in New Telecommunication Services," Telecommunications Policy, Vol. 12 No. 3, September, 1988.

### 4.1 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. A discussion of state telecommunication infrastructure development follows in Section 6. However, exactly what constitutes advanced telecommunication for businesses is a disputable issue.

Relatively large businesses in rural areas, whether in the service or manufacturing sector, often require broadband (high-speed) communications capability to maximize operating efficiency and keep up with their urban and suburban counterparts. Broadband in this case refers to digital transmission speeds of 45Mbs and higher. At such speeds, high quality data services and video telephony are possible. Such transmission speeds are much greater than the narrowband ISDN service which is currently being deployed. Broadband service generally requires fiber-optic facilities, while narrowband service may be provided over more traditional copper facilities. Microwave and fiber technologies are capable of supporting both narrowband and broadband services but, as already explained, fiber is expected to be the dominant medium in the future.

Since fiber-optics not only allows for future broadband telecommunications *and* simultaneously provides for integrated narrowband services, there is some question as to whether incurring the costs of narrowband ISDN on copper facilities is worth it in the long run. Some analysts believe early deployment of broadband fiber-optic facilities is the way to go, bypassing the deployment of narrowband digital service on copper. In the case of business customers, the author tends to agree with this position. Even though most well-known business customer services may be provided on narrowband digital facilities, very high-speed data and full motion video telephony will require fiber-optic facilities.

Rural economic development partially depends on attracting businesses that require efficient telecommunications. Thus 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 do this is through an aggressive state-wide plan for a fiber-optic network infrastructure.

### 4.2 Residence Subscribers

The deployment of advanced rural telecommunication facilities for residence subscribers should be viewed in several stages. Dedicated fiber-optic access lines are generally not required to support the demands of residential customers. As noted previously, fiber-optics is cost effective in shared-use applications typical of business subscribers. For residence subscribers, network capability for narrowband digital service should be the first priority because it can support most known end-user services, such as computing, database services, and imaging and video services up to the T1 rate (1.5Mbs). Achieving this objective requires two things: upgrading older central offices to provide digital switching capability, and upgrading subscriber loop plant to provide digital transmission with low error rates.

The cost of upgrading rural subscribers to digital central office switches is estimated to be about $2.5B or $250 per rural subscriber.[28] This is not beyond the financing capability of the average rural telephone company, even at existing subscriber rate levels. REA companies have about five million subscribers; assuming half need to be upgraded to digital switching at $250 per subscriber[29], the total upgrade cost is about $625M. Current REA company total annual cash flow is over one billion dollars, and construction spending is also estimated at about one billion dollars.

Upgrading the loop plant of rural telephone subscribers for digital service presents a greater 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. Current loops are engineered to support analog voice at 3-4Khz, and very

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[28] Assumes 20 million rural subscribers with half already served by digital central office switches.

[29] In a recent study of switching upgrade costs for rural loops ("Rural Network Modernization in U.S. West," draft, July 25, 1989), Julio Molina and E. Reed Turnquist report average per subscriber digital upgrades at $300-500 in one state and only $180 in another. They also state that a reasonable near-term target is as low as $150 per subscriber.

low speed data service up to 9.6Kbs. To attempt more than this is to risk intolerable errors in transmission. Thus, the motivation to upgrade the rural loop plant is that current bandwidths 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 replacement of investment through rapid depreciation. Increased cash flow from depreciation, which would be an important source of finance for new loop plant, also implies rate increases for current subscribers or 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 (all the data in the previous Tables and Figures represent original book cost). However, new digital loop carrier systems mitigate the high costs by significantly increasing sharing of loop plant capacity among many subscribers, resulting in lower future per subscriber costs.

Generally, the main problem with upgrading rural subscriber loops for digital service is the presence of loading coils on about forty percent of them. These must be removed by cutting out the load coils and replacing the cable at the load coil point. Normally, this would be all that is required in the physical loop digital upgrade. If needed, loop carriers or a remote switching terminal may be installed. However, rural telephone companies have a substantial amount of buried "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 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 time period of ten years or so. For "non-filled" cable loops, however, it is indeed costly and an aggressive rehabilitation program may require relatively heavy external financing. It would be very costly to rehabilitate the buried non-filled loop plant with gel-filled cable. However, 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).

The estimated cost of upgrading rural loops to provide for narrowband digital service using filled cable is about $100 to $200 per subscriber. For non-filled cable the average cost could be as much as $2,500 per subscriber. 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 remote subscriber terminal (RST) or digital loop carrier system. The loop architecture assumes that the average customer uses a fiber trunk connecting an RST to a digital host central office and filled distribution cable. Where no RST is available one must be installed. Thus fiber-optics and fiber-compatible RSTs are the primary features of state-of-the-art rural loop upgrades.

For situations where it is simply too expensive to use the recommended loop architecture, there are several alternative choices including satellite, existing coaxial cable television links, 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.

## 5.0 Case Studies

This section provides case studies of alternative technologies shown to be useful in either upgrading or constructing rural telecommunications access lines. In most examples the subscriber lines can support advanced narrowband digital services. In others, the purpose of the construction is simply to provide basic service to previously unserved remote locations.

### 5.1 Fiber-Optics

The use of fiber-optics in rural telephone plant is new and generally confined to interoffice trunk facilities.[30] Due to high-capacity video transmission requirements, fiber-optics is also popular in rural education ("distance learning") applications. Two prominent examples are the Educational Telecommunications System in rural Minnesota and the Panhandle Telephone Company system in Oklahoma.

Many small independent telephone companies are using more fiber-optic connections to support shared toll network facilities and to interconnect with Bell companies and other toll carriers. When a rural company has digital central office capability, fiber-optics provides a high-quality and easily expandable network for aggregating the toll traffic of local service subscribers. Since larger telephone companies are rapidly adopting fiber-only policies for interoffice plant, small telephone company interconnection must also move in this direction. One example is Merrimack County

[30] For a brief summary of issues and local network architectures see, "Fiber to the Home: Not Yet, But Get Ready," OPASTCO Technical Committee, Roundtable, Winter, 1989.

Telephone, a small New Hampshire company, serving only 5,400 subscribers in 225 square miles. With REA financial assistance, a fiber-optic link connected to the local Bell network improved service for all of Merrimack's customers.[31] In another interesting application, the small rural company, Roanoake & Botetourt (R&B) Telephone Company, installed fiber-optic network facilities allowing R&B to interconnect with other local exchange companies or toll carriers so as to jointly provide toll service. Thus, the small rural company was assured of some role in the lucrative toll and toll-access businesses. Though there are no federal restrictions on the entry of small rural carriers into these businesses, efficient aggregation of rural customers' toll traffic is a problem. Fiber-optics, in addition to providing a possible solution, opens up new revenue opportunities for small rural companies.[32]

5.2 Rural Radio

Another relatively new technology for rural telephone companies is Rural Radio Service. Pursuant to a 1986 REA petition to the FCC, BETRS was finally authorized by the Commission in its *Report and Order* in CC Docket No. 86-495, January 19,1988.

BETRS is often considered a viable alternative for rural loop plant upgrades where wireline upgrades are prohibitively expensive. However, even for basic local exchange service, BETRS costs about twice as much as the average rural loop. The cost for known BETRS systems is between $4,000 and $11,000 per subscriber, and may even be more when subscriber densities are thin or when they are farther than 15-25 miles from the base station. This is still relatively inexpensive compared with the costs of long wireline loops, and should be seriously considered as an alternative. The BETRS equipment manufacturers' goal is an average of $2,000 per subscriber and they are making some progress towards it. It should be noted that these estimated costs for BETRS do not assume ISDN capability, which generally is beyond the service capabilities BETRS currently offers.

The BETRS technology was first deployed in October, 1986 in Glendo, Wyoming and in the Flint Hills area in Allen, Kansas. The Mountain Bell customers in Wyoming were previously without any telephone service, while the Kansas subscribers had existing 4-party service on relatively old cable that required an upgrade.

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31 "Merrimack Makes Bell-Independent Fiber Connection", Roundtable, Winter, 1988.

32 For a discussion of these opportunities see, "R&B Turns Adversity into Opportunity," Roundtable, summer, 1988.

International Mobile Machines Corporation (IMM) provided S&A Telephone Company with the Ultraphone system for the first REA field trial in Allen, Kansas.[33] In this trial the per subscriber cost of the system was about $4,200 for 50 subscribers averaging about 10 miles from the base station radio. Service quality was very good for these customers, but an experimental subscriber about 25 miles away from the base station understandably had trouble with signal strength, because the base station transmitter tower was only 100 feet tall. This system was able to make use of an existing toll microwave tower which helped keep costs down.

After three years the S&A system is quite reliable with minimal maintenance costs when the initial construction was done properly. One area for concern, however, is the vulnerability of the facilities to lightning bolts which can knock out service and permanently destroy the radio units. Unfortunately the base radio station of the S&A BETRS system is not redundant so that if it is disabled, all subscribers will lose service. Even with careful electrical grounding, beyond those of vendor installation recommendations, 3 out of 21 of the S&A subscriber radio units have been destroyed, requiring replacement. However no other significant unanticipated maintenance costs have arisen. Overall, the system owner said he would still use Ultraphone if a similar upgrade decision were required again.

Ultraphone subscriber units cost about $2,300. With power supply units, battery, antenna, and installation, the engineered first-costs come to about $3,130 per subscriber with the remaining costs attributable to system common equipment which can vary substantially depending on the terrain and on the sharing of existing telephone company facilities.

Many other BETRS systems in the U.S. do not have the luxury of being part of an REA industry trial and do not have the same terrain or subscriber density of the S&A system. Some other major telephone companies report per subscriber costs in the range of $5,000-$10,000 or even more.[34] Recently in a rural GTE exchange in Idaho, the costs of a BETRS system serving 29 subscribers was estimated to be about $11,000 even with sharing of some existing toll microwave facilities. In this case the subscriber terminals were relatively expensive at well over $3,000 each, and the installed cost was

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[33] For a description of this trial see, "How the REA Field Trial on a TDMA BETRS Radio System Was Done," March 28, 1989 and "S&A Puts BETRS to the Test," Arthur D. Biggs, Roundtable, Fall, 1988.

[34] For example, BellSouth reports 3 systems with 50 subscribers at an average cost of $7,000 per subscriber. Mountain Bell reports similar results.

almost $6,000.[35]

Besides the IMM Ultraphone, Rockwell International offers a Rural Radio system called the CXR-424 Collins Exchange Radio. The installed per subscriber cost for this system is between $5,000 and $10,000. The Rockwell system, designed for relatively low-density subscriber areas compared to Ultraphone, is currently used by some small Texas exchanges. The system is designed for 24 customers per base station. Though subscriber units cost about $4,000 each, they may serve 2 subscribers each if the subscribers are in reasonable proximity for sharing. Current systems have about 15 subscribers each.

## 5.3 Satellite

Probably the most interesting application of satellite technology for rural telecommunications is the VSAT system of Wal Mart Stores. This is an extensive system used for both voice and data telecommunications, but only on a closed network for point-to-point or point-to-multipoint service. Wal Mart currently leases capacity on 2 satellite transponders for a total 28Mhz full-time frequency from Satellite Transmission Leasing Corporation. The service capacity is 45% voice, 22% data, plus spare and overhead, with 84 digital voice channels. While digital voice service using satellite technology is relatively "bandwidth-hungry," Wal Mart manages to be cost-effective on satellite by piggy-backing voice on its data network. Using 6- digit internal numbers, connection delays for calls on the Wal Mart network is only about 2 seconds. When the internal network is busy, traffic overflows onto the public telephone network. Nationwide, the Wal Mart VSAT network has about 1,600 nodes which provide data and information to run the 1,500 stores and 17 distribution centers.

There are other major VSAT systems for Holiday Inns, K-Mart, Ford and others. Many of these companies, like Wal Mart, have some plant locations in rural areas. While voice applications are almost exclusively on closed networks, the advantages for satellite-based long distance data transmissions are clear. For businesses located in rural areas, such networks may be very useful for transactions services, inventory control, video, et cetera.[36]

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[35] Private correspondence between author and Idaho Public Utilities Commission, January 1989.

[36] For further discussion of VSAT applications see, "VSAT Technology for Today and For the Future-Part 4: Real-World Applications Prove Benefits," Communications News, January, 1988.

Delivery of television service is one important application for satellite technology in rural communications. The National Rural Telecommunications Cooperative (NRTC) presently has 560 electrical cooperative members that are interested in providing satellite cable television service to over 12M rural subscribers. Currently, focusing on one-way C-Band service at a cost of about $600-$800 per subscriber, NRTC is also considering VSAT Ku-band service for non-video digital telecommunications up to 56Kbs. NRTC reports that the costs of expanding the current cable television satellite service for two-way is prohibitive at $5,000-$15,000 per subscriber.

### 5.4 Coaxial Cable

Today, coaxial cable for local rural communications is almost completely restricted to one-way cable television service. However, many rural cable companies are owned and operated by small telephone companies. Over 478 applications have been made by telephone companies to the FCC to provide cable television service in their service area under an FCC waiver; 438 have been granted.[37]

A survey of many rural cable television systems owned by rural telephone companies found that monthly rates for service are comparable to those for dense urban areas. Telephone companies surveyed had between 380 and 13,000 basic telephone service subscribers and between 10 and 12,000 cable television subscribers. Most of the companies surveyed share telephone and cable system facilities. In many cases cable head-ends share the telephone company's switching office building; and, except for the larger systems, labor is also shared. Most operators state that they are not in the cable business to make money (in fact many made it clear that they do not make money in cable), but rather to meet their customers' demands for service.

The Community Antenna Television Association (CATA) reports that cable television penetration in rural areas is actually higher than in urban and suburban areas (estimated at over 60%). Currently rural cable television companies serve about 15 subscribers per mile of cable plant. CATA would like to see it expand to areas with only 10 subscribers per mile, but costs remain high. Some rural cable television systems rely on satellite (est. 10%) and fewer use microwave technology. Based on the amount of coaxial cable in rural America today there does seem to be potential for its use for new rural telecommunications, although at present there is none.

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[37] See David Irwin and Sara Siegler, "The Video Game Rules for Telco Players," Roundtable, Winter, 1989.

## 6.0 State Infrastructure

Today's rural telecommunications infrastructure is a patchwork quilt of subnetworks with many owners and operators, featuring a broad spatial distribution of network facilities. Though this situation may be *locally* efficient for telephone subscribers because of technical efficiency and good customer service in very diverse, thin local markets, it is probably not *globally* efficient from an infrastructure perspective. The main areas for improvement are coordinating regional communications activities; correcting inequalities in customer service options and capabilities across geographic areas of the state is also a top priority. With good coordination these problems are not necessarily expensive to overcome.

The infrastructure approach to state telecommunications planning minimizes deployment costs of advanced public networks by taking advantage of potential synergies among public and private network investments. Compatibility and easy interconnection between public and private communication networks may favor technology adoption in cost/benefit calculations for investment in public network infrastructures. Rural economic development primarily depends on attracting new business to rural areas or stimulating expansion of existing businesses; a process that is more likely to occur if preceded by a high-quality communications capability, for both internal and external use with suppliers and customers.

Part of the key to more rapid economic development in rural America is for policymakers to view telecommunications as an enabling factor in the planning equation for attracting business. The payoff for any state will be much greater if businesses drive the development process. It would be of limited value if investment in advanced telecommunications for residence subscribers were undertaken before that for business subscribers. The approach recommended herein gives first priority to investment in the shared public network infrastructure, so that wherever business may ultimately choose to locate, they will not be far from a point of interconnection to a high-speed digital public network node. The preferred window of technology deployment for high-speed digital networks for businesses is 1-5 years, while for residence subscribers it is 5-20 years, depending on location and local telephone plant characteristics. Hence, business demand drivers will ultimately speed the process of technology adoption.

The available data for rural areas indicate that there are many communication networks and facilities, some of which are quite advanced, that are not being used efficiently from an infrastructure perspective. Many private, public, and quasi-public networks have a variety of specific communications applications which could support infrastructure development for an entire state or region if efficiently interconnected to the public switched telephone network.

Other authors, noting this inefficiency, have recommended that state planning agencies be empowered to at least study infrastructure coordination, make recommendations for development, and perhaps provide expert assistance and financial support to infrastructure firms.[38] This author thoroughly agrees and recommends that such coordination take place at the state level, which is where regulatory and planning authority lies. Proper coordination and planning can generate many possibilities for relatively efficient communication infrastructure development in rural areas. Currently, pockets of advanced communication capabilities occur in private and quasi-private local networks, without due concern for how they contribute to overall infrastructure development.

For example, educational communications over fiber-optic and satellite facilities in closed networks are not interconnected to public telecommunication networks.[39] As another example, many high-capacity intercity networks use microwave and fiber-optics for large customer applications and have substantial spare capacity running through rural areas. This presents a net revenue opportunity for the owners of such networks if they were interconnected to public network facilities. Interconnection possibilities include tail-end microwave hop-on and hop-off, and fiber interconnection from urban drop-off points. However, no one is charged with the responsibility of investigating such possibilities; and in many cases the owners and operators of such specialized networks do not have the time, responsibility, foresight, or expertise to evaluate interconnection possibilities.

Because the social benefits of efficient public telecommunications networks

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[38] This is the recommendation in Parker et al., supra note 1.

[39] For a summary of education networks and systems, see Office of Technology Assessment Report, Linking for Learning, November, 1989. See also "Interactive Television: Technology Linking Rural America," OPASTCO Technical Paper No.2, December 1989. More examples of the use of fiber for interactive video learning are found in the Minnesota Educational Telecommunications System, where public education joined up with rural telephone service providers. See "Minnesota Independents Tune into Fiber Opportunities," Roundtable, Winter 1988. Rural Oklahoma's Panhandle Telephone Cooperative also provides extensive educational telecommunications on a fiber network, described recently in a talk by Gary Kennedy, Panhandle Telephone Cooperative, Inc., Guymon, Oklahoma, presented at the Fifth Conference on State Telecommunications Regulation, January 22, 1990, Salt Lake City, Utah.

exceed the sum of private benefits, the initiative to bring together public and private interests must come from the government. Recent experience with private sector competition and telephone deregulation indicates that the public telecommunications infrastructure is increasingly fragmented due to the proliferation of private networks utilizing a host of technologies and due to the incompatibility of proprietary devices, interfaces, and protocols. In this setting, private industry groups are slow to reach agreement on infrastructure issues such as standards, interconnection, and public network efficiency. This is understandable because much of the private networks represent a large, as yet unrecovered, investment in proprietary communications systems.

However, businesses do understand the importance of efficient end-to-end service capability using both public and private network facilities. They would be receptive to public initiatives to coordinate and plan for infrastructure development, which would include setting specific timetables, and establishing efficient processes for creating network standards and trials for new technologies stressing easy interconnection and interworking (interoperability across vendor equipment and network facilities). An example of such a public initiative, albeit one for mostly urban applications, is the recent New York State Department of Public Service plan for ISDN development.[40]

The rapid pace of technological change affects many new alternatives for development of rural communication infrastructures which heretofore would not have been considered. Two very important developments of particular interest are: advances in high-powered satellite and radio communications (including cellular service), and the introduction of digital fiber-optics. As previously stated, satellite and radio services are now available to fill in many gaps in infrastructure development, especially where geographic topology presents a barrier to cost-effective wireline communications.

The implications for infrastructure development are much more profound in the case of fiber-optics. For the first time a dielectric, low-cost, high-capacity, reliable communications medium is available to support the future communications requirements of rural America.

Due to its revolutionary nature as a new communications paradigm, many telecommunications engineers overlook the potential of fiber optics for rural

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[40] The ISDN Trial in New York State, The New York State Public Service Commission, Report, March 15, 1990.

applications. The same is true of many radio applications.[41] Even though costly to deploy for much of the rural loop plant, the use of fiber optics in shared plant facilities is more cost-effective than most alternative technologies whenever two-way real-time service is required. Two-way real-time capability is central to advanced telecommunications. The major cost factor for fiber-optics, as with most wireline technologies, is trenching for underground cable and conduit, which is generally preferred to aerial construction, because of aesthetics, extension of service life, and reduction of maintenance costs. Since trenching is so expensive it may be avoided by less expensive construction methods like direct burying, plowing, or aerial construction. This type of construction will not present a burdensome cost compared to similar installation costs of traditional copper- pair cable.

The problem cost and major expense at this time is the optical/electronic interface equipment at the ends of the circuit, especially at the subscriber end. Fiber-optic cable splicing and electronics costs are relatively high, but rapid progress in reducing such costs continues, and probably will not be a limiting factor over the long term.

The use of a dielectric transmission medium, such as fiber-optics, provides an unprecedented opportunity for inexpensive infrastructure development by taking advantage of new-found synergies of combining existing electric utility distribution infrastructures with that 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 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.[42] The ground wire in the cable supports the requirements of electric utilities, and the fiber communications capacity may be resold.

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[41] Some of the aversion that rural telephone companies have to delivering POTS via electronic carrier frequency is probably due to the fact that, in years past, some service was provided on buried cable loop carrier which performed poorly. Such memories of service failure die hard. The other reason is that an unfamiliar loop technology causes craft persons to be uncomfortable with it, and their lack of training increases its maintenance costs.

[42] See Charles R. Russ, "Composite Optical Groundwire-Design & Economic Considerations," unpublished paper, Alcoa Fujikura Ltd., June 7, 1988.

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-cost 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 choosing to locate in rural areas are often able to get sufficient power, while advanced communications capability is lacking. If the shared infrastructure were available, business might be more likely to locate and expand in rural areas.[43] Safety communications for fire and alarms are other new service applications which place 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. To help spur such cost-efficient developments, the Electronic Power Research Institute is beginning to develop industry standards.

Rural telephone companies, long desirous of entering directly into the lucrative toll market, could begin to take advantage of the revenue opportunities that a fiber-optic infrastructure could provide, not to mention the possibilities for providing new data and video services which fiber-optics could support. This is very important if it is true that traditional large telephone company toll subsidies enjoyed by small rural telephone companies will eventually 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 backbones may also allow rural subscribers to purchase digital services and access remote databases of enhanced service vendors.

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

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[43] Such real-world considerations were expressed by Ralph Minor of Pal Valley Electric Coop in Jonesville, Virginia; a small but widely-dispersed rural utility (private correspondence).

of all subscribers. In the early stages, such coordination will concentrate on surveying all of the communication facilities, public and private, and evaluating short-term 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 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 of 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 allow for 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. The following is one example of how this type of planning may begin for the state of Kentucky.

### 6.1 Kentucky

The Appendix to this report shows the existing various infrastructures for Kentucky (except for gas and water companies). Maps are provided for: public power grid, highways, railroads, telephone company switching offices, regional airports, and tertiary schools. The maps indicate that there are many logical possibilities for location of network nodes for infrastructure planning. There are also 123 hospitals and numerous public libraries which also may be candidates for network node points. As the Appendix makes clear, almost all regions of the state have some reasonable proximity to one or more node point candidates. Thus no business customer, even in rural areas, would necessarily be very far from a high-capacity digital public network access point. This is important as it more easily cost-justifies private construction of digital access facilities by business subscribers. It would be very difficult generally to justify any public subsidy of business subscriber access lines for new digital service, so it becomes important for the shared public network to be available for access at reasonable private costs.

Already existing are several private and quasi-public communication networks deployed throughout various portions of the state. Although many of them are used for specialized purposes and may not be compatible networks, state planners can at least monitor the situation to identify synergies which may be exploited at minimum marginal cost. Installation costs for fiber-optic transmission facilities are quite low when rights-of-way and towers, poles, or conduit already exist, which is the case for many locations on the public power grid. The distribution infrastructure for electricity in rural areas is ripe for supporting deployment of new communication facilities. In thin rural markets, spare infrastructure capacity may be utilized for the mutual benefit of power companies-- who may lease distribution system access and use new communication transmission capacity-- and telecommunication service providers, who cannot otherwise justify the costs of providing advanced telecommunication services in such thin markets.

## 7.0 Regulatory Implications and 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 obviously are 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. 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. This is where the role of state government may be most helpful, identifying where public and private communications network activities may complement each other 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, considered a rural state, there are many existing locations which could generate enough traffic demand to justify a fiber, radio or satellite hub, depending on the specific demand application(s) required. 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 cost-effectively deployed, 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 ones 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 flows generally 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 towards only those companies that need it most instead of towards entire classes of small companies as is currently the case.[44]

**8.0 Financing Alternatives**

[44] See Fuhr, supra note 13.

The costs of the deployment of efficient communication infrastructures are high compared to any historical measure of the costs of technology adoption. The reasons are two-fold: the technological trends are: 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 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-effectively introduce it 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, under the traditional finances of telephone utilities, it appears likely that internal capital flows will fund much of infrastructure deployment costs. Borrowing is the next alternative to consider. The U.S. Department of Agriculture's Rural Electrification Administration (REA) and Rural Telephone Bank (RTB) 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. There are other major sources of funds for telephone companies besides the Department of Agriculture, including Banks for Cooperatives (part of the Farm Credit System), Rural Telephone Finance Cooperative, and the National Cooperative Bank.[45]

Unlike large telephone utilities, many rural companies are already highly leveraged. This is not bad in and of itself, but 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.

REA, RTB, and some other lender practices are basically sound for financing advanced rural telecommunication infrastructures because they operate within an incentive structure which tends to give the right signal to borrowers to make good investments. REA and RTB use "equity-based" financing and loans that are usually

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[45] See "Financing Telco Growth," Roundtable, Fall 1989.

"self-liquidating". Furthermore, 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 REA 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 revenues 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 untargeted ones, would be much worse and often are 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.[46] 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 REA's loan authority or could be distributed based on financial need. Whenever subsidies are not targeted there are potentially wasted resources. The introduction of basic telephone "lifeline" service based on a "needs" (income) test is a good example; this has proven to be much more socially efficient than a blanket subsidy for all local service subscribers, even for those who 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 revenues and should therefore always be included in any loan repayment formula, even if the repayment is only a partial one.

There are many other market-based financing possibilities, including revenue growth from existing and new services and advertising. Advanced rural telecommunication networks will be able to support a whole range of new services and lines of business for telephone companies. The most lucrative is toll and toll access services. Many rural companies rely largely on other vendors to supply toll and access services, including measurement and billing, for their local service customers. The high-capacity of digital fiber-optics is changing this situation dramatically. Now many small rural telephone companies can share fiber-optic facilities to begin to provide toll and

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[46] See Fuhr, supra note 13, for a discussion of the subsidy flows in the current revenue sharing system. There is little correlation between costs, financial need, and subsidy flows, and no targeting mechanism exists in the current formula.

access services. There are already many such operating arrangements.

Another potential high-growth market which digital rural telephony makes possible is data and computing services, including remote database access, transaction services, audiotex and videotex, shopping-at-home, etc. Ultimately revenues from providing entertainment video on fiber-optic subscriber lines will be possible.

Another revenue opportunity which rural telephone companies realize from new digital technology is advertising and tele-marketing revenue. Vendors wanting to efficiently tap the purchasing power of rural consumers will be willing to pay for access to that market segment. Due to expanded bandwidth on residential phone lines, advertising need not tie up the entire line. Shopping over the phone can occur along with normal voice conversations using ISDN technology. In some novel advertising techniques, rural customers willing to let vendors advertise products which interest a particular household, would actually receive a monthly subsidy from the vendor(s), reducing their phone bills. One such advertising technique is called "Phone Spots", where local telephone subscribers agree to let very short advertising messages be transmitted between rings of the telephone so as not to disrupt the telephone call itself.[47]

## 9.0 Conclusions

The key to rapid adoption of advanced technology for rural telecommunications 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. The infrastructure approach 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

[47] Phone Spots, Inc., P.O. Box 156, Weston, MO 64098.

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 the generally the most cost effective technology for shared network service applications. Fiber is not cost effective for dedicated (non-shared) customer facilities, like residential loops. 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, multi-media 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.

## APPENDIX-KENTUCKY INFRASTRUCTURE

CHART 1--County Map

CHART 2--Telephone Company Central Office Switch Locations

CHART 3--Electric Power Grid

CHART 4--Railroad Lines

CHART 5--Interstate Highways and Parkways

CHART 6--Airports

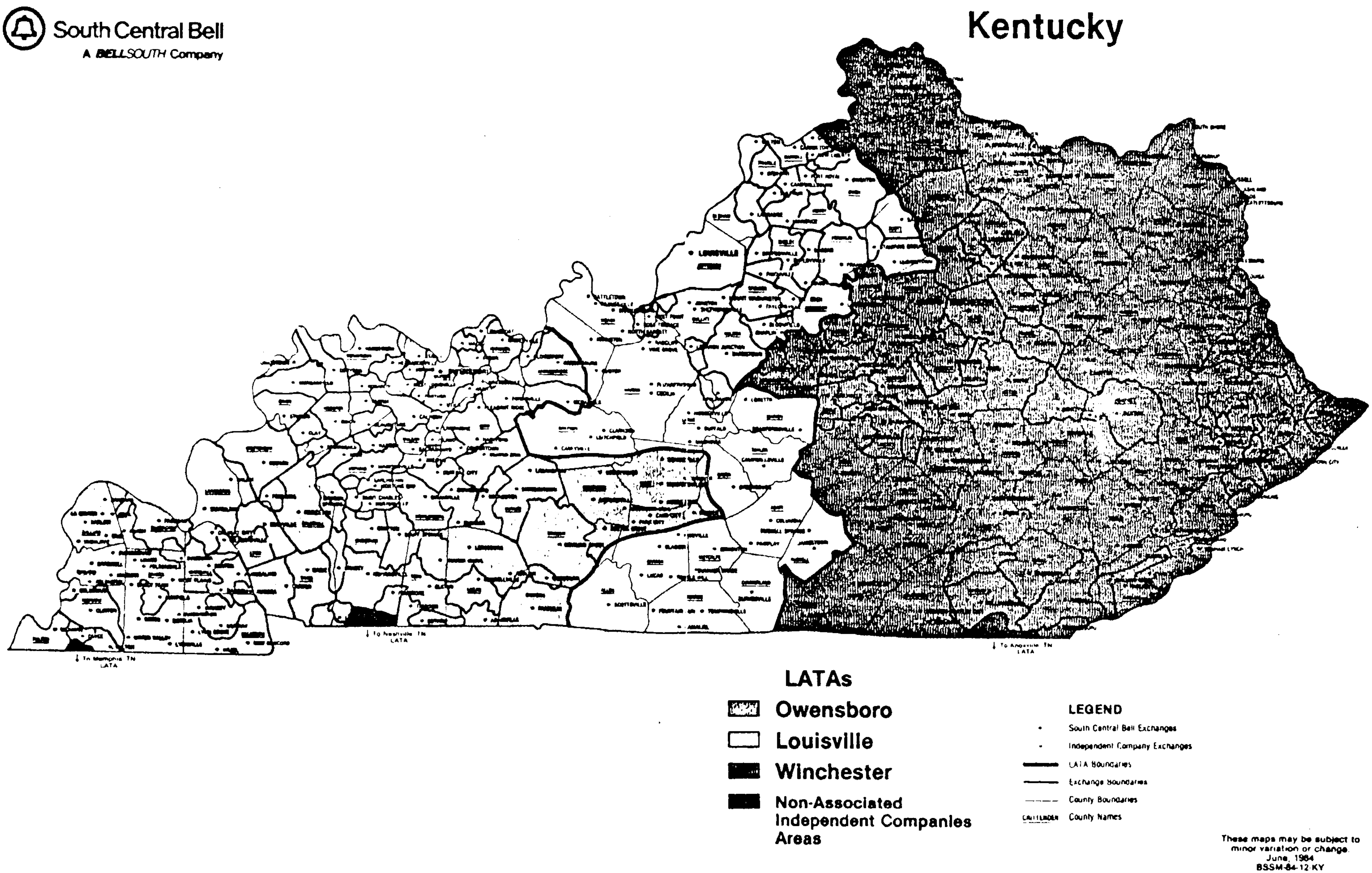
CHART 7--Colleges and Universities

Chart 1

# KENTUCKY


U. S. DEPARTMENT OF COMMERCE
BUREAU OF THE CENSUS

Chart 2



South Central Bell
A BELLSOUTH Company
Kentucky
LOUISVILLE
To Memphis TN LATA
To Nashville TN LATA
To Knoxville TN LATA
LATAs
Owensboro
Louisville
Winchester
Non-Associated Independent Companies Areas
LEGEND
South Central Bell Exchanges
Independent Company Exchanges
LATA Boundaries
Exchange Boundaries
County Boundaries
County Names
These maps may be subject to minor variation or change.
June, 1984
BSSM-84-12-KY

Chart 3

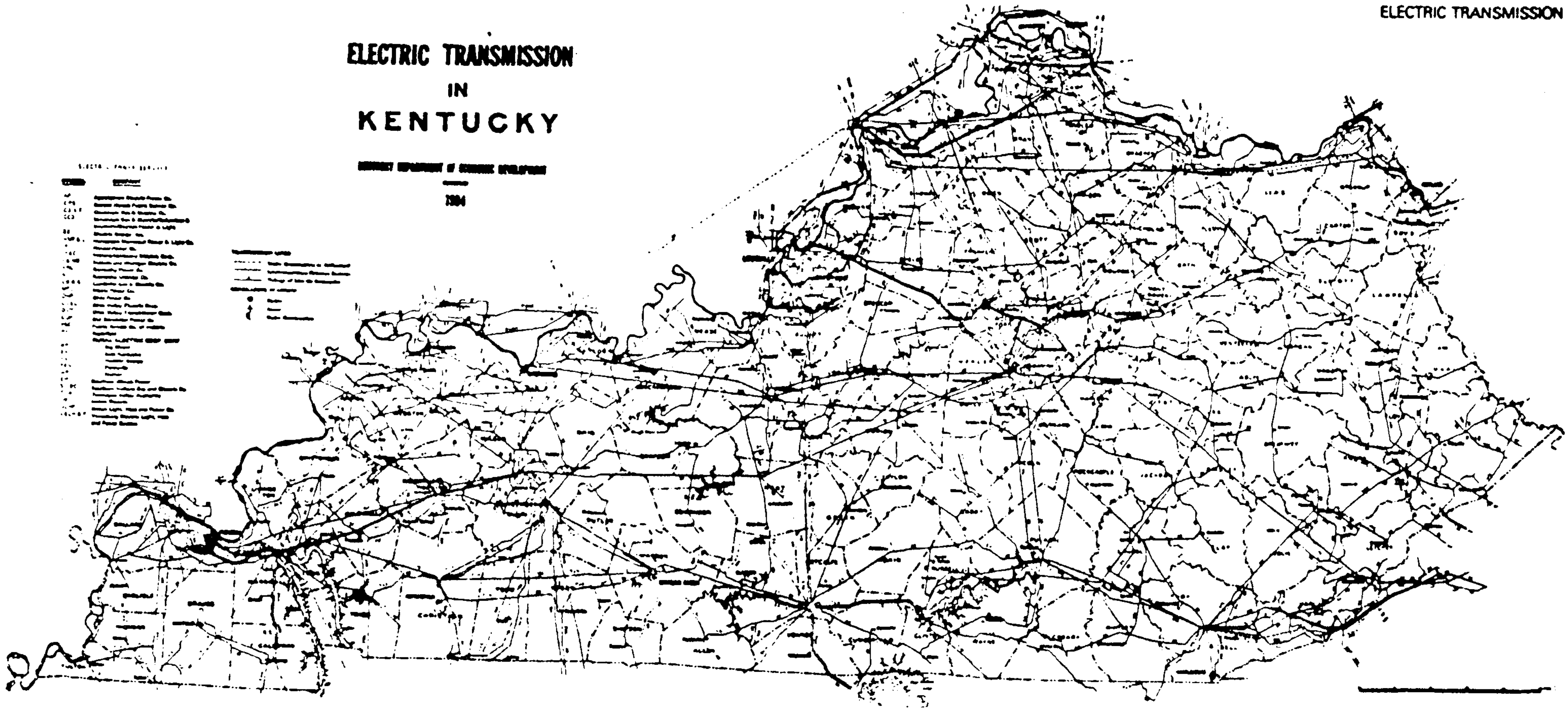

ELECTRIC TRANSMISSION
IN
KENTUCKY
ELECTRIC TRANSMISSION

Chart 4

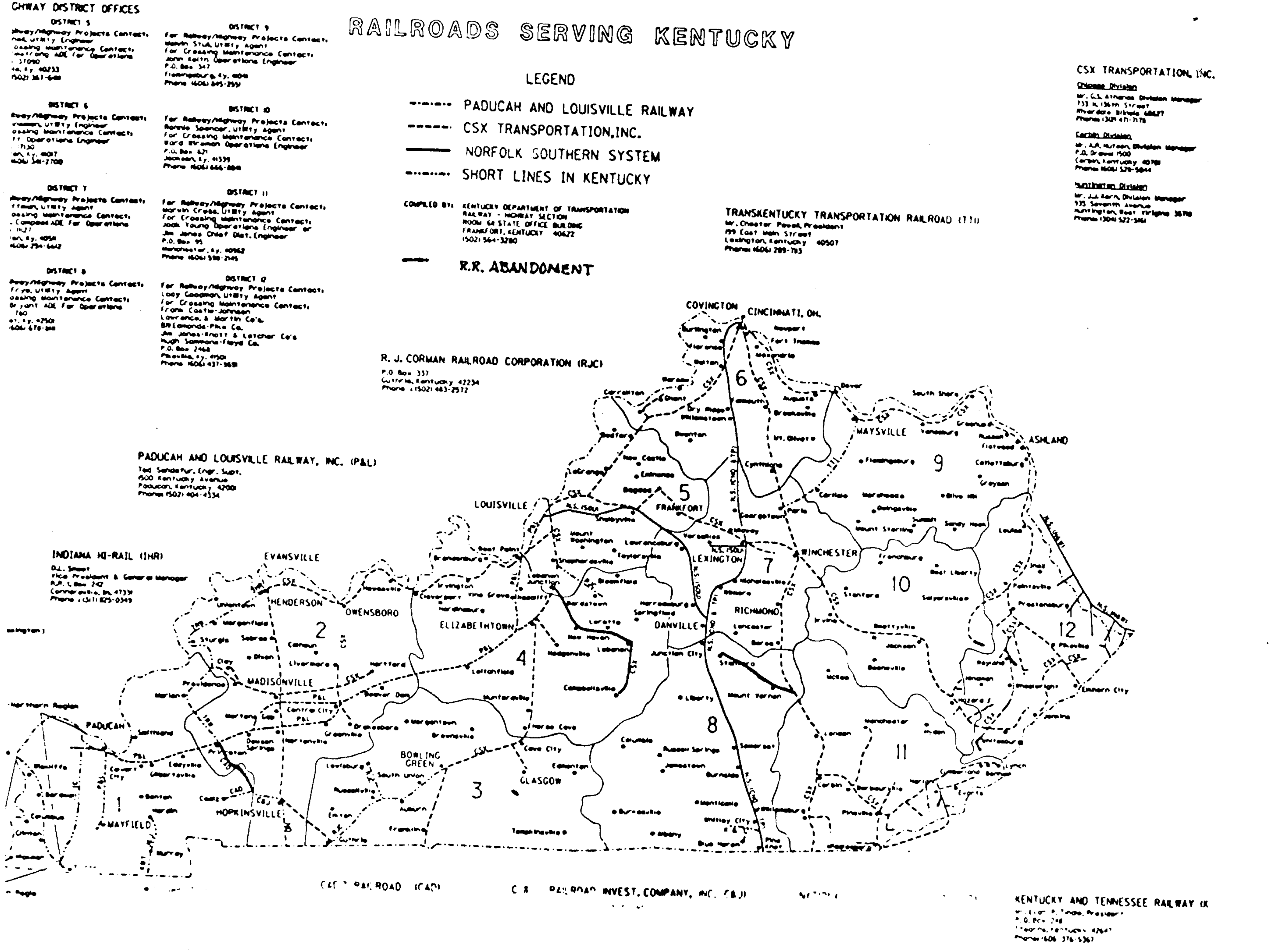
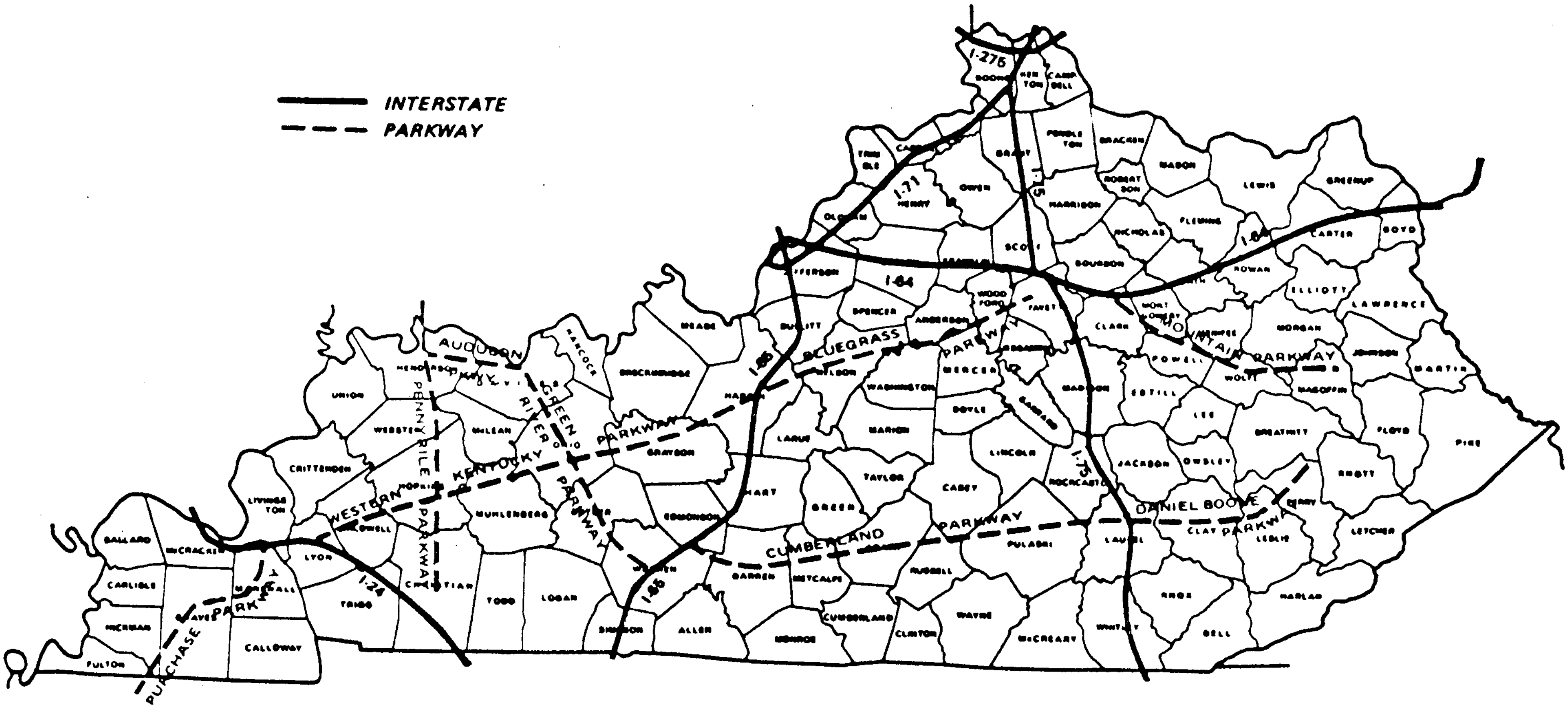

RAILROADS SERVING KENTUCKY
LEGEND
PADUCAH AND LOUISVILLE RAILWAY
CSX TRANSPORTATION, INC.
NORFOLK SOUTHERN SYSTEM
SHORT LINES IN KENTUCKY
R.R. ABANDONMENT
COMPILED BY: KENTUCKY DEPARTMENT OF TRANSPORTATION
CHWAY DISTRICT OFFICES
CSX TRANSPORTATION, INC.
TRANSKENTUCKY TRANSPORTATION RAILROAD (TTI)
R. J. CORMAN RAILROAD CORPORATION (RJC)
PADUCAH AND LOUISVILLE RAILWAY, INC. (P&L)
INDIANA HI-RAIL (IHR)
KENTUCKY AND TENNESSEE RAILWAY (K
COVINGTON
CINCINNATI, OH.
MAYSVILLE
ASHLAND
LOUISVILLE
FRANKFORT
LEXINGTON
WINCHESTER
EVANSVILLE
HENDERSON
OWENSBORO
ELIZABETHTOWN
DANVILLE
RICHMOND
MADISONVILLE
PADUCAH
BOWLING GREEN
GLASGOW
HOPKINSVILLE
MAYFIELD
1
2
3
4
5
6
7
8
9
10
11
12

Chart 5

# KENTUCKY'S INTERSTATE HIGHWAYS AND PARKWAYS



## COMMERCIAL AND COMMUTER AIRPORTS SERVING KENTUCKY

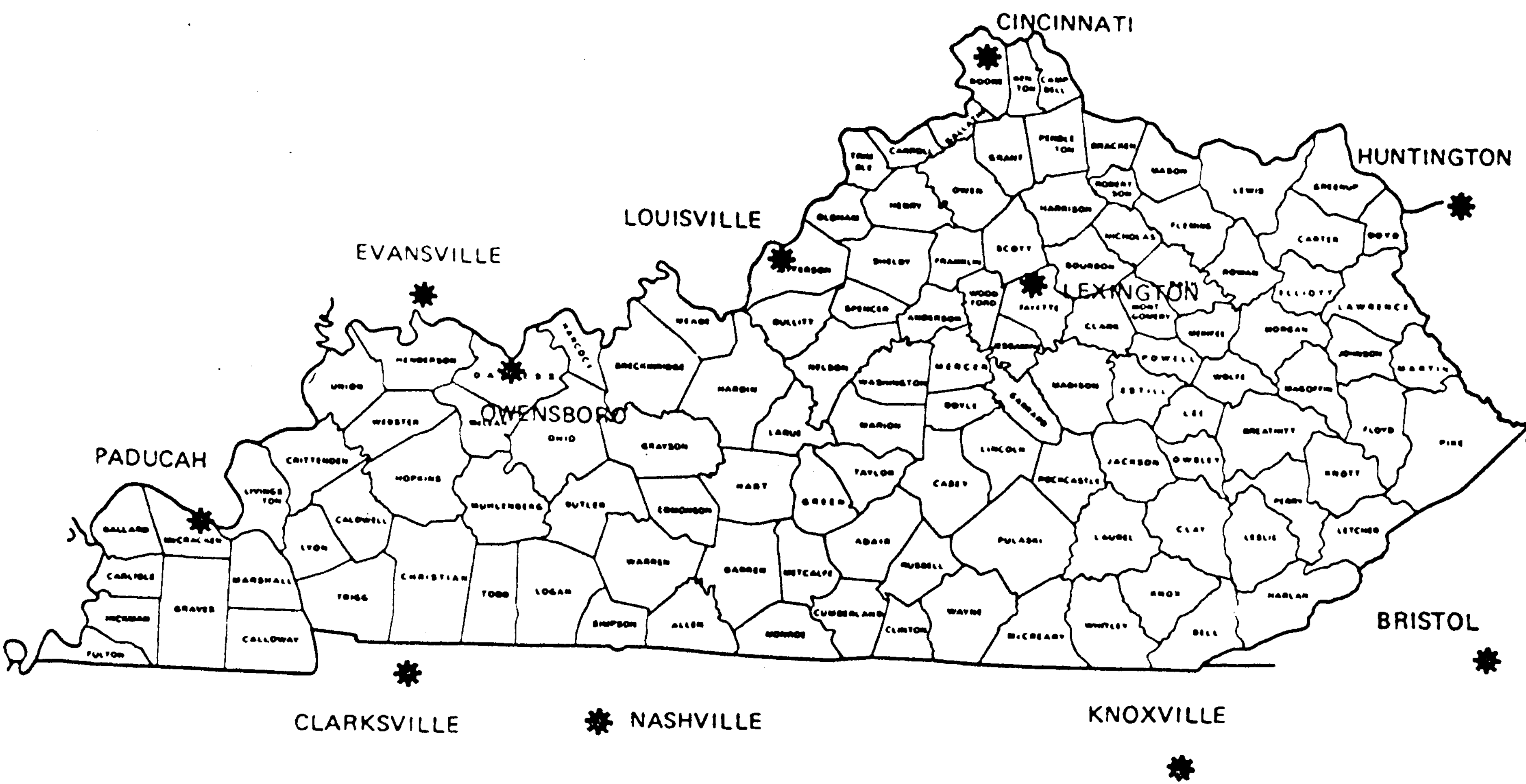


Chart 7

# KENTUCKY COLLEGES AND UNIVERSITIES