NRRI 90-16

AN ANALYSIS OF A PORTION OF THE COST OF CONVERTING A LOCAL TELEPHONE UTILITY NETWORK INTO A NETWORK CAPABLE OF DELIVERING BROADBAND AND CABLE TELEVISION SERVICES TO ALL SUBSCRIBERS

October 18, 1990

A Report to The National Regulatory Research Institute

Prepared by

Julia A. Miezejeski
Michael Miller
Bruce L. Egan

Northern Business Information/Datapro
a Division of McGraw-Hill, Inc.
157 Chambers Street
New York, N.Y. 10007-1015

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FOREWORD

The public policy debate over whether telephone utilities should be allowed to provide cable television services has largely centered on cross ownership and market dominance issues. However, another important issue, the cost of converting a public switched telecommunications network into one capable of delivering the full range of broadband and cable television services, has received less attention.

Because of the variety of the broadband network design options available to telephone utilities, state commissions have a need for a reliable framework that can be used to identify the broadband deployment option being implemented by a utility and the cost of the option. This report by Northern Business Information/Datapro will allow a commission to identify options and costs.

Of course, the NRRI, NARUC, or NARUC member states do not necessarily endorse the particular costing method employed in the course of this study. The NRRI feels, however, that the simple engineering cost model used is a reasonable model and provides a benchmark that can be used by other cost studies. Further, the analysis herein does not necessarily assume or favor any particular ratemaking method. We appreciate the supplementary financial support for this project provided by the Center for Advanced Study in Telecommunications of The Ohio State University.

Douglas N. Jones
Director
NRRI
Columbus, Ohio
October 1990

EXECUTIVE SUMMARY

The costs of achieving broadband communications capability for residential customers on the public telecommunication network is substantial; to some, astronomical is the more appropriate term. Most of the costs (50-90 percent) are caused by upgrading the dedicated portion of subscriber loop plant to fiber optics and the opto-electronic equipment required to make it work. Fiber-to-the-Home (FTTH) systems cost anywhere from $1,500 to $15,000 per residential customer, depending on various factors, such as subscriber density, system features, and service capability. This puts the total cost of ubiquitous FTTH in the range of $100-$1,000 billion. The median of all system cost estimates for FTTH is in the $3,000 range for the early 1990s. Fiber-to-the-curb (FTTC) systems, which save money by utilizing copper and coaxial cable facilities of the last segment of subscriber loop plant, are between one-third and one-half the cost of FTTH. This represents a per-subscriber cost that is about equal to average costs of new telephone company copper-pair loops. These costs represent rather simple systems, which basically provide integrated loop functionality duplicating the current capability of plain old telephone service (POTS) and traditional one-way video or cable television service. However, these systems do allow for brand new two-way, high-speed service offerings at minimum additional costs such as videotex, high-speed data and fax, imaging, shopping at home, distance learning, telecommuting (working at home), and new multimedia services.

Both telephone and cable television companies see two-way broadband networks as a strategic advantage as they compete for new telecommunications service markets in the future. Interestingly, even though current telephone and cable company networks differ greatly in cost structures, both would incur substantial additional costs for FTTH or FTTC systems that provide two-way service. Since the costs of achieving broadband network capability are so high, it is important that the public network evolve in such a way as to minimize the overall cost to network subscribers. This study provides evidence of the costs of residential broadband service and provides a generic model to identify and classify the costs of various broadband systems. The purpose is to assist regulators in their efforts to

monitor and evaluate the costs of broadband investments to public network subscribers.

Costs of current fiber-in-the-loop (FITL) deployment strategies and patterns are presented and evaluated. Current broadband trial costs and vendor equipment costs are very high as they represent prototype (as opposed to production) costs. As such, these costs are not representative and should be discounted regarding the mass market. A simple generic broadband subscriber loop design is presented, which identifies the various categories of costs for various broadband systems. Estimated production costs are also given, and may be used by regulators to gain an understanding of the structure and level of prospective broadband network investment costs.

There are basically two primary generic network architectures that subsume all anticipated systems: FTTH and FTTC. Beyond these are two fundamental underlying technological distinctions for delivering the various services (using both digital and analog signals): passive systems (nonswitched) and active systems (switched). Passive network systems usually employ a "bus" architecture typical of cable television plant, and active systems usually employ "star" architectures typical of telephone networks. Beyond this, many variations on system design use novel combinations of passive and active systems and architectures, such as single, double, and triple star. Traditional "bus" architectures, such as cable television networks, used "tree-and-branch" architectures, while traditional star networks resemble "hub-and-spoke" architectures. However, new "ring" architectures allow for various hybrid "bus" and "star" technologies, especially since the relatively new method of "wave division multiplexing" was introduced. This allows a convenient method of "channelizing" a single broadband subscriber loop (coax or fiber) to provide simultaneously a mix of high-quality narrowband and broadband services.

The results of this analysis indicate that it will not be difficult to track and assign well over 50 percent of the construction costs of local exchange carrier broadband subscriber loop plant. The reason is that most of these costs involve nontraditional technology in the dedicated portion of subscriber loop plant (for example, the coaxial and fiber distribution and drop cable) and loop electronics specifically required to convert optical to electronic signals and vice versa. Such facilities simply are not required for traditional telephone service and are, therefore, the responsibility of nontraditional services. The remainder of cost monitoring, tracking, and assignment will be more difficult as they represent joint costs of shared trunk and switching plant for both traditional and nontraditional services. Nevertheless, this is the challenge, and some recommendations for identifying and classifying such costs are contained in Chapter 1.

CHAPTER 1

INTRODUCTION

Increased competition within traditional lines of business has inspired the local exchange telephone companies to diversify and seek new sources of revenue. One area that draws considerable interest is the cable TV industry. However, the telcos face legal restrictions barring them from operating cable TV networks.

Prohibitions in the 1984 Cable Communications Policy Act prevented the regional bell operating companies (RBOCs) from operating cable TV networks. Recently, both federal and state regulators have begun to reconsider these restrictions. The costs of new fiber-based networks capable of providing cable TV services will play a vital role in the debate. Equally important are the costs associated with other broadband services, apart from cable TV. Telcos are eager to exploit opportunities selling other broadband services such as video-on-demand, home banking, and home shopping. From an operations standpoint, once a broadband network is in place, telcos would then package existing narrowband services--plain old telephone service (POTS) and low-speed data--together with the broadband delivery to customers.

Traditionally, investment decisions by telecos and cable TV operators alike were made in a monopoly environment dominated by issues of service quality, cost savings, and capital recovery. Unlike investment decisions of the past, future investment decisions will be made in an increasingly competitive environment.

No doubt, both LECs and large cable TV operators view aggressive deployment of fiber as a strategic advantage. "Whoever gets more fiber in the ground first, wins!" seems to be the prevalent thought process in the telecom community.

Despite current regulatory and legal restrictions, telephone companies see that installing high quality, high capacity fiber in the network will position them to meet the future needs of large customers and third-party vendors whose services currently cannot be provided by telephone companies directly. What's more, telephone companies believe that in the near future, fiber lines will be cheaper to install and maintain, and will provide clearer connections for voice conversations. Underlying these plans for generating new revenues and cutting operating costs is the reality that hundreds of billions of dollars must be spent to convert today's United States local phone system into a full fiber-optic network. Clearly, this will be the largest construction project ever undertaken by the telco community.

Cable TV operators see the telephone companies as a serious competitive threat as potential entrants into the cable television business. They face a bitter fight to maintain their local cable television monopolies. Like some telcos, cable operators are intent on expanding and envision intercity video distribution using fiber optics to provide the programming requirements for several local systems.[1] This could enable cable television's penetration in the telecom business for internode transport and ultimately to connect end-users. Cable TV firms also have growth strategies that call for diversification through new service applications. They are upgrading their networks with fiber in anticipation of this growth. If cable television is first with ubiquitous fiber installations, widespread bypass of telephone company local facilities will be likely.

A clear cost structure, segmented by service offerings and by network configurations is needed to formulate responsible public policy for the telephone and cable TV industries. For policy makers, the need for a generic costing mechanism is urgent. Telcos and cable TV operators are now considering several strategic plans for building broadband networks. These service providers have remained flexible in their network planning. Recently, the RBOCs chief network planners at Bell Communications Research (Bellcore) endorsed a residential broadband architecture that is a radical departure from the architecture that Bellcore endorsed previously.[2] In this fluid environment, the purpose of this report is to develop a framework to identify and analyze costs associated with the specific construction alternatives that a LEC could pursue to provide cable TV services and other broadband services.

The remainder of this chapter will provide an overview of subscriber loop architectures, network evolution and telephone company fiber loop trials.

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1 "Kahn Plans All-Fiber Overbuild in N.J.," *Cablevision*, October 12, 1987.

2 Special Report SR-TSY-001681, Issue 1, June 1980.

Subscriber Loop Architectures

Currently there are about sixteen different subscriber loop architectures being considered by the telephone and cable TV industries. Each of these can be grouped into three general categories: fiber-to-the-home (FTTH), fiber-to-the-curb (FTTC), and fiber backbone networks. Figure 1.1 provides a basic view of a telephone company local network architecture for FTTH. Figure 1.2 represents a similar view for FTTC. We will limit our descriptions to the most dominant architectures within each category.

Fiber-to-the-Home

Fiber-to-the-home is characterized by the use of fiber-optic facilities (shared and dedicated) in the construction of the loop portion of the network to the subscriber's home. The first FTTH installations were deployed in traditional "star" architectures whereby service is provided on equipment dedicated to a single customer. Telcos began using the star technology because it allowed them to use the existing distribution equipment offered by suppliers and was consistent with their installed base and operating and engineering expertise. For example, AT&T's switched-star architecture fits well with its SLC Series 5 subscriber loop carrier system, which has been installed widely by all RBOCs since the early 1980s.

Single Star Architecture

The single-star architecture uses dedicated fiber-optic facilities from the central office all the way to the subscriber's home. The only resource that is shared is the central office. Figure 1.3 shows the network components utilized in a single star architecture.

Double-Star Architecture

When multiplexing equipment is introduced to the system at remote terminal sites, the architecture becomes a double star. Some resource sharing is provided at the remote terminal (the serving area interface or SAI), where optical signals are

FTTH TRIAL TOPOLOGY

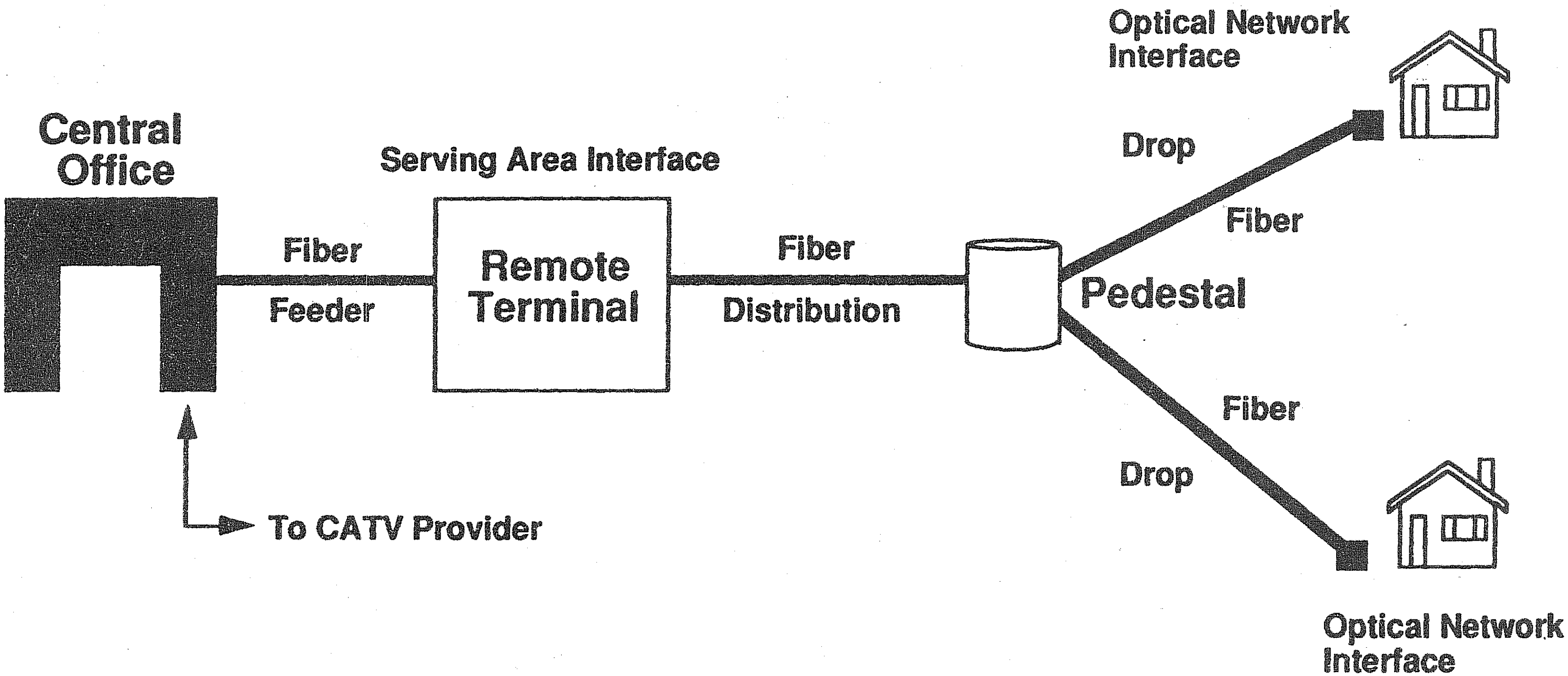

Figure 1.1
Fiber-To-The-Home

FTTC TRIAL TOPOLOGY

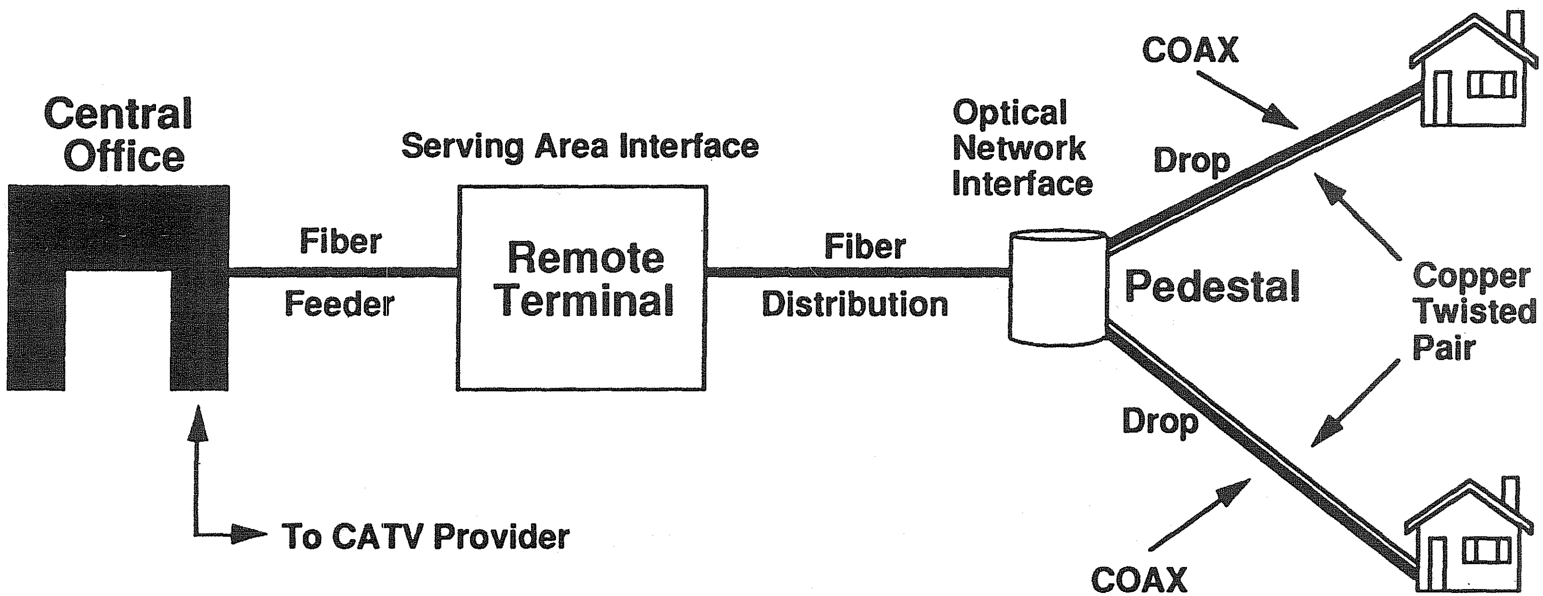

Figure 1.2
Fiber-To-The-Curb

Single-Star Architecture

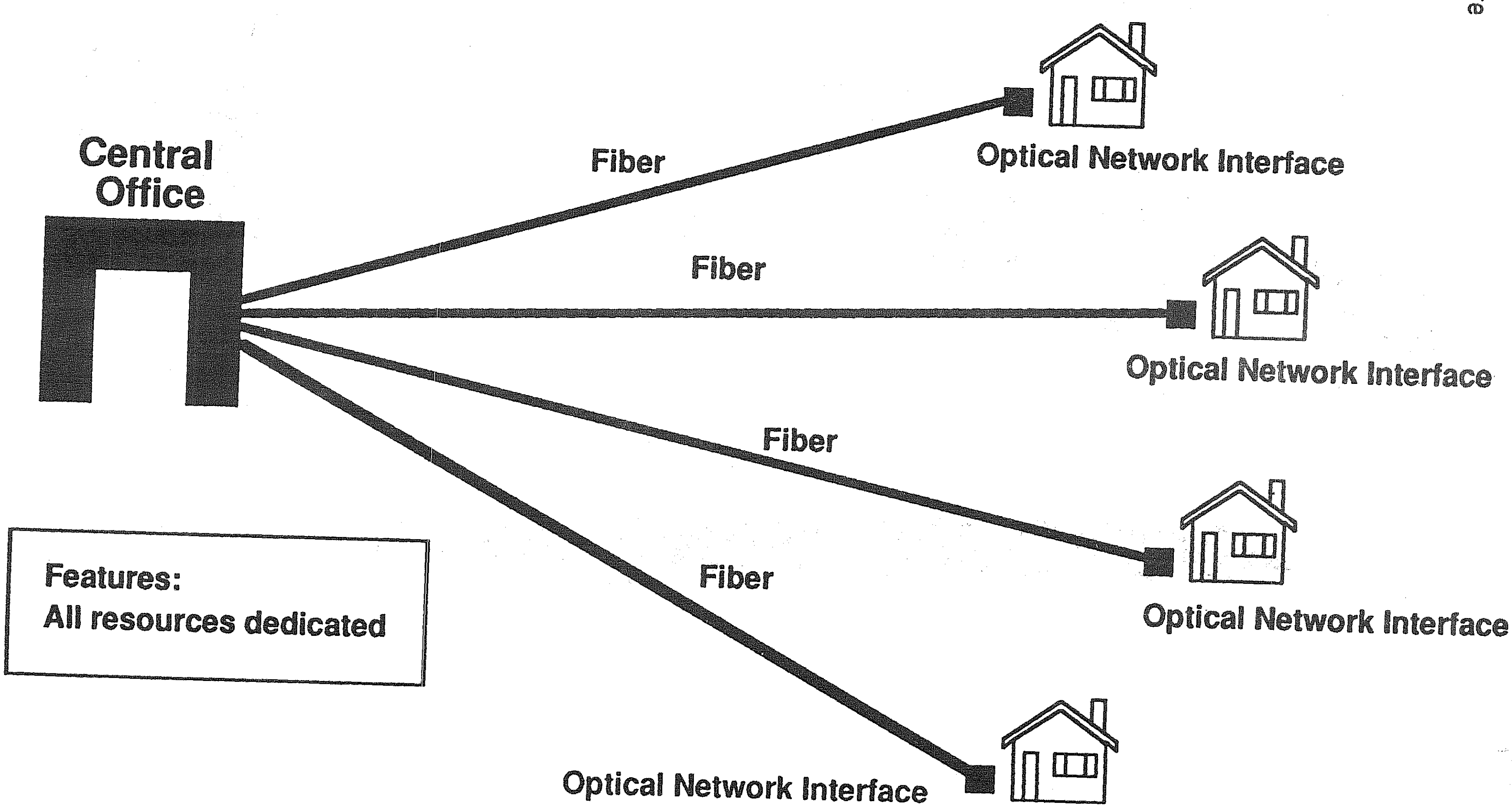

Figure 1.3
Single-Star Architecture

multiplexed from each home.[3] In state-of-the-art loop architectures, the multiplexing equipment at the serving area interface usually consists of a group of digital loop carrier systems. Figure 1.4 provides a simple view of the double-star architecture, which is also referred to as an active (switched) double star. Passive optical networking (PON), a new technology currently being studied by several telephone companies, offers higher levels of resource sharing and a cost-effective means of upgrading to broadband services. Higher levels of resource sharing are achieved when one channel becomes multiple shared channels through lightwave signal splitting. Additional channels can be allocated among subscribers as needed.[4] This technique uses fiber splitters, optical couplers, and/or wave division multiplexing (WDM). An example of passive optical networking is illustrated in figure 1.5, which shows Bellcore's passive photonic loop architecture. This arrangement is capable of POTS and cable television-type service on a single fiber optic access line. Wave division multiplexing techniques may be used to provide an analog broadband service capability while at the same time providing narrowband digital or analog POTS. WDM uses electronics to "channelize" a single fiber loop, allocating bandwidth within the same physical facility to each type of customer service as required. This architecture is also referred to as a passive (nonswitched) double star.

Fiber to the Curb

Fiber-to-the-curb architectures are characterized by the presence of fiber facilities from the central office to the pedestal. With FTTC, the pedestal is the point at which the fiber is terminated and the copper or coaxial cable begins distribution.

The "last mile" (slang for the last segment or dedicated subscriber loop portion) of distribution cable, opto-electronic conversion and subscriber electronics represent the major costs associated with FTTH. By contrast, with FTTC, opto-electronics are shared at the pedestal by at least four homes (rather than dedicated to each individual subscriber as in FTTH). In addition, FTTC drop cables

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[3] Mary C. Henry and Daniel F. Zinsser, "The Telescope: Telecommunications Equipment Trends and Directions," Goldman Sachs Investment Research (March 1990), 9.

[4] Ibid., 17-19.

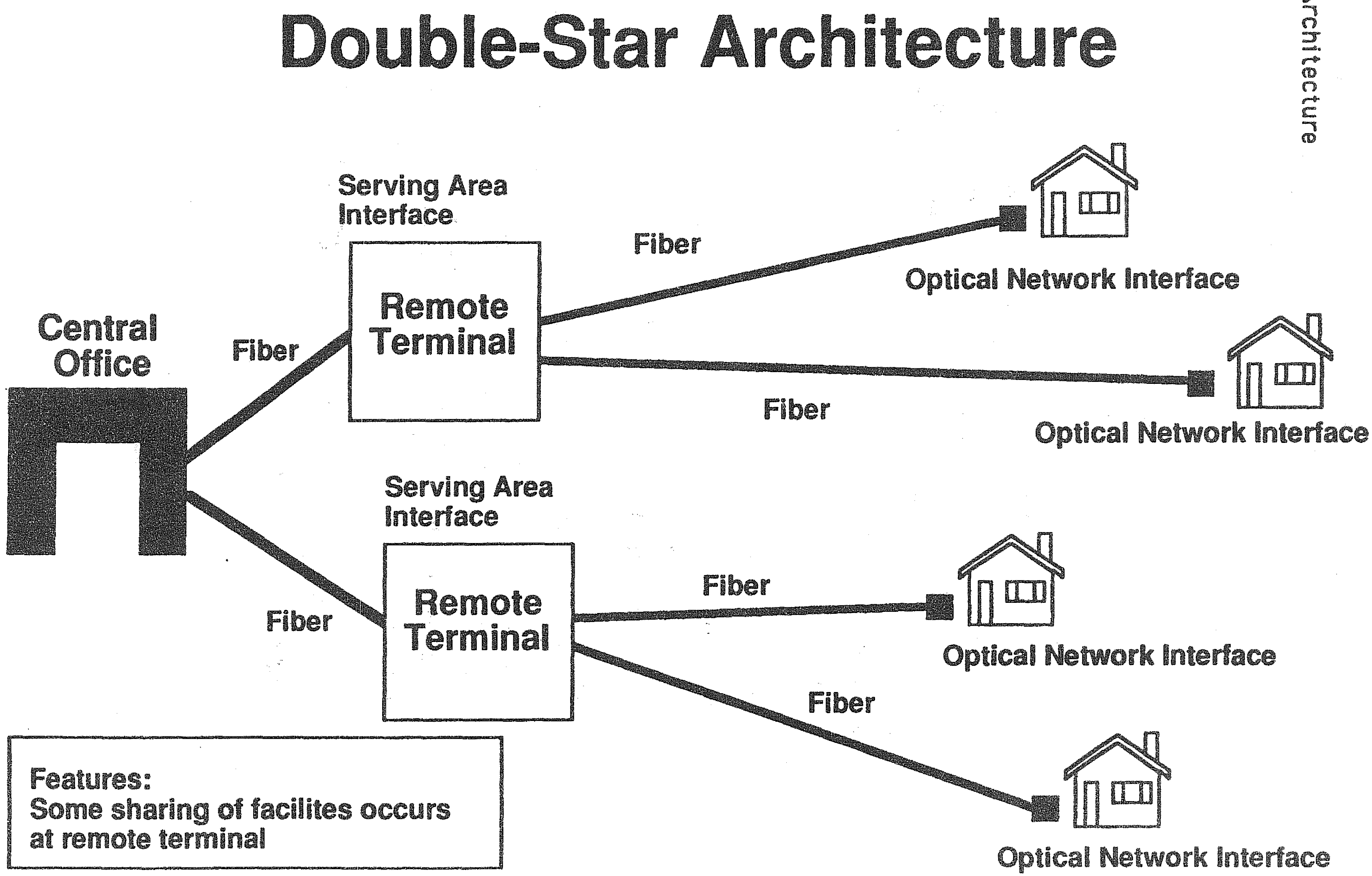
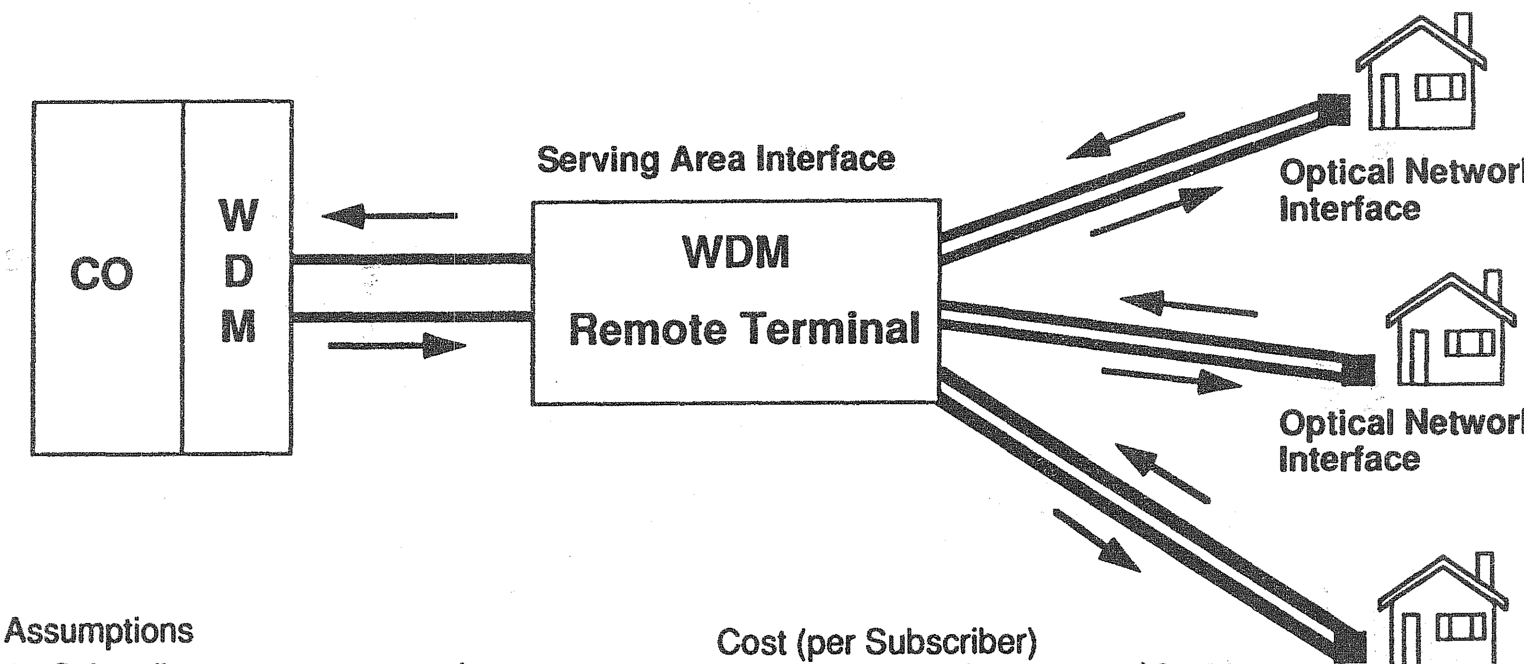


Figure 1.4
Double-Star Architecture

Figure 1.5
Passive Optical Networking

Advanced Fiber-To-The-Home



Assumptions

16 Subscribers per remote node

Services include:: POTS, 2-way data and video conference, 1-way 4 channel video and video database

* Bellcore Passive Photonic Loop

Cost (per Subscriber)	
Serving Electronics	$2,000
O/E, E/O	700
WDM	250
Drop and Distribution	400
Feeder	200
Other	300
Total	$3,850

from the pedestal to the home are either copper or coaxial cable rather than fiber. The most popular FTTC architectures in telephone company trials today are the triple-star and bus.

Triple-Star Architecture

This FTTC system employs a triple-star architecture where fiber runs to the pedestal and standard twisted pair copper cable runs from the pedestal to as many as four homes.[5] Certain phone companies view this architecture as most beneficial for rehabilitation projects and short loop constructions. The increase in resource sharing in triple-star installations will drive the cost per subscriber down closer to today's copper based installations. The triple-star architecture is depicted in figure 1.6.

Bus Architecture

The bus architecture is the most popular (and economical) FTTC system for narrowband applications. The Raynet loop optical carrier (LOC) system is being trialed by Ameritech, BellSouth, and NYNEX. One bus will support as many as 192 subscribers. However, original telephone company construction will support a lower number to provide for growth and additions. Skepticism prevails in the industry over whether this design can be easily upgraded to FTTH or to two-way broadband capability.[6] Figure 1.7 displays the bus architecture. The bus design was originally developed for multimode fiber but Raynet's new LOC2 system will accommodate single mode fiber, the current industry standard. Raynet claims that through passive optical networking, this new system will support up to 384 telephone subscribers and offers upgradeability to broadband services.

Fiber Backbone Networks

The hybrid fiber/copper or fiber/coax network generally implies a fiber-optic backbone, or trunk, interconnected to either telephone company twisted pair or cable company coaxial cable for the last network segment. The fiber backbone topology will likely become the new cable TV industry's standard for implementing

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[5] Ibid., 9.

[6] Ibid., 13-17.

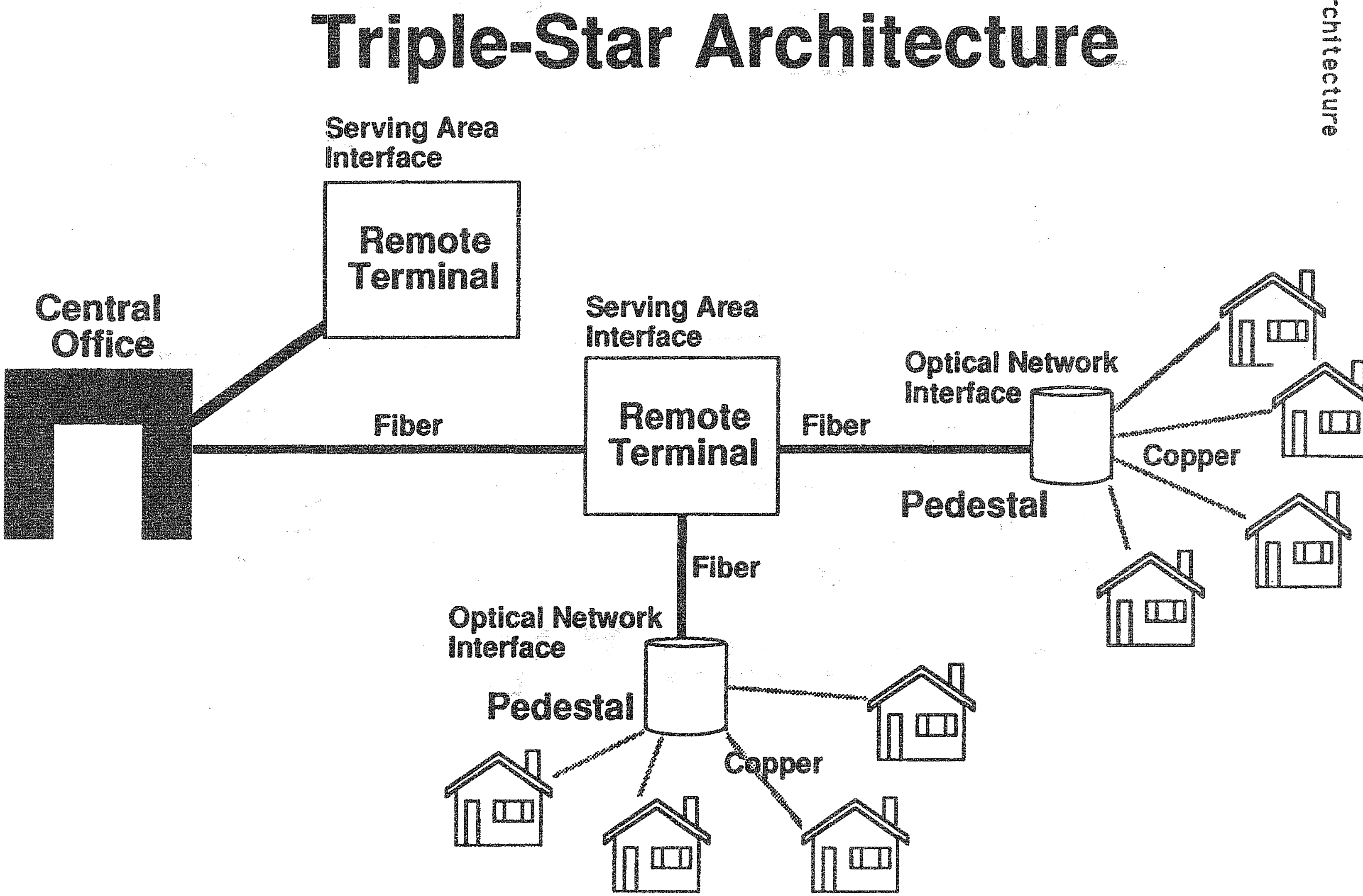
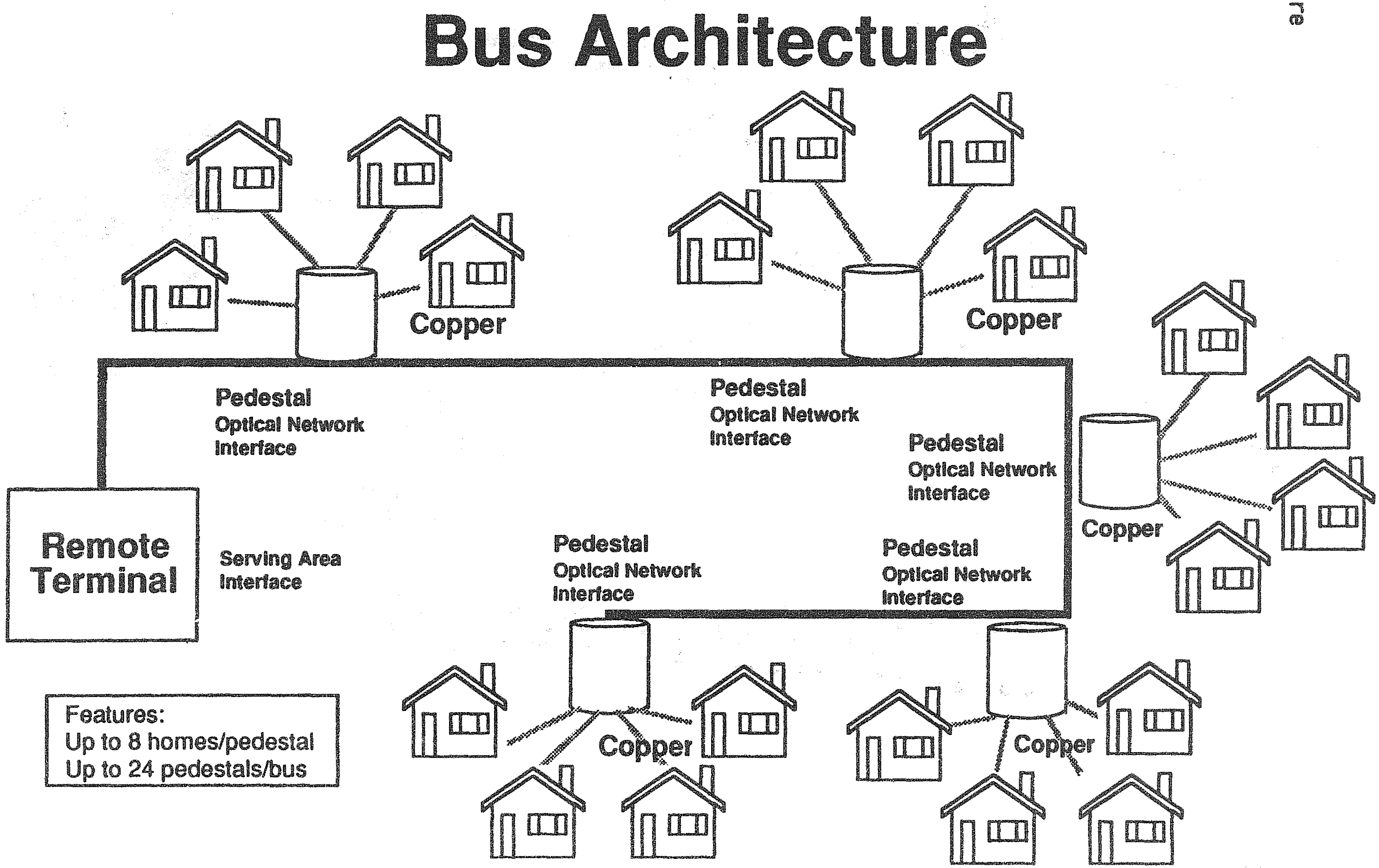


Figure 1.6
Triple-Star Architecture

Figure 1.7
Bus Architecture



fiber-optic technology. More existing cable systems feature tree-and-branch, one-way architecture. Two-way service is possible with additional electronics for bi-directional amplifiers. However, the tree-and-branch architecture's many coaxial cable signal amplifiers cause system reliability problems as signal errors cascade through several amplifiers. By using fiber optics instead of coaxial cable in the trunk network, signal amplifiers (and the maintenance associated with them) are effectively eliminated, enhancing signal quality and service reliability. Furthermore, the fiber optic hub points may be interconnected thereby allowing for signal redundancy or alternate routing possibilities in the event of node failure. In addition, a fiber backbone can enhance picture quality, expand overall system bandwidth, and allow for two-way narrowband service possibilities at minimum additional cost.

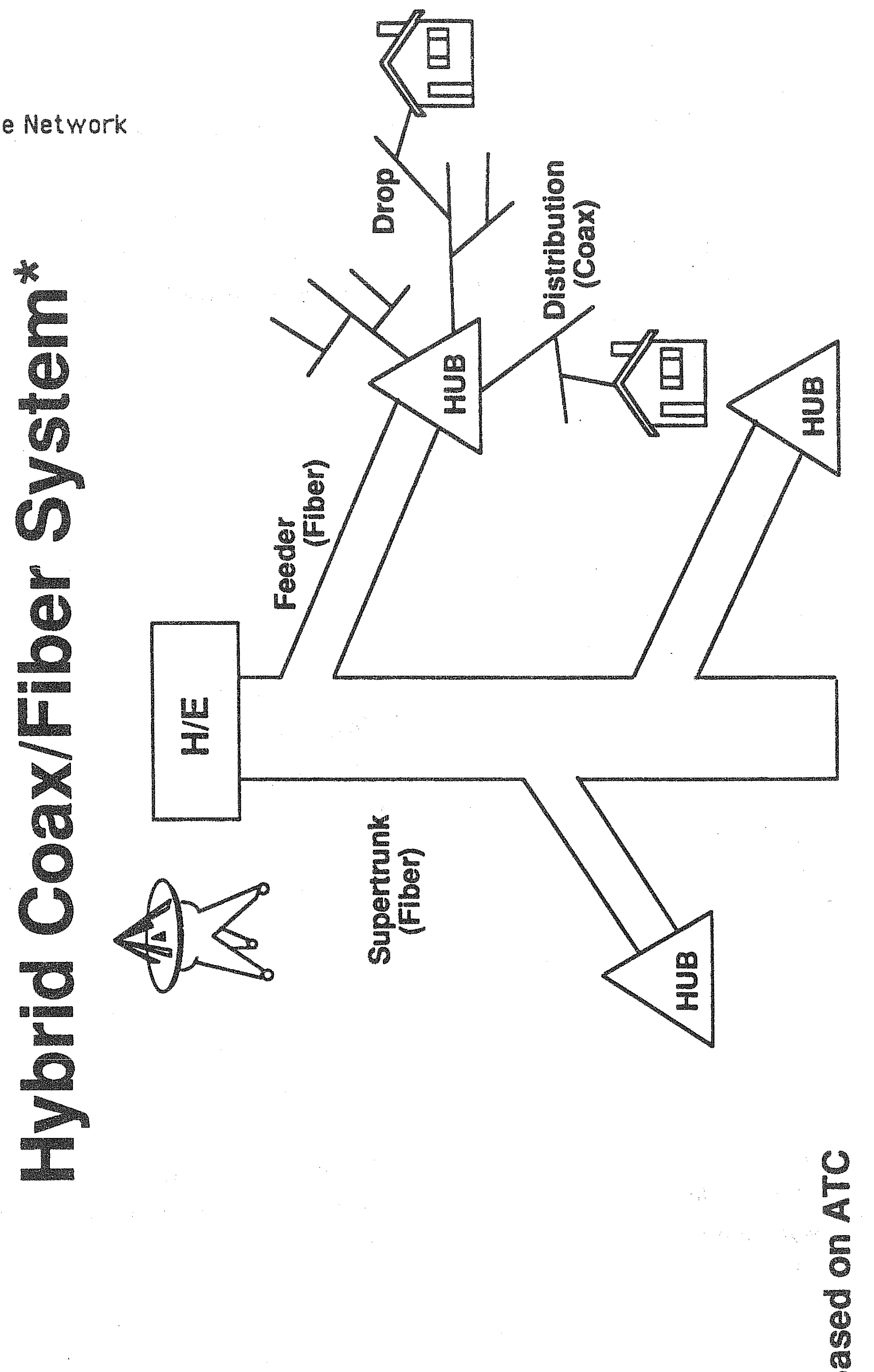
Telephone company fiber backbones (fiber feeder plant) are less interesting from a customer's perspective since the service capabilities of copper loops are not significantly enhanced for residential customers. The primary motivation for telephone company fiber backbone deployment is the cost efficiency of high density, shared plant. Basically, the telephone company fiber backbones are deployed to replace nonfiber trunk and feeder plant. The cost justification logic for telco fiber backbones is identical to that which justifies use of any replacement of copper pairs: to expand capacity and narrowband signal quality and save on maintenance costs.

Perhaps the most significant result of telephone company deployment of fiber backbones is that cable companies or others may be able to efficiently interconnect to it from headend or fiber-hub points in order to achieve intercity two-way switched and point-to-point service. This situation is intuitively appealing to industrial logicians since the relative strengths both of telephone companies (with high bandwidth interoffice and intercity facilities) and cable companies (with high bandwidth local distribution facilities) may be combined for the benefit of residential subscribers. Figure 1.8 provides a basic view of the fiber backbone architecture.

Loop Network Evolution

Now that we have provided general descriptions of the basic fiber loop architectures, it is important to understand how these network architectures may be

Figure 1.8
Fiber Backbone Network



able to evolve to FTTH. Figure 1.9 shows a simple view of today's telephone loop network. In today's service-oriented marketplace, the facilities of telephone companies and other communications providers are generally specific to the particular type of service offered. These network configurations are not integrated and include a mix of both analog and digital transmission technologies. Future network facilities will be capable of simultaneously offering a broad range of services. With broadband network technology, functions such as basic switching and transmission are commodity-like, and customers will be able to use these capabilities for whatever final services they demand. Ultimately, customers may be able to obtain a host of basic network functions over a single access facility.

The first stage of the network evolution, (assuming interexchange trunks are already converted to fiber) begins with integrated services digital networks (ISDN). ISDNs feature a single integrated access link including access to a host ISDN network switch, and intelligent signaling network. Basic components of the signaling network include ISDN switches, digital transport facilities and signaling systems, including signal transfer points (STPs) and network control points (NCPs) for database services.

At this stage the copper feeder cable is the next logical segment to be replaced by fiber, thereby creating a "fiber backbone" system that may evolve to FTTH and FTTC systems, using star, bus, or star-bus configurations. Remote nodes (remote terminals) located on the customer side of the host ISDN processor (serving area interface or SAI) may be used to provide certain features and functions. The serving area interface becomes fiber-compatible through the placement of appropriate digital loop carrier technology. The use of sophisticated equipment or "intelligent" remote nodes may provide customers with "smart" access. The features and functions which "smart" access provides will likely be in the category of enhanced services, not POTS.

In stage 2, copper loop distribution cable may be replaced with fiber. Next, at an interim stage 3, the costly opto-electronic (O/E) conversion function may be installed at a pedestal and shared by many customers through FTTC installations. These installations require the placement of fiber-compatible pedestals, the point at which optical-to-electrical and electrical-to-optical conversions take place.

The final migration is to stage 4 (FTTH) as the subscriber drop may be replaced with fiber and the primary optical network interface may be moved to the subscriber's home. This last network segment (drop) may become longer than the

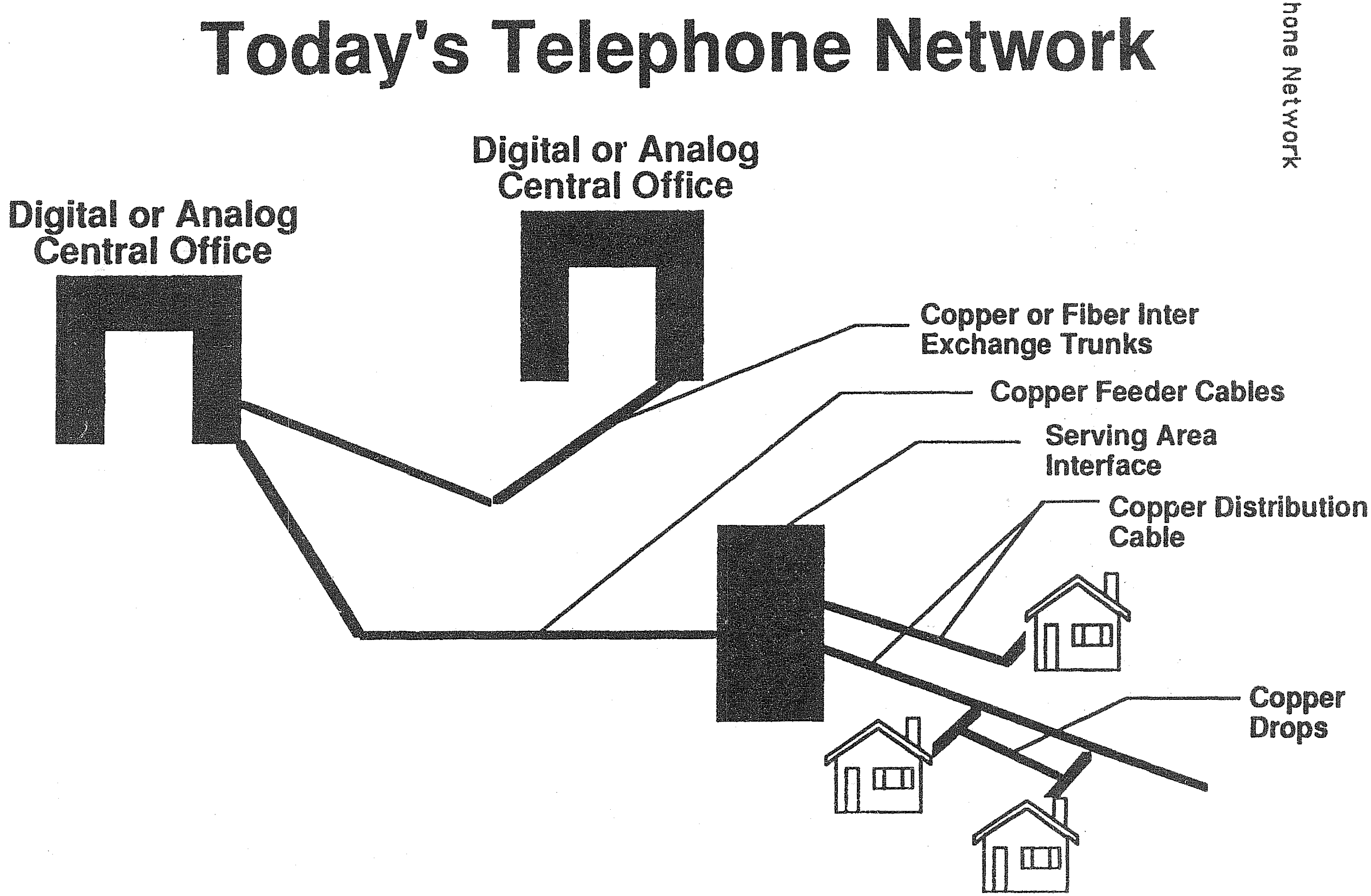


Figure 1.9
Today's Telephone Network

traditional copper drop due to equipment sharing among several customers from the pedestal location. Traditional drops do not necessarily share poles and pedestals. The timing of this final stage will be determined by service demand, improved technology and economics. Figure 1.10 depicts the major stages of loop network evolution.

Telephone Company Fiber Loop Trials

In this section we will present brief descriptions of selected telephone company fiber loop trials. For a complete list of trials, see figure 1.11.

Contel

Contel's trial in Ridgecrest, California uses AT&T's FTTH double-star architecture. The remote terminal (two SLC Series 5s) is located about three miles from the Ridgecrest central office and provides 192 houses with two voice lines each. At the central office an AT&T 5 ESS provides the switching for POTS brought in to each home on fiber at a 1.544 Megabits per second (Mb/s) rate. Since the goal of this trial was to make it as cost effective as possible, only a single fiber is deployed to each house. A distant terminal (AT&T's name for its optical network interface) is flush-mounted on the side of each house. The distant terminal is powered off the 100-volt AC source provided to the home. Eight-hour battery backup is provided. We estimate that the customer's power bill would be increased at most by $0.18 per month. Fiber cables with a maximum of ninety-six fibers are used for the distribution loops.

Contel's Sydney, New York FTTH trial will be a rehabilitation job that will use fiber cable strung from poles. Construction for this trial began in July 1989. One hundred sixty-six residential customers, thirteen small businesses, and five major businesses were scheduled for hookup by March 30th of 1990. This trial is one of the first fiber optic aerial trials ever to be conducted. Initially only POTS will be provided, but delivery of data and video will be considered later. In all, the Sydney Lightwave Project construction costs are estimated at $1.2 million. This trial utilizes the AT&T SLC series 5 system over single mode fiber. The optical/electrical unit in the distant terminal will use approximately 2.5 kilowatts, costing ratepayers roughly $0.23 per month in extra power charges.

Loop Network Evolution

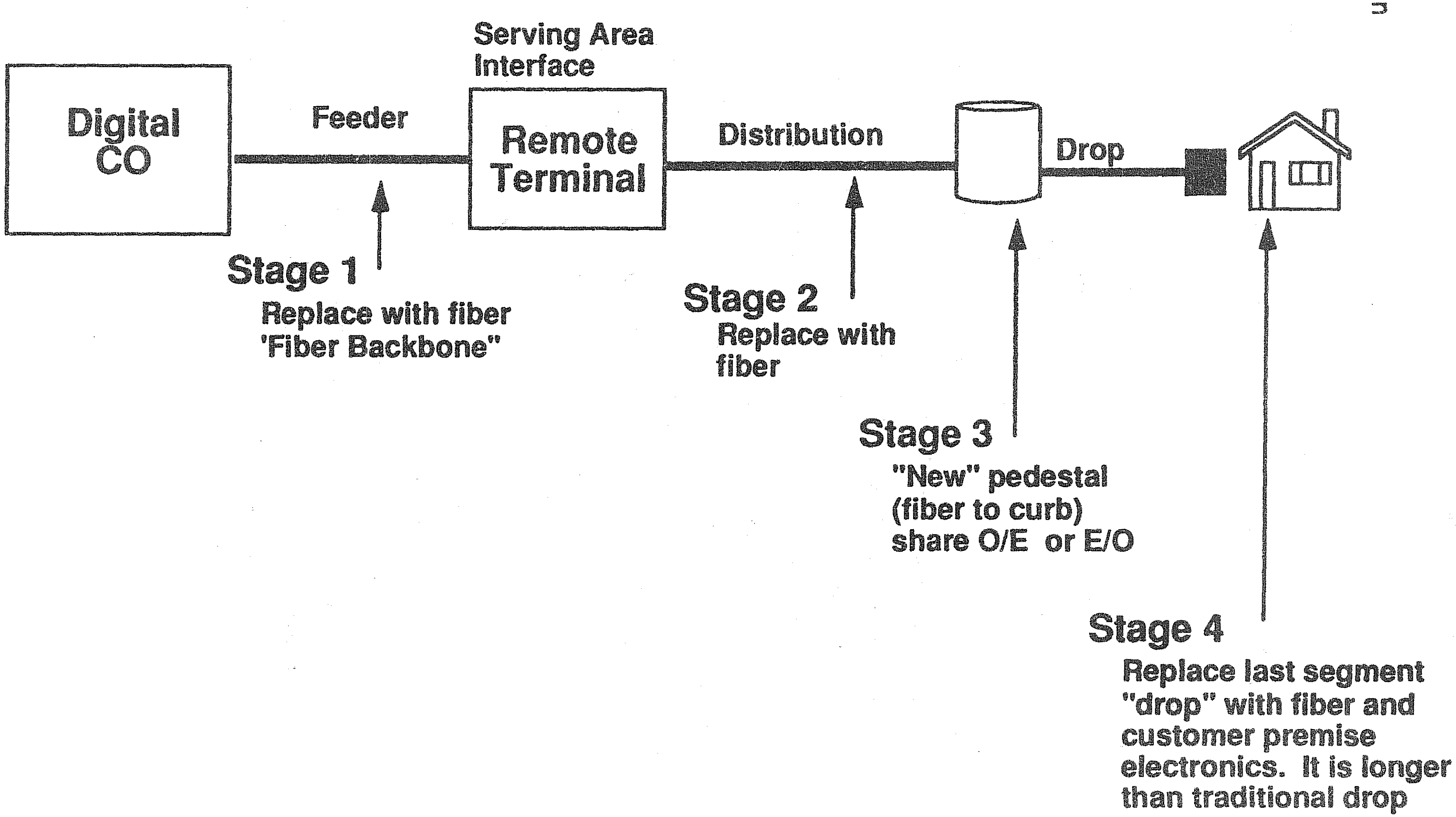


Figure 1.10
Loop Network Evolution

FIGURE 1.11
TELEPHONE COMPANY FIBER LOOP TRIALS

Telco	Location	Start Date	Number of Homes	Type of Service	Key Supplier	FTTH/F
Alltel	Piper Glen, NC	1989	50	POTS	R-Tech	FTTC
Ameritech	Jefferson Mdws, OH	1990	100	POTS	Raynet	FTTC
Centel	Tallahassee, FL	1989	100	POTS	AT&T	FTTH
Contel	Ridgecrest, CA	1989	100	POTS	AT&T	FTTH
Contel	Sidney, NY	1989	600	POTS		
Contel	Rancho Las Flores, CA	1991	350	POTS, video, other CA enhanced services	AT&T, R-TECH Raynet	FTTC
Contel	Wyoming, MN	1989	240	POTS	AT&T	FTTH
Bell Atlantic	Loudon County, VA	1989	126	POTS, digital video	BBT	FTTC/F
Bell Atlantic	South Brunswick, NJ	1988	104	POTS and data	AT&T	FTTH
Bell Atlantic	Perryopolis, PA	1989	100	POTS, CATV, switched FM video, multimode fiber	Alcatel	FTTH
BellSouth	The Landings, GA	1989	192	POTS	AT&T	FTTH
BellSouth	Lakeview Terrace, SC	1990	100	POTS	AT&T	FTTH
BellSouth	Norcross, GA	1990	N/A	POTS	Raynet	FTTC
BellSouth	Sawgrass, FL	1990	N/A	POTS	NTI	FTTH
BellSouth	Memphis, TN	1988	100	POTS	AT&T	FTTH
BellSouth	Coco Plum, FL	1989	200	POTS	AT&T	
BellSouth	Governors Island, NC	1989	49	POTS	AT&T	
BellSouth	Heathrow, FL	1988	4000	POTS, ISDN, digital CATV, transport (data security, meter reading, energy mgmt)	NTI	FTTH
BellSouth	Hunter's Creek 2, FL	1989	117	POTS	AT&T	FTTH
BellSouth	Hunter's Creek 1, FL	1986	251	Digital CATV	AT&T	FTTH
BellSouth	Morrocroft, NC	1990	126	POTS	AT&T	FTTH
Cincinnati Bell	Cincinnati, OH	1989	100	POTS	AT&T	FTTH
GTE	Cerritos, CA	1989	5000	POTS, digital CATV, advanced broadband GTE (video on demand, home banking, Amer. Lightwave shopping, security, utility meter reading)	AT&T GTE Amer. LW	FTTH
NYNEX	Lynnfield, MA	1990	100	POTS	Raynet	FTTC
Southwestern Bell	Mira Vista, TX	1989	100	POTS and CATV	Amer. LW	FTTH
Southwestern Bell	Leawood, KS	1988	134	POTS	AT&T	FTTH
Southwestern Bell	Olathe, KS	1989	260	POTS	AT&T	FTTC
US West	Mendota Hghts, MN	1989	100	POTS	AT&T	FTTH
US West	Scottsdale, AZ	1989	96	POTS	AT&T	FTTH

Bell Atlantic

Bell Atlantic's Perryopolis, Pennsylvania trial is a FTTH rehabilitation project providing voice and video services over multimode fiber strung from poles. Video services are provided through Helicon Cablevision, the local cable TV company. Alcatel's RCV-IG switched-star system delivers two POTS lines and two video signals to each of ninety-two subscribers' homes. The analog switched video system has a forty channel capability, and Impulse Pay Per View is also being provided through this system. Bell of Pennsylvania will construct 1.3 route miles of fiber-optic cable at a cost of $450,600 for outside plant, central office, and support material and labor.

BellSouth

BellSouth is deploying AT&T's SLC Series 5 Feature Package D system (formerly known as "Project Phoenix") for POTS only in FTTH configurations at the following locations:

> Hunter's Creek 2, Orlando, Florida serving 117 homes
>
> Coco Plum, Miami, Florida serving 119 homes
>
> The Landings, Savannah, Georgia serving 192 homes
>
> Governor's Island, North Carolina serving 42 homes
>
> Morrocroft, North Carolina serving 96 homes
>
> Lakeview Terrace, Charleston, South Carolina serving 100 homes
>
> The Grove of Riveredge, Memphis, Tennessee serving 75 homes

Standard dual POTS channel units will be housed at the remote terminal (RT). Each channel unit provides two voice frequency channels per fiber. All connections between the central office, RT, and the distant terminal (optical network interface), will operate at a rate of 1.5 Mb/s. Bi-directional optical transmission is accomplished at 1,300 nm. The distant terminal (DT), which is a weather-proof module mounted on the wall of the customer location, has capability of four standard voice frequency channels. The DT will run on customer-provided commercial power with battery backup.

Hunter's Creek 1, Florida

Through this FTTH trial, Southern Bell will transport video signals to a maximum of 300 homes in the Hunter's Creek 1 community. Fiber cable will provide two discreet TV channels per subscriber from a selection of thirty-six channels. Genstar, the cable TV operator will control access to these channels. Parallel coaxial cable will be deployed to the 300 residences. Due to the prototype nature of this system, Southern Bell will not expand these facilities unless Genstar has future growth requirements.

Heathrow, Florida

This FTTH trial utilizes Northern Telecom's Fiber Worth broadband digital-star architecture. Four hundred thirty five Mb/s are delivered to each subscriber to provide four switched 107 Mb/s video channels, one basic 144 Kb/s ISDN channel, and two 64 Kb/s POTS channels.

The project was initiated in June 1988 with the installation of a single-mode optical fiber cable carrying POTS service. In November, ISDN was added. In July 1989, digital-switched video was added. Service was initialized originally to 256 homes and a maximum of 4,000 homes will eventually receive service. The Heathrow system includes a digital set-top-converter and wireless remote control unit. The system allows viewers to call up and pay for video-on-demand by pressing a button. Interactive services make use of the system's upstream signaling capability over the same fiber that carries the television's signal downstream to the home. Telcom is the cable TV operator in this community. The project cost is $3,001,245.

NYNEX

The Lynnfield, Massachusetts FTTC trial uses Raynet's LOC system to provide 130 POTS lines to 100 homes within an existing neighborhood. The rehabilitation project covers an area where the loop length is 13,900 feet on average. The remote terminal (RT), contained in a controlled environmental vault, houses an NEC 1840A 135 MB/s fiber optics transmission system, Raynet's LOC head end (office interface unit) and ancillary equipment. NYNEX will most likely upgrade this installation to Raynet's new equipment, LOC 2, sometime in 1991.

NYNEX studies reflect that costs for narrowband services will range from $1,000 to $1,800 per line in 1993. As production volumes rise, costs will decrease.

The company maintains that cost allocations are customized according to loop lengths and serving area. Therefore, NYNEX believes that a general cost structure for loop fiber installations does not exist.

Other Trials

Trials by GTE and Southwestern Bell are described in Chapters 2 and 3, respectively.

Brief Summary of the Cost Model

The "model" is a six-part cost categorization of the generic FTTH and FTTC configurations that appear in Chapter 1 of the report. While they are quite simple, they are required as a point of departure for the categorization of costs for all known and anticipated residential broadband systems. The purpose of their simplicity is two-fold: to be simple enough that any regulator or interested policymaker may understand the fundamental network architectures that residential broadband service implies, and to be general enough in specification that any vendor's broadband system would fit into the generic model.

The rest of the illustrations in the report show variations of the generic broadband model and reveal differences in architecture and potential functionality of both current (narrowband) and prospective (broadband) loops. The illustrations of "star" and "bus" networks show architectures which have occurred in the literature to date, including some which are only on the drawing board. Since it would be premature to suggest exactly how the evolution of various loop plant architectures will occur, we only suggest a logical progression of fiber downstream in the subscriber loop plant. It is obvious that digital and fiber optic loop plant will "creep" out toward the residential subscriber premises, but it is presumptive to assume it will be deployed ubiquitously all the way to the home. We only include FTTH as a possibility--incidentally, not a near-term one.

Hence, regulatory commissions will be concerned first about FTTC systems, which may be in a production (nonprototype) mode by the mid-1990s. By this time many subscriber lines will be served from digital central offices. Therefore, the issue of allocating basic costs of installing current generation digital central offices to new broadband services will not be a pressing one from a cost-causality perspective; rather it simply represents the next generation of switching plant (predominately narrowband), which commissions will have to deal with as always. As more and more digital switches are installed, it becomes more difficult to continue "interworking" of digital and analog public network facilities.

The model is composed of six basic cost categories and is the basis for categorizing various, direct, system-residential broadband system costs. There are three basic cost categories in the generic model: central office, feeder loop plant, and subscriber distribution and drop. Beyond these three cost categories (which are designed to be consistent with current subscriber loop architectures so that cost comparisons are easy between historical narrowband and prospective broadband loops), there are three refinements made for newer loop architectures: the serving area interface (remote node or terminal -- popular in state-of-the-art narrowband loops); pedestal (popular in design of new broadband loops); and subscriber premises/network interface (necessary in FTTH systems to perform optical-to-electronic signal conversion and perhaps for local powering). For examples of equipment and component types that fall into each of these categories, refer to the list in Chapter 5.

All known or anticipated vendor systems will be able to fit within these generic loop plant cost categories. Once a vendor's system specific technologies (for example, analog/digital, fiber optic/coaxial cable) and architectures are identified, the component and equipment prices may be classified into their proper cost "buckets" specified in the generic model (namely the six cost categories, or "buckets," above).

Once each vendor's system equipment and component costs are identified and put on a per-subscriber basis, their costs may be juxtaposed for evaluation. This comparison requires that the functionality (in terms of services supported and reliability and quality), as well as assumptions of subscriber density and demand, be carefully considered. Such a comparison is beyond the scope of this study; however, the generic model is available herein and presumably the model may be computerized in a spreadsheet or database format.

This is a generic engineering cost model. It is not a cash flow investment evaluator, nor is it a "stand-alone" cost model. It is a useful evaluator of engineered, furnished, and installed (EF&I) incremental costs. It is useful to track incremental construction costs for residential broadband "capable" subscriber loops. (They will also provide for narrowband services.) Fortunately, well over 50 percent of the costs of most residential broadband systems (that is, broadband "capable" to the subscriber premises) are readily identified as being caused by broadband functionality. Only a fraction of costs represent joint costs for supporting existing narrowband services, thereby minimizing cost assignment problems. However, diligence in cost tracking and reporting is necessary. Exact categorizing of costs should follow our recommendations for treatment of costs.

There are many estimates of per-subscriber costs of residential broadband systems in the text and Appendix of the report. Most are difficult to compare, since they do not report costs consistently, or disaggregate cost data to the level of the cost categories in the model. Nevertheless, it is possible to compare the aggregate per-subscriber costs between different vendors and systems. We performed an analysis to arrive at broad averages for per-subscriber costs of FTTH and FTTC systems so that regulators may have benchmarks by which to evaluate specific costs as they may arise. It would not have been useful to try to classify each vendor system surveyed into the model, because so few of them broke out their publicly available cost information.

The model may not be used to evaluate "stand-alone" broadband network costs for the telephone company. It does indicate, however, the total "stand-alone" costs of cable television systems, and provides broad estimates of incremental costs of upgrading them for two-way services. The reason the model cannot be used for "stand-alone" cost analysis of telephone companies is that it ignores common costs (overhead) and much of the joint cost of common network facilities.

We refer to the RAND report[7] because it is the most comprehensive set of disaggregated system cost data available. We know of no other source of data where so much original effort was put forth. Its major value added to this effort was simply the raw data which allows us to illustrate in detail how the generic model is used. There are many other sets of cost data available, but they are less complete.

The RAND study critically hinges on subscriber density and demand estimates for a specific residential video service (video-on-demand or "video juke box"). Our study makes no specific demand assumptions; rather, it presents a cost model and framework of analysis for regulators who will have to consider locally whatever demand and subscriber density conditions exist.

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7 Leland L. Johnson and David P. Reed, "Residential Broadband Services by Telephone Companies? Technology, Economics, and Public Policy," RAND Corp., June 1990.

Recommendations for Regulatory Treatment of Costs

1. There are generally substantial marginal-cost advantages to using fiber optics and digital central office switches, instead of copper, coaxial cable, and analog network plant in certain situations. Therefore, to the extent that such fiber-optic transmission and digital switching plant is installed to replace older technology it should be allowed in the rate base under existing rules and regulations as it simply represents the next generation of public network infrastructure (even though it may also be useful for new broadband services).

2. The cost models presented in figures 1.1 and 1.2 should be used as a "least common denominator" for identifying costs of telco broadband network plant (especially entertainment video services, like cable television). It is convenient as a point of departure for categorizing the various cost categories across a vast array of current and potential subscriber loop architectures, and yet it is easily mapped into current subscriber loop plant cost categories, thereby highlighting the differences.

3. Many cost categories in the models are just for the provision of broadband services such as coaxial and fiber-optic cable in the depicted portion(s) of subscriber loop plant. Thus these costs should be assigned accordingly.

4. Shared subscriber loop plant is a joint cost, shared not only by subscribers, but also by any number of customer services (including multiplexed narrowband services). There should be no efforts to arbitrarily assign costs of shared coaxial cable, radio, or fiber optic loop plant. Instead, a concerted effort to track such costs and the reason for their being incurred through diligence in inquiry and accounting methods, is recommended so that their proper assignment may be ascertained. Some of these costs will be assigned to unregulated narrowband and broadband services, and some to traditional network voice and data services. Questions for identifying and tracking such costs through Commission inquiry are provided in Chapter 7.

5. Current usage-based cost allocators can cause problems when broadband and narrowband services share outside plant facilities jointly because of the extraordinary differences this would imply for tariff rates. Thus, a more careful identification of prospective costs for loop transmission and central office equipment is the best answer to cost assignment problems. This accounting must be done on a company-by-company, region-specific basis to be meaningful.

6. Many of the costs of FTTC and FTTH are quite easily tracked and accounted for besides the dedicated subscriber loop coaxial cable and fiber-optic transmission facilities mentioned above.

(a) Wave division multiplexing equipment (WDM), whether located at the central office, remote terminal, pedestal or subscriber network interface units, is used for providing broadband services and therefore the costs incurred may be safely assigned to such services. The cost model provided illustrates where such costs are likely to be incurred, what they represent (in terms of equipment), and what their magnitude may be relative to other costs of broadband "capable" subscriber loops.

(b) Subscriber optical network interface units (ONI) and associated electronics (for example, EO/OE, codecs, muxes, signal combiners, transmitters, receivers, and so on) are assumed to be required only to support broadband services (or at least nontraditional narrowband services) since they are connected to dedicated subscriber loop plant discussed above.

(c) Central office (CO) and remote terminal (RT) electronics are generally for shared subscriber loop plant and therefore are relatively more difficult to classify between narrowband and broadband service categories. For this reason, a careful accounting and tracking of such costs at the margin will be required. Some of these costs are obviously for broadband service, such as channel selectors and should be assigned accordingly. In the case of fiber muxes, OE/EO, codecs and other devices, these will generally fall into the category of shared loop plant, and should not be arbitrarily assigned using traditional usage-based allocators or otherwise. Such costs should be carefully accounted for and assigned at the margin to services for which they were incurred (if identifiable) according to the proposed questions provided in Chapter 7. Many of the devices and equipment in this category simply represent the next generation (and in many cases current state-of-the-art) loop architectures.

(d) Splicers, connectors, and other minor cost categories should follow, as best as is practicable, the cost categories listed above since these costs are ancillary to the primary facility they support. Specifically, if these costs are ancillary (meaning used in conjunction with) dedicated subscriber loop plant for coaxial cable and fiber optics, they should be assigned to broadband service categories accordingly. If these costs are ancillary to shared subscriber loop plant, they should be assigned to the appropriate joint cost category described above and using the model as a guidepost for demarcation points.

(e) All labor costs and installation, and operations, administration, and maintenance (OA&M) costs should follow their respective cost categories above using the same rules for dedicated and shared subscriber loop plant, and following the cost model provided. In many (probably most) cases, expense categories such as these may be directly assigned to services using careful accounting and tracking methods.

(f) All other cost categories are likely to be minor in magnitude to those listed and may have to be handled on a case-by-case basis, especially if they do not coincide with the cost model.

7. There is still the issue of "interoffice" or "internode," and "hubbing" facilities for transmission and electronics. In the case of connections between cable company headends to telco central offices and remote terminals, all costs for such links should be assigned to broadband services. In the case of fiber-optic rings and internode connections for alternate routing, these costs should be assigned to the public network services joint costs, and not to any particular service unless they are dedicated to only one or more subscribers, in which case, they should be assigned to that subscriber(s). These types of costs generally represent the next generation of redundant and back-up ("survivable", "self-healing") public networks and should not be arbitrarily allocated. Associated engineered, furnished, and installed (EF&I) costs and OA&M costs of these types of facilities, whether shared for broadband services or not, should follow the same guidelines.

Assumptions and Methodology

All data in this report were obtained through:

> telephone interviews with industry experts in telephone companies, cable TV companies and equipment vendor companies

> telephone company publications and press releases

> industry trade papers

> FCC documents

> industry studies and conference proceedings

It should be noted here and throughout this report that costs associated with trial networks are prototype costs. Through our discussions with several telco personnel we have repeatedly heard that the costs of fiber installations are highly dependent on the density of the neighborhoods and the distance from the remote terminal. These costs cannot be automatically used to measure future costs which are associated with volume production and improvements in network component technology.

General cost guidelines and cost model hierarchy in chapter 5 were derived from varied studies conducted by Northern Business Information/Datapro and other industry experts of fiber technology, and through an exhaustive survey of subscriber loop models and trials.

All cost data within this chapter 6 were derived from Leland L. Johnson and David P. Reed, "Residential Broadband Services by Telephone Companies? Technology, Economics, and Public Policy," RAND Corp., June, 1990.

It should be noted, however, that additional cost data from other sources are contained in Chapter 8.

CHAPTER 2

FIBER NETWORK CONSTRUCTION: GTE

Description of Loop Fiber Installations to Date

Cerritos, California FTTH Trial

GTE is providing fiber dial-tone service to 100 customers in the Cerritos trial area. In the fall of 1990, they began to test video on demand and switched video (full motion video telephone). Apollo Cablevision is providing cable TV services over their coaxial network. GTE Mainstreet, an interactive television service, provides home shopping, banking and information services. Centerscreen will provide enhanced pay-per-view service.

The Cerritos lab test is a conduit system that could virtually support any of the proposed architectures. GTE will choose a star and distributed star by the end of 1990.

The FCC gave permission in April 1988 for GTE of California to construct and maintain cable television transport facilities in Cerritos for Apollo Cablevision's exclusive use as cable TV operator. GTE Service Corporation will make use of system bandwidth that is not required by Apollo. Technical evaluations will be made to compare the use of coaxial cable and optical fiber, along with copper wire in transport of voice, data, and video signals. Apollo has agreed to permit its video programming to be alternated between coaxial and optical fiber as long as prior notice is given and service is not disrupted. Cable TV service is initially provided to approximately eighty homes using a 78-video channel, bidirectional, subsplit facility consisting of a single feeder design from headend to taps. All facilities are located in Cerritos, which has an estimated population of 55,000 (16,000 living units). There are no topographical features requiring special construction or added costs. GTE will recover costs for construction and maintenance over a fifteen-year period, as set forth in the lease agreement with Apollo Cablevision. Therefore, the construction is economically justified.

Today's Cost Items

Trenching		$4,253,378.00
175.5 miles		
Outside Plant		$1,853,280.00
Conduit		
Coaxial Cable		
Fittings/Boxes		
Network electronics		
Premise Equipment		$912,000.00
Materials/Labor		
Headend Equipment		$338,000.00
Headend Electronics		
Engineering		$128,000.00
	Total	$7,484,558.00

Based on the estimate that 5,000 homes will eventually subscribe to both narrowband and broadband services in the Cerritos serving area, the final cost per subscriber would be $1,497.

Future Local Loop Fiber Installations and Costs (with Cable TV)

GTE did not offer any information regarding future plans for constructing fiber loops offering cable TV services. However, based on the services tested during its trial, we can estimate the costs of a similar future network. The example presented in figure 6.1 in Chapter 6 of this report closely resembles the Cerritos network of the future. Today, however, the network under construction is a combination of two networks, the GTE narrowband network with Apollo Cablevision's fiber/coaxial broadband network.

Future Local Loop Fiber Installations and Costs (without Cable TV)

STE did not offer any information concerning their future plans to construct narrowband fiber loops. Please see the extensive cost data in Chapter 6.

CHAPTER 3

FIBER NETWORK CONSTRUCTION: SOUTHWESTERN BELL

Description of Loop Fiber Installations to Date

Leawood, Kansas FTTH Trial

This POTS trial is based on AT&T's SLC Series 5 system to the Halbrook Farms subdivision where 132 new homes are under construction. The first customer was installed on October 27, 1988 and now over 100 customers are served via fiber. Southwestern Bell's conclusions from the Leawood trial are:

1. The overall concept of providing POTS service over fiber is viable.
2. The provisioning and maintenance costs are higher than anticipated. However, new products and procedures will lower these costs.
3. Testing, powering, splicing, and assignment issues require enhancements.
4. Economic parity with copper is possible as these issues are addressed.

Olath, Kansas FTTC Trial

Southwestern Bell is utilizing AT&T's FTTC system which employs a pedestal-based triple-star architecture in this trial. First service was available on February 21, 1990. Currently six customers are served in the Cedar Creek subdivision of Olath, Kansas. This FTTC installation eventually will serve 260 homes.

Mira Vista, Texas FTTH Trial

The FCC approved Southwestern Bell's trial application on June 20, 1989 to build a transport and distribution network for provision of cable TV service for the Mira Vista subdivision of Fort Worth, Texas. Sammons Communications will be the sole provider of this service for the area. Four simultaneous video channels and up to four POTS lines will be transported simultaneously downstream over one fiber. A second fiber from each home will transport four voice circuits and video signaling information upstream toward the central office. Service was initialized to the first home on December 7, 1989 and now twenty homes are receiving POTS and cable TV service. During the trial, between eighty and one hundred homes will be served over fiber. The FCC application was approved on the basis that Southwestern Bell needs to determine whether fiber-optic technology can be deployed, operated, and maintained in a cost-effective manner.

A maximum of sixty-one CATV broadband audio and video channels will be transported from Sammons' headend to Southwestern Bell's controlled environmental vault (CEV), a distance of 9.8 route miles. Southwestern Bell will: (1) install multiplexing and O/E signal conversion equipment to be located at its leased and segrated equipment room at Sammons' headend; (2) install approximately 1,000 feet of fiber-optic cable from its equipment room at Sammons' headend to Southwestern Bell's Edgecliff central office; (3) activate approximately 9.8 route miles of four strands of existing fiber-optic cable from its Edgecliff central office to the subdivision; (4) install demultiplexing and O/E signal conversion equipment at its CEV located in the subdivision; (5) bury 22,050 feet of single-mode fiber-optic cable for local distribution plant in the subdivision and place twenty-seven associated drop terminals (the distribution plant will run from Southwestern Bell's CEV to various drop terminals in the subdivision); (6) bury 165 feet of fiber optic drop cable per residence (the drop will run from the drop terminal to the optical network Interface (ONI) located at each residence); (7) install an ONI at each residence; and, (8) provide three set-top and remote control units per residence. Figure 3.1 shows the route schematic for the Mira Vista trial. Also, see figure 3.2 for a diagram of the RT-to-home video link.

Today's Cost Items

Leawood, Kansas FTTH Trial

Although Southwestern Bell did not share specific cost element information with us regarding this trial, they were willing to confirm our assumption that provision of POTS over fiber costs approximately $3,000 per subscriber in current dollars. Southwestern Bell maintains the position that it "Will deploy a high quality, reliable fiber-optic network into the local loop, which can be upgraded for broadband video transport, when this network can be deployed for the equivalent cost of a copper network."

Figure 3.1
Mira Vista Route Schematic

Route Schematic Headend to Home

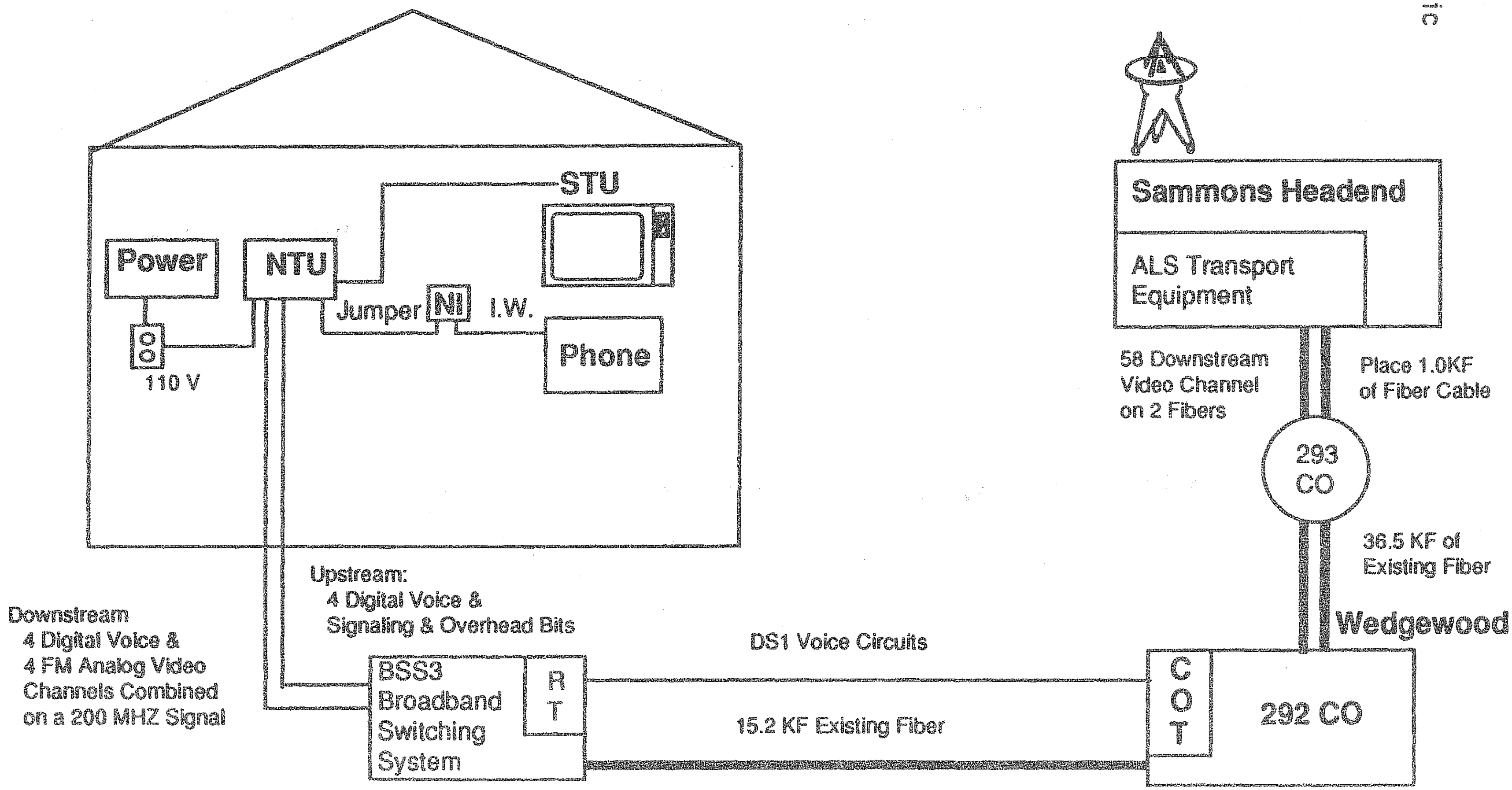
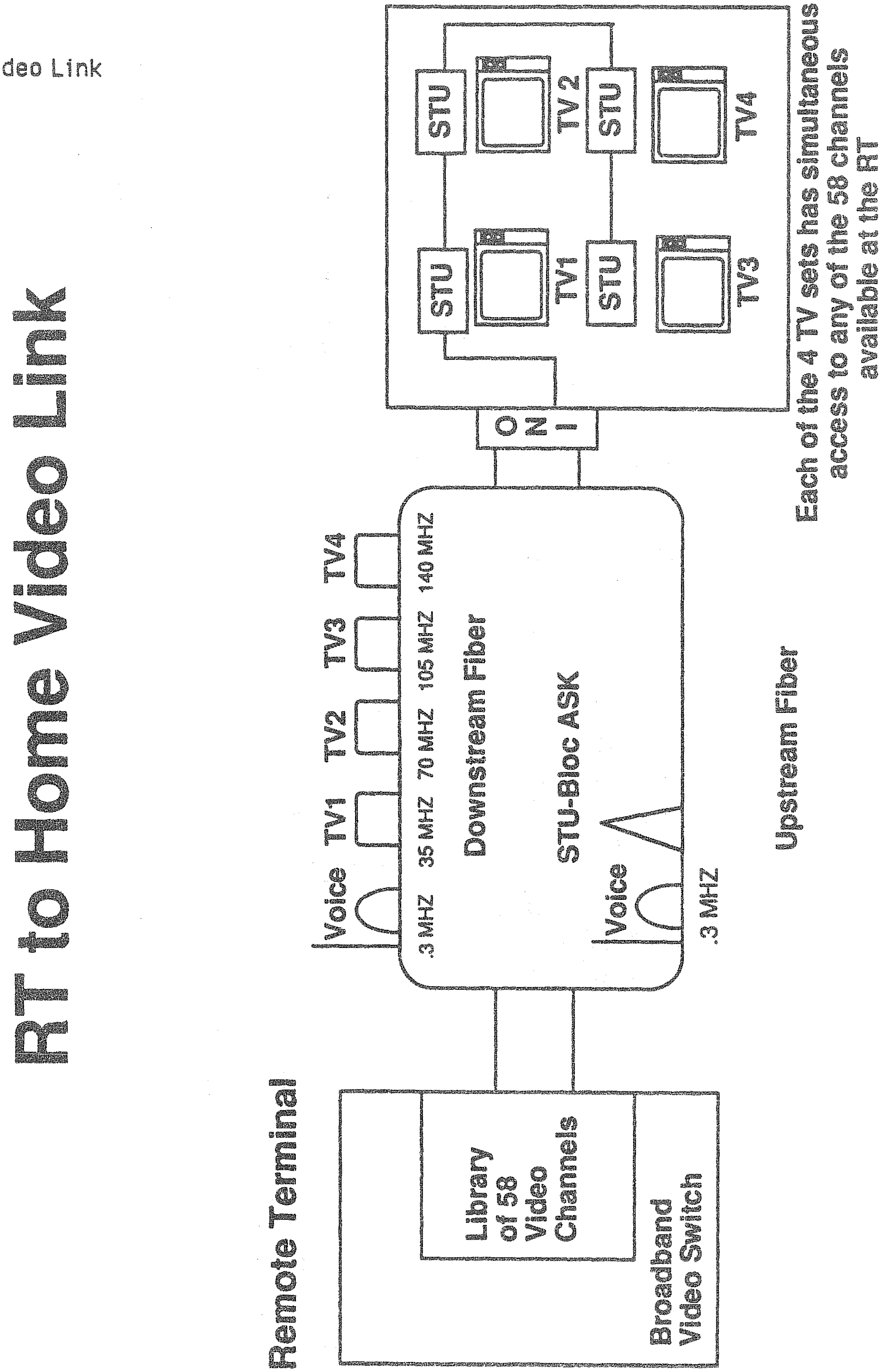


Figure 3.2
RT to Home Video Link



Olath, Kansas FTTC Trial

Southwestern Bell did not share specific costs but was willing to confirm our assumptions that the cost per subscriber is between $1,000 and $1,500. Southwestern Bell's own costs studies have shown that FTTC reduces the installed first cost of deployment by 20 percent to 30 percent. Southwestern Bell projects that they will initially deploy fiber to the pedestal (FTTC) to the local loop from 1990 to 1992, and will eventually deploy FTTH beginning in the 1992 to 1995 time-frame.

Mira Vista, Texas FTTH Trial

Southwestern Bell will spend approximately $1,084,600 for central office and outside plant equipment, material and labor as follows:

PROJECT COSTS
($ 000)

TELEPHONE PLANT ACCOUNTS	GROSS ADDITIONS
Circuit Equipment	558.4*
Outside Plant: - Exchange Optical Fiber Cable	320.5*
- Service Wire (Drop Cable)	39.3
- Telecommunications Equipment Located on Customers' Premises	166.4
TOTAL	1,084.6

*Includes Other Support such as Training, Documentation, etc.

MAJOR ITEMS OF MATERIAL AND LABOR

CIRCUIT EQUIPMENT	QUALITY	ESTIMATED COSTS MATERIAL	LABOR
Install At Headend:			
- Common Equipment and Plug Ins:		237.2	24.0
Wideband Video Modulator	62		
Frequency Division Multiplexer	62		
Two Channel Audio Modulator	24		

Universal Mainframe	24
Power Supply Module - 48 VDC	24
1,300nm ILD Transmitter	2
1,300nm Pin Receiver	1
Combiners and Cabling Hardware	1
Network Management System	1

Initial Deployment to 100 homes would bring installed first costs per subscriber to $10,846. However, a total of 1,000 subscribers are expected to eventually reside in Mira Vista, which will bring the cost down to $1,085.00 per subscriber.

Future Local Loop Fiber Installations and Costs (with Cable TV)

Figure 6.1 in Chapter 6 closely resembles future costs for this Southwestern Bell's broadband network. Southwestern Bell stated that it would not provide FTTH POTS plus video, if permitted to do so in mass deployment, unless "in place" costs were $700 or less per subscriber.

Future Local Loop Fiber Installations and Costs (without Cable TV)

Southwestern Bell revealed that it was planning an aerial rehabilitation trial. Please see the extensive cost data in Chapter 6.

CHAPTER 4

FIBER NETWORK CONSTRUCTION: AMERICAN TELEVISION AND COMMUNICATIONS CORP./JONES INTERCABLE INC.

Description of Loop Fiber Installations to Date

American Television and Communications Corp. (ATC)

ATC chose to upgrade a portion of one of its older systems to 550 MHz with fiber backbone technology. The coaxial distribution cable of the original system remained unchanged. The system chosen has been in operation for more than fifteen years.[1] The upgraded portion is the Pinehurst node of ATC's Orlando system which had been delivering thirty-six channels of video over 375 miles of 270 MHz plant. There are 10,000 subscribers served by this distribution node.[2] The installation is a hub-to-hub application tying all hub sites with fiber, reducing amplifier cascades, and improving signal quality. The initial purpose of this installation is to increase reliability by having a redundant fiber route in place as a backup system. The project is currently about 80 percent complete.

Jones Intercable Inc.

Jones' Augusta, Ga. system is a rebuild using a fiber backbone to serve 59,879 subscribers over 1,267 miles of plant.[3] The system deploys AM and FM fiber technologies over a hybrid fiber/coaxial cable area network (CAN). The CAN design

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[1] Perry Rogan, Raleigh B. Stelle III, Louis Williamson, "A Technical Analysis of a Hybrid Fiber/Coaxial Cable Television System" (American Television and Communications, 1988).

[2] Claude T. Baggett, "Cost Factors Relative to the Fiberoptic Backbone System," *NCTA '88 Technical Papers,* (Washington, D.C. National Cable Television Association), 1988.

[3] Laurence Swasey, "Jones Switches on First Leg of Augusta Fiber Plant," *Multichannel News,* June 26, 1989.

is being used to improve signal quality by reducing the number of trunk amplifiers between the system's headend and the subscriber.[4]

Today's Cost Items

ATC's Orlando System	
Headend Costs	$116,000.00
Conversion Nodes	63,220.00
Fiber Trunking	
Cable Cost	47,530.00
Construction Labor	134,126.00
Total Costs	$361,126.00
Cost Per Subscriber	$ 36.11

Jones Intercable

Jones' Augusta project cost is $15 million. The costs per subscriber is $250.

Future Fiber Installations and Costs (with Other Broadband Services and Telephony)

ATC and Jones shared no future construction plans with us. The Jerrold "System K" architecture mentioned in Chapter 5 is a likely candidate for cable company construction in the event that it was permitted to provide telephony services. However, sufficient demand for real-time interactive broadband services would have to be demonstrated.

"System K":

> is a switched-star system

> is hybrid fiber/coaxial cable

> provides four channels of switched-video service to each subscriber

> serves four homes through each optical link

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4 "Jones Intercable's Georgia System Is Its Largest of 3 Fiber Projects," *Fiber Optics News,* July 3, 1989.

> transmits in FM-Frequency Division Multiplexing (FDM) format with carriers starting at 60 MHz and extending to 660 with 40 MHz spacing.

> can be readily upgraded for telephony transmission through a POTS plus data interface added to the tap

The laboratory model successfully transmits high-quality FM video through low-cost lasers, demonstrates digital switching of FM video signals, and transmits two-way over single mode fiber. It is estimated that "System K" would cost less than $1,000 per subscriber for 64 to 128 video channels in the 1995-2000 time frame.[5]

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5 David E. Robinson, David Grubb III, "A High Quality Switched FM Video System," *IEEE LCS3,* February 1980.

CHAPTER 5

CONSTRUCTION COST BENCHMARKS

The most advanced network architectures feature two-way, on-demand, broadband communications, and have very high deployment costs in the range of $1,500 to $15,000 per subscriber. With about one hundred million subscribers in the United States, this suggests a total cost of FTTH in the range of $100 to $1,900 billion for universal deployment. Deployment costs of FTTH are substantial whether for telephone companies, cable companies, or others. Fiber cable itself is relatively inexpensive. The two main incremental cost factors for FTTH are the initial engineering and construction costs for laying fiber cable all the way to the subscriber premises, and the costs of opto-electronic components and devices required to allow existing CPE to interface with, and operate on, the photonic distribution network. Cable companies, which use passive transmission ("bus" or nonswitched) in their subscriber loop architectures could pursue a residential broadband construction program which would cost much less than a traditional telephone company switched loop architecture. However, to provide network functionality equivalent to telephone companies, cable technology deployment costs would still be substantial, in the lower range of cost estimates for telco-supplied FTTH. It is important to note that the cost estimates at the lower end of the range provided are mostly forward-looking, meaning they assume mass deployment using production equipment costs. Those FTTH cost estimates at the high end of the range are usually based on limited deployment and some prototype equipment and service arrangements.

FTTH

A survey of existing engineering cost estimates for FTTH, on a subscriber-line basis, is given in figure 5.1 for a wide range of access line configurations and functionalities, including estimates of the costs broken out by central office equipment (COE) and feeder plant. At this early stage, none of the cost estimates can be dismissed out of hand since the estimates are extremely sensitive to assumptions regarding network architecture and the costs of devices and

FIGURE 5.1

THE COST OF FIBER FOR ADVANCED SERVICES

Study	Total/Sub	COE	%	Feeder	%
1.	2,000	78	3.90%	206	10.30%
2.	2,460	1,835	74.59%	15	0.61%
3.	18,100	6,820	37.68%	900	4.97%
4.	2,280	180	7.89%	700	30.70%
5.	7,500	NA		NA	

Notes on Each Study:

1. Marvin Sirbu et al., "An Engineering and Policy Analysis of Fiber Introduction into the Residential Subscriber Loop," Department of Engineering and Public Policy, Carnegie Mellon University, 1987. Sirbu assumes widespread introduction of fiber in the 1995-2000 timeframe, using a switched double star architecture. Subscriber is served both by a CO and RT serving up to 1,000 subscribers. Other assumptions: The average cost drops as demand increases; $2,000/sub. is for new builds where 20% of the homes have fiber, 60% of those use new fiber services; all subscribers have access to ISDN lines. Fiber for feeder costs $0.10 per meter; the average feeder length is not given and does not include installation costs. Local loop/distribution is separated into two components, the RDU and the Subscriber premise.

2. M. Faroque Mesiya, "Implementation of A Broadband Integrated Service Hybrid Network," *IEEE Communications Magazine,* 26 No. 1 (January 1988), 34. Study assumptions: Switched double star architecture; no demand assumptions used and ISDN is in place and costs are sunk; at least two TV channels and voice/data via the ISDN BRI; 2,000 subs. per RT. Feeder cost ($15) only considers 1.5 km fiber line. Cost of modulating and multiplexing TV signal from the headend to the CO/RT not included. Swithing costs include both CO and RT. Loop/distribution costs include "network termination unit" and a TV set-top unit. MTU provides interface for fiber pair and the CPE at sub. premise. MTU will cost $500 and the set-top unit will cost $110. Cost of the subscriber loop fiber is not included in the analysis

3. United Telecom Technology Planning, "Fiber in the Subscriber Loop," February 1988, 47. Study assumes new system build, switched double star with 1,444 subs. per CO. Each sub. may access 32 TV channels (one switchable). ISDN is assumed. Broadband switch provides 140 megabits to sub. Fiber length from CO to RDU is 20,000 ft. Includes installation costs. Study groups both subs. premise and the RDU cost under Loop/Distribution. RDU serves 288 subscribers. Dist. length is approx. 1,500 feet, drop is 150 feet. Cost/sub. for cable, spicing, connectors, and placement is about $1,107. Multimode fiber from RDU to the sub. premises and uses subscriber interface unit.

FIGURE 5.1 (Continued)

THE COST OF FIBER FOR ADVANCED SERVICES

4. Testing Under Way: Fiber Comes Home." *Data Communications*, June 1987. Study is for target cost. No mention of component costs or other details.

5. Bellcore Estimates in "Outlook for Fiber-to-the-Home: Healthy But Cloudy," *Lightwave*, February 1989.

components. The most often quoted numbers are in the range of $1,500 to $3,000 per subscriber for an all-fiber deployment scenario.[1]

There is no such broad survey of FTTH cost estimates for cable television companies, however the range of costs in figure 5.1 includes systems using passive delivery of video on a fiber-optic bus, typical of cable delivery systems. The cable industry has not shown any significant interest in FTTH since they view their broadband coaxial cable subscriber loops as adequate for two-way residential broadband service when fiber optics are deployed in their trunk network. Figure 5.2 provides estimates of fiber access line costs assuming POTS-only service is offered initially. As fiber-optic device and component costs fall and progress is made in photonic/electronic interface units, POTS-only FTTH systems may be efficiently upgraded to provide advanced two-way services. Many vendors of FTTH systems and equipment have announced migration strategies for subscriber loop plant from basic to enhanced functionality, some ultimately providing for high-quality two-way real time broadband service.[2]

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[1] However, the studies use a variety of assumptions regarding technological advancement over time, and those with cost numbers at the low-end usually refer to prospective rather than current costs. For purposes of conservatism, we choose current costs or the high end of the range.

[2] Several major telecommunications equipment manufacturers are involved in developing advanced FTTH systems, including AT&T, Northern Telecom, Fujitsu, Siemens, Ericsson, Alcatel, and others. For a look at some subscriber loop migration scenarios, see Mike Frame, "Migration to Broadband"; and Ray McDevitt, "Video Services Impact on Fiber in the Loop," *Proceedings, Fiber Optics Futures Conference*, Monterey, CA, April 23, 1990.

FIGURE 5.2

THE COST OF FIBER ACCESS FOR POTS

Study	Date	Cost/Sub
1. Corning	1988 1995	$4,600 $2,300
2. United Telecom	1988 1995	$2,800 $2,000
3. BellCore	1988	$3,000
4. CTIS	1990	$3,100

Notes on Each Study:

1. Corning Glass, Filing in FCC CC Docket #87-266: Telco-Cable Ownership, 1987, Attachment page 5.
2. United Telcom, "Fiber in the Subscriber Loop," p. 49.
3. "Outlook for Fiber-to-the-Home: Healthy But Cloudy," *Lightwave,* February 1989.
4. Center for Telecommunications and Information Studies, Columbus University.

Figure 5.3 shows a stylized FTTH loop architecture consistent with today's state-of-the-art loop plant design. Our estimate of POTS fiber access line costs for this stylized residence network service configuration which could exist in the early 1990's may be considered a "target" for relatively short loop fiber installations. This represents a subscriber served by a digital central office, serving area interface and digital loop carrier. The total network cost per subscriber is estimated to be about $3,000. Notice for this particular loop architecture, the feeder portion of per-subscriber costs is only about $100 or roughly 3 percent of the total costs of subscriber loop plant. The remainder of the costs derived from distribution plant (two-thirds) and electronics (about one-third of the total per-subscriber costs).

Cost of Fiber POTS

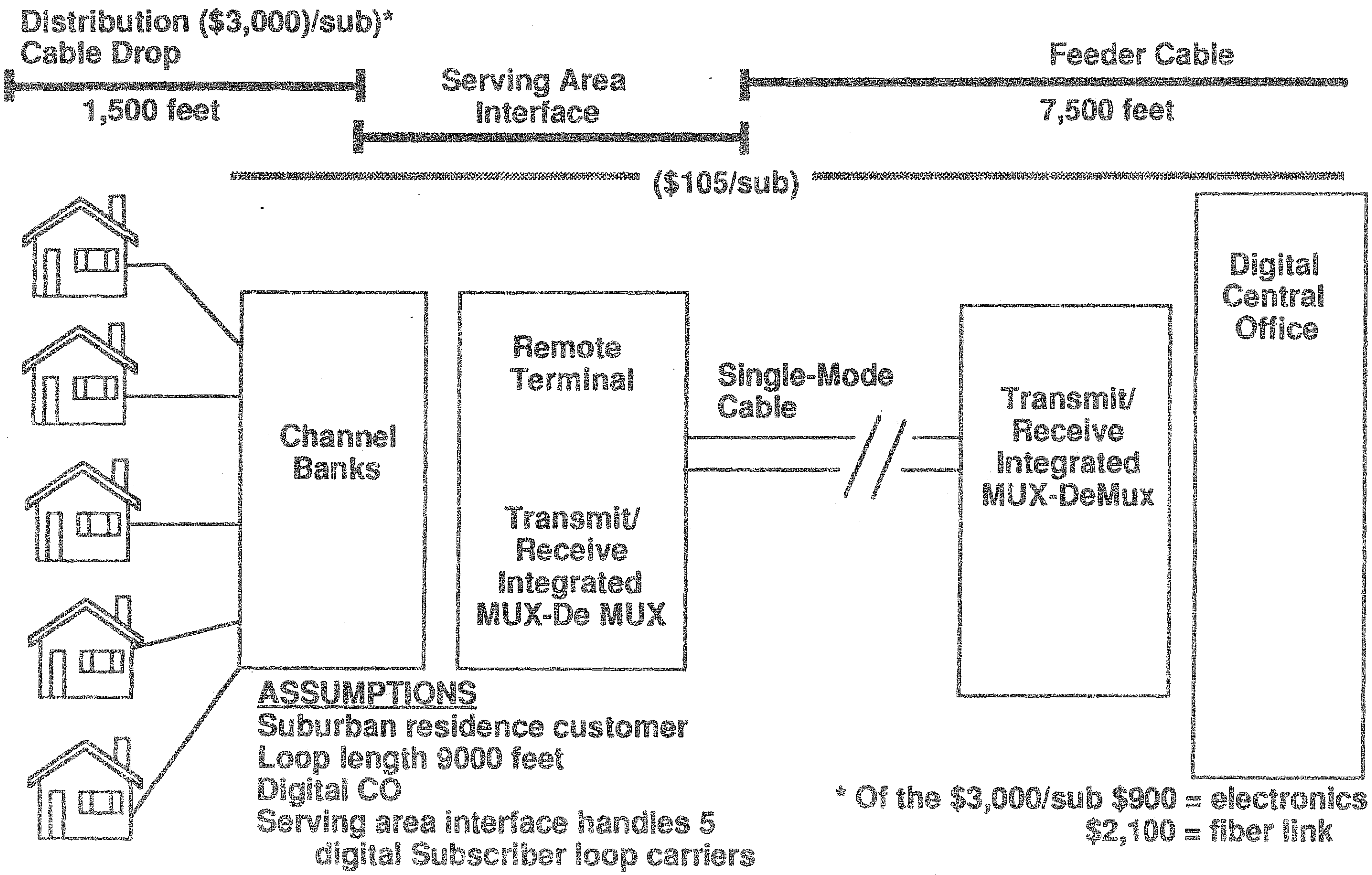


Figure 5.3
Cost of Fiber Pots

Fiber Backbone Networks

Telephone companies and cable companies alike can deploy fiber backbone networks at a small fraction of the cost of fiber-to-the-home because fiber is exceptionally well-suited for shared (nondedicated) subscriber plant and will likely be preferred in new trunk and feeder facilities construction based on cost savings alone.

Figure 5.4 is a stylized view of a fiber backbone trunk network for cable companies. For a telephone company fiber backbone refer to figure 5.3, assuming that only the central office to digital remote terminal portion of the access line would be fiber, and the remainder of the loop would remain copper.

Given the available data, either telephone companies or cable companies can upgrade the local distribution networks with a fiber-optic backbone for about $100 per subscriber. This, however, is where the good news ends for telephone companies. Even though cable or telephone company fiber backbone costs are about the same per-residential subscriber the difference in quality, reliability, and future functionality leaves no comparison between cable and telephone companies--cable companies win hands down. A telephone company fiber backbone, while perhaps more reliable and of higher quality from a network engineering and maintenance perspective, holds virtually no service advantage for customers; subscribers still only get two-way narrowband telecommunications due to the limitations of the existing copper loops.

Fiber-to-the-Curb

There is a big difference in the costs of fiber backbone networks and FTTC, whether for cable or telephone companies. In fact, most available estimates of per-subscriber costs of FTTC for two-way broadband networks are ten times that of per subscriber fiber backbone costs, in the range of $1,000 to $1,500. However, FTTC is still only about one-third to one-half the per subscriber costs of FTTH and, in the case of telephone companies at least, FTTC may offer a significant increase in network functionality for subscribers, while fiber-feeder backbones do not. As a result, there is substantial interest in telephone company deployment of FTTC. A host of telephone company FTTC network architectures have only recently been proposed by a number of vendors and others are still in the laboratory development stage.

Figure 5.4
Fiber Backbone Network

Hybrid Coax/Fiber System*

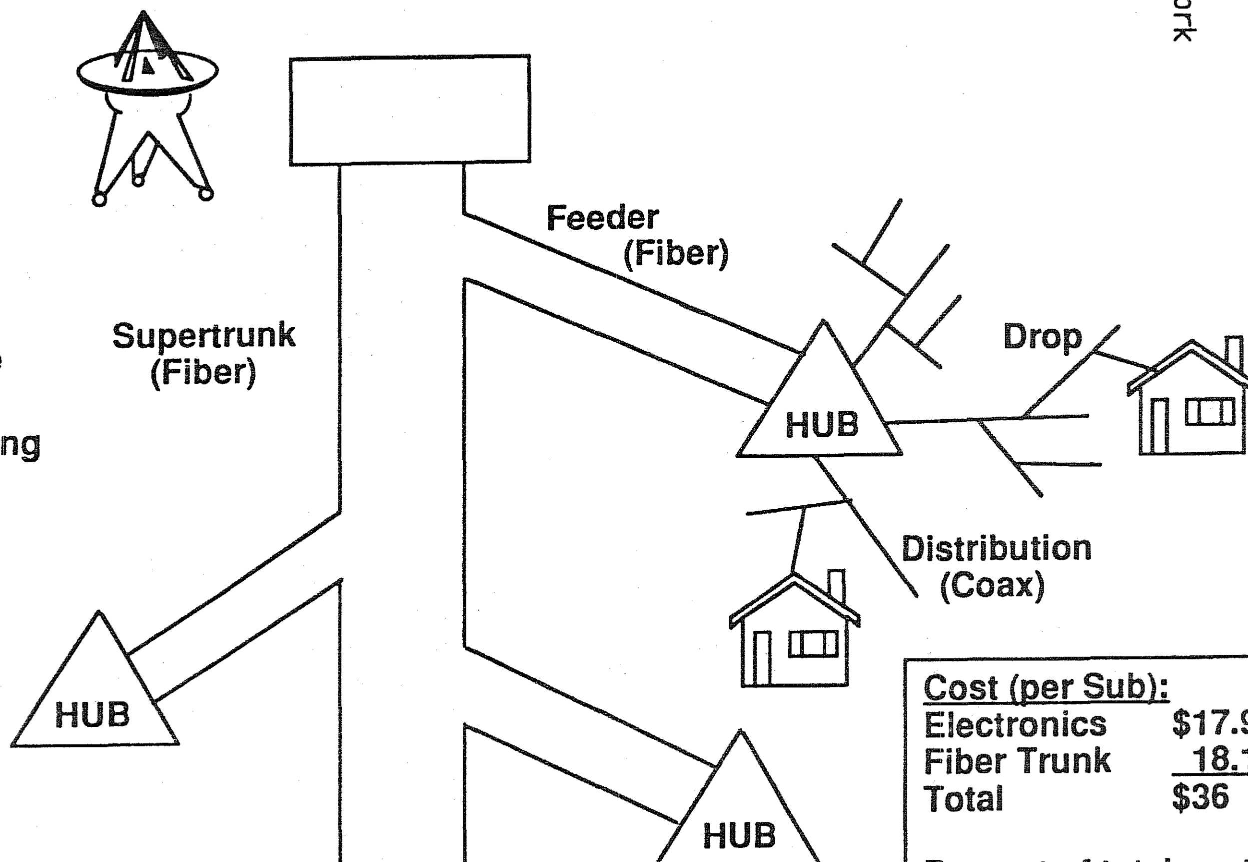
Assumptions

10,000 Subs

375 total miles of plant

51 miles of fiber backbone

The fiber backbone is the only part of the plant being replaced



Cost (per Sub):	
Electronics	$17.9
Fiber Trunk	18.1
Total	$36

Percent of total cost	
Electronics	49.6%
Fiber Trunk	50.3%

* Based on ATC

Reliable cost data are sparse, however some major industry sources put the total per-subscriber costs of FTTC at nearly equal to the costs of new copper access lines.[3] This is not surprising considering the cost advantages of fiber in shared network facilities. The dedicated subscriber portion of the loop makes FTTH so expensive. FTTC allows for sharing of opto-electronic network interface devices and components among many subscribers. In some prototype FTTC systems, telephone companies plan to share remote opto-electronic interface points among four to twelve subscribers.

Telephone companies must deploy FTTC since fiber-feeder backbones simply do not offer much added value for customers. With FTTC, a high-quality broadband capability may be achieved by interconnecting to coaxial cable for the final subscriber loop segment. Initially, only POTS and one-way video will be likely in telephone company FTTC networks, but this is the minimum configuration necessary to match the potential functionality of advanced two-way cable television networks. In fact, as of this writing, almost all BOCs have endorsed a policy of FTTC instead of FTTH for their next generation of broadband-capable subscriber loop plant.

Cable companies as well need to deploy FTTC to be able to match the potential subscriber network functionality of telephone company FTTC. However it is a bit easier for cable companies since the critical (and relatively expensive) last network segment--the subscriber connection--is already broadband coaxial cable. There may be cost effective ways to connect cable fiber-optic backbones to telephone company switched network facilities to achieve a high-quality two-way telecommunications capability. The cost data available to date, however, indicate that cable company FTTC deployment costs could also be quite high at $1,000 per customer and more. One such system which was recently proposed appears in figure 5.5.[4]

Cost of Power

Unlike copper wire, fiber cable cannot carry enough power to run network components. Therefore, the cost of power in a fiber network represents a

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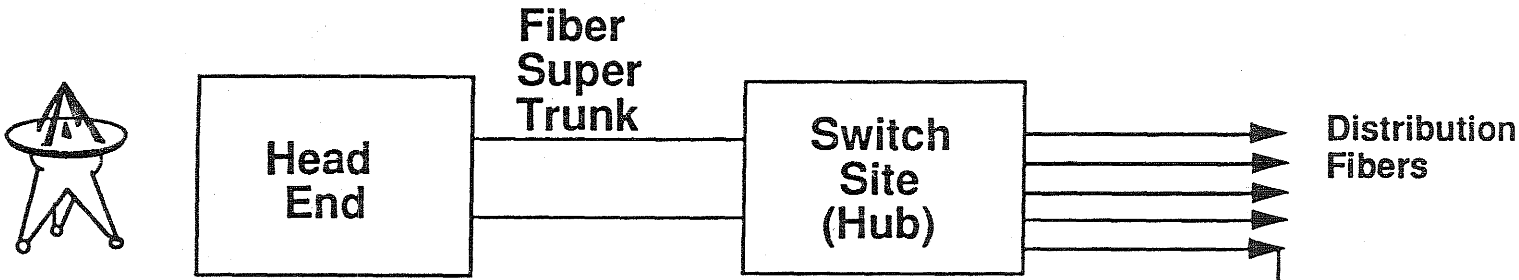
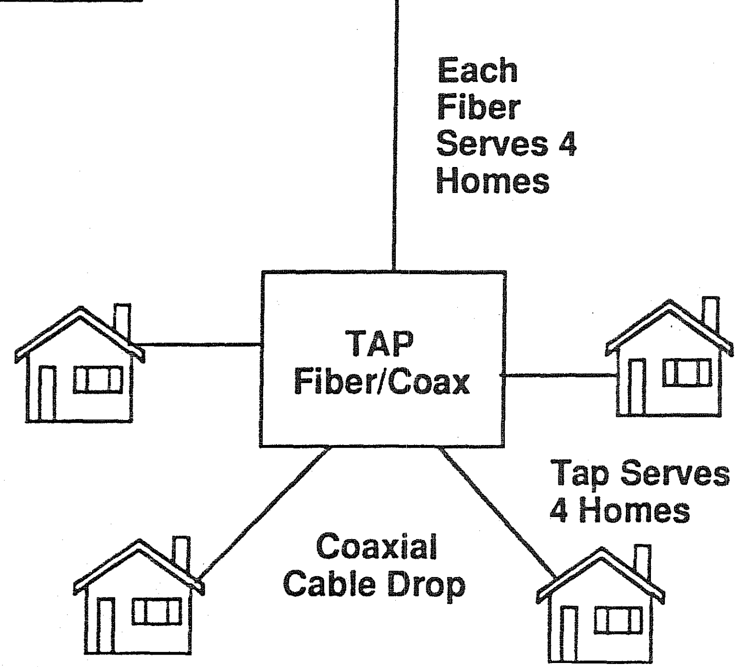
[3] For some FTTC cost estimates and vendors, see "RBOC FTTC Order Signals Start of New Era in Fiber"; "Telcos Say FTTC is Only an Interim Step to FTTH," *The Cable/Telco Report,* May 1990.

[4] Robinson and Grubb, "A High-Quality Switched FM Video System."

Jerrold Labs "System K"





Approximate cost/sub $1000

<u>Assumptions:</u>
Hub serves < 1000 subs.
128 total TV channels
4 TV channels per home
20 digital audio channels
Upstream data link 10 kbs
2-way voice and data
capable, up to T1 rate

Figure 5.5
Jerrold Labs "System K"

significant part of total investment as network performance requirements call for continuous powering of the network. Decentralized electronics require direct connection to local commercial AC power or a separate copper network and backup power must be available in case of commercial power failure. In particular, the optical network interface must have continuous power, regardless of its position within the network. Several studies have calculated the cost of power at different locations within the network. "For a thirty-year life cycle, Goldstein et al.[5] estimate the worth of a watt at the output of the central office serving copper lines to be about $20. Mistry et al.[6] estimate the worth of a watt to be roughly $25 at the [serving area interface] of a digital loop carrier system, and an astounding $165 for a fiber network extending all the way to the home."[7] The costs of powering the optical network interface located at the subscriber premise are identified in figure 5.6. Figure 5.7 provides estimates of the cost of power for different network architectures.

General Cost Guidelines

Before we identify the major cost categories of the generic model in figures 1.1 and 1.2, it is useful to review some "rules of thumb" that represent the average cost relationships:

1) The cost per subscriber for FTTH systems that provide both narrowband and broadband service:

> electronics[8] usually represent one-third to one-half of the total cost of subscriber loop plant.

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[5] M. Goldstein, M. E. Jacobs and J. J. Suozzi, "Worth of a Watt-Implications for Systems and Service Designers," *International Telecommunications Energy Conference*, IEEE, 1978, 387-390.

[6] K. Mistry, T. Taylor, and R. Willis, "Cost of Power-The User's Perspective," Bellcore, Morristown, New Jersey (1989).

[7] Johnson and Reed, "Residential Broadband Services by Telephone Companies? Technology, Economics, and Public Policy," 89-96.

[8] Video switching and control (channel selectors), multiplexers, wave division multiplexers, optical transmitters, optical receivers, power, channel terminals (banks), optical network interface, line cards, circuit packs, line terminals, repeaters (amplifiers).

FIGURE 5.6

CAPITAL COSTS OF POWER SYSTEM TO THE OPTICAL NETWORK INTERFACE
(In dollars)

Power System Component	Cost/Watt/ Subscriber	Description
Power transformer	6.9	Cost of $50 per watt shared over the number of subscribers per pedestal, with 90$ power efficiency [(50/8(1/0.9)]
8-hour battery backup	8.9	Batteries cost $1/watt-hour assuming a 10-year lifetime and 90% power efficiency [(8)(1)(1/0.9)]
Battery charger	5.0	Constant voltage charger to maintain batteries
ONI converter	5.0	
Power drop wire	5.0	Use the existing copper pair for power delivery
Utility power connection	18.7	Connection from utility pole to the pedestal-shared over the number of subscriber per pedestal [150/8]
Total	49.5	Total capital costs per line per watt for locally powering the optical network interface and providing backup power from the curb

Figure 5.7

INVESTMENT COST PER HOME PASSED OF POWER SYSTEMS WITH ALTERNATIVE NETWORK ARCHITECTURES
(In dollars)

	Type of Network Service			Cost by Network Location (Watt/Line)			
Network Alternatives	Narrow-band	Distrib-uted Video	Switched Video	Central Office $10/watt	Remote Node $15/watt	ONI $50/watt	Overall Total Cost
			Active Double Star				
Digital loop carrier	*			1	36		37
Narrowband on fiber	*			1	45	150	196
Voice and distributed video	*	*		1	60	250	311
IBN	*	*	*	2	75	300	377
			Passive Double Star				
IBN	*	*	*	10		300	310
			Switched Star				
IBN	*	*	*	40		300	340
			Cable Networks				
				ONI	Trunk & Feeder		
Coaxial cable		*			17		17
Fiber backbone		*		6	15		21

> feeder represents approximately one-tenth of total cost.

> loop and distribution represent approximately one-half of total cost.

2) The cost per subscriber for narrowband FTTH systems:

> usually about $1,000 less that FTTH broadband systems.

3) The cost per subscriber for FTTC systems:

> total cost is usually one-third to one-half of FTTH total cost.

> electronics represents one-half to three-quarters of total cost.

> coaxial drop from curb (pedestal) is about $200, twisted-pair copper drop from curb (pedestal) is usually $100-$150.

4) Aerial installations cost one-third to one-half of underground installations.

Model Cost Category Hierarchy

The traditional model for subscriber loop costs is divided into three categories:

1) Central Office
2) Feeder
3) Distribution and Drop

The state-of-the-art disaggregated model for subscriber loop costs developed in this report is divided into six categories where (3) and (4) are components of distribution and (6) is added for FTTH applications.

1) Central Office
2) Feeder
3) Serving Area Interface
4) Pedestal (used in both copper distribution plant and FTTC)
5) Drop (pedestal or pole to customer premise)
6) Optical Network Interface (FTTH) - Subscriber Premises.

In FTTC applications, the optical network interface (OE/EO conversion) is performed at the pedestal. In FTTH applications, the OE/EO conversion may be performed at the optical network interface at each subscriber's home. Each of the six cost categories of the cost model are described below.

Central Office Equipment and Installation

The Central Office category of the cost model is divided further into the following components:

> signal combiners

> video switching and control (for example, channel selector)

> codecs

> optical transmitters

> multiplexers/demultiplexers

  * Broadband multiplexers

  * Voice/data multiplexers

  * Wave division multiplexers

> line interface card (voice, data, ISDN)

> power

In Chapter 6 we present examples of fiber loop applications and identify specific cost data for central office equipment components.

Installation

In most examples, equipment costs are installed first costs which are the total costs of engineering, equipment purchase, and installation for a subscriber area.[9] This is true not only for the central office portion of the cost model, but for other portions of the model as well. Installed first cost is a common economic measure used for copper installations but imposes substantial limitations on this model because it does not differentiate between start-up costs and future costs. In a "media-intensive copper solution," initial installations will be oversized to avoid future placements, often resulting in unused pairs. In contrast, "electronic-intensive fiber solutions allow costs to be spread over time." The modularity of fiber allows

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[9] S. T. Kaish, "An Economic Perspective on Fiber in the Loop," AT&T Bell Laboratories, 1989.

electronics to be added as future growth is required, therefore disposing of the possibility of "stranding unused investment." In addition, fiber has the potential for increasing revenues substantially from advanced broadband service. For these reasons, as well as others, it is argued that net present value measures should be applied in the case of fiber due to the "benefit of deferring the cash flows associated with growth."[10]

In some of our cost examples, however, current and future costs are clearly identified.

Feeder Equipment and Installation

The feeder category of the cost model is divided further into the following components:

> fiber cable

> cable sheath

> inner duct

> splices, connectors

Installations

Since fiber-optic cable requires more time to splice, connect, and test than copper or feeder cable, labor costs are higher. Since this is a significant issue, finding new ways to reduce the complexity of these operations will help control costs. The use of new splicing systems is being considered in order to make outside plant technicians equally comfortable working with fiber or copper. The quality of fiber splicing is sensitive to environmental conditions and variations in preparation. One such system, the Fibrlok, was developed by 3M Corporation. The system "can permanently splice cleared, clean fibers in less than 45 seconds," according to 3M. The product is also effective in extreme environmental conditions.[11]

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[10] Ibid.

[11] Richard A. Patterson, "Fiber to the home? A lot will depend on how you splice it," *Telephony,* June 12, 1989.

Since installation costs for feeder cable are significant, some network models exemplified in Chapter 6 contain cable installation as a separate cost component.

Distribution and Drop Equipment and Installation

This category of the cost model is more complex and is divided into the sub-categories of serving area interface, pedestal, drop, and optical network interface. Each of these subcategories is broken down further into the equipment components that comprise them.

Serving Area Interface

> remote video switching (channel selector)

> multiplexer, demultiplexer

> channel terminal (bank)

> optical transmitter

> optical receiver

> wave division multiplexer

> repeater (amplifier)

> couplers, splitters

> power

> controlled environmental vault

Distribution

> fiber cable

> cable sheath

> inner duct

> splices, connectors

Pedestal

> circuit pack

> optical transmitter

- optical receiver
- couplers, splitters
- line terminals
- connectors
- bridgers
- power

<u>Drop</u>

- fiber cable
- copper cable or coaxial cable (FTTC)
- cable sheath
- splices, connectors

<u>Optical Network Interface</u>

- electronics O/E E/O
- optical transmitter
- optical receiver
- ISDN chip
- ranging protocol chip
- digital/optical - analog/electrical converter
- WDM
- cabinet
- broadband multiplexer
- video codec
- power
- connectors
- circuit packs
- other electronics

Installations

As explained earlier, all costs are installed first costs, unless indicated otherwise in an individual application example.

Operation, Administration, and Maintenance

Field experience with fiber in subscriber loop architectures has not yet reached a satisfactory level to predict the actual expenditure required for OA&M. One study claims that automation of provisioning, assignment, and record-keeping activities will substantially decrease these costs in comparison to copper loops.[12]

Both the cable and telephone industries have accumulated information from studies that estimate OA&M expenses. Once fiber is installed in mass quantity, network performance will be more reliable. Many experts agree that OA&M expense is approximately 15 percent of total subscriber cost today, and that it will be less than 15 percent within a few years.

Southwestern Bell estimates maintenance costs for distribution at $12 a line a year with copper, one-time provisioning costs of $38 and annual costs of $3.50 a line for customer churn. With a FTTH configuration, they estimate no change in provisioning costs, the elimination of churn costs, and maintenance cost declines up to 45 percent or $7 a year.[13]

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[12] Kaish, "An Economic Perspective on Fiber in the Loop."

[13] Linda W. Seale, Robert C. Furniss, and Seth Newberry, "Economics of Fiber in the Loop," Raynet Corp., February 1990.

CHAPTER 6

APPLYING THE FRAMEWORK

We have accumulated data from several network studies and trials. However, the data we received from the RAND Corporation are the most comprehensive and disaggregated. Therefore, we use them in our cost model. In figures 6.1 to 6.6, we present costs for selected FTTH and FTTC architectures. We also present costs for a typical fiber-backbone network.

Cost Database

Figures 6.1 and 6.2 indicate future costs, which are based on the assumption that usage of optical components will be widespread in the 1995-2000 time frame. In figures 6.1 to 6.7 electronic network components are marked up by 40 percent to cover the costs of site engineering, field installation, and acceptance testing.

The network layout for figures 6.1 to 6.5 and 6.7 is as follows:

> underground construction

> 24 remote terminals

> each remote terminal is 3,072 meters from the central office

> 25,600 households served (CO serves as an RT)

> all households subscribe to telephone service

> video applications

- one switched video channel selected from 64 "distributed" video channels or from on demand video.
- 20 percent of video subscribers request access to a second switched video channel with usage equal to one-half the usage on the primary channel.

> 622 Mb/s capacity in the distribution loop to accommodate four high-definition television channels in addition to a narrowband signal

> 10-year life is assumed for electronic components

> 20-year life is assumed for nonelectronic components

Figure 6.1 Active Double Star with Switched Video

This network model exhibits a fully loaded integrated broadband network.

This model:

> assumes a data rate of 155.52 Mb/s (SONET STS-3 rate) for each video signal

> assumes a total data rate of STS-12 to each subscriber, equal to four STS-3 broadband channels

> calls for multiplexing multiple video channels up to a feeder rate of STS-48

> cost is highly sensitive to the cost of broadband multiplexers and depends strongly on subscriber demand for switched video

> total CPE cost per video subscriber is $298

Figure 6.2 Passive Double Star

This model:

> calls for an input signal of STS-1 into the CPE which provide enough bandwidth for one compressed NTSC video channel and voice services (N-IDSN compatible)

> cost of CPE per video subscriber is $351

Figure 6.3 FTTH Narrowband Network

This model:

> assumes a double-star architecture

> cost of CPE per home passed is $167

> optical network interface is placed at the subscriber premises

Figure 6.4 FTTC Digital-Loop-Carrier System

This model:

> places single mode fiber in the feeder portion of the network at multiples of the DS3 rate (45 Mb/s) to carry voice signals from the central office to the RT

> a demultiplexer reduces the DS3 signal at the RT into DS1 signals (1.5 Mb/s) that feed into subscriber line channel banks to distribute the voice signals to appropriate copper wire pairs at the DSO rate 64 Kb/s

> assumes no costs are assigned for the central office switch

> places optical network interface at the RT

Figure 6.5 FTTC Fiber/Copper Narrowband Network

This model:

> places optical network interface at the pedestal

> exploits the high capacity of fiber by sharing transmission facilities over more subscribers in the distribution portion of the network

> creates a segment between the RT and the pedestal for placement of fiber but delays fiber deployment in the drop

> offers a prime alternative for rehabilitation projects where a telco already has a network in place

> connects each fiber from the central office to eight pedestals, each serving eight subscribers on an optical fiber bus

> assumes an output of DS1 signals from the central office to eight pedestals on the fiber

> drop is the same as in figure 6.4

Figure 6.6 Fiber Backbone Coaxial Cable Network

This model:

> assumes the same network layout as the above models except it is more compact-the mean feeder loop length decreases to 1,660 meters

> represents the fiber backbone technology currently being implemented by cable TV companies

> carries sixty-four channels of distributed video with no switched capacity

> can be upgraded to provide switched video services

Figure 6.7 Active Double Star Without Switched Video

This model:

> presents estimates of the costs of providing narrowband and nonswitched or distributive video

> presents savings at the central office, feeder loop, and remote terminal amounting to $261 per home passed

> CPE consumes one less watt of power resulting in a saving of $50

FIGURE 6.1
INVESTMENT COST
FTTH - Active Double Star
1.5 Hours On-Demand Viewing Per Week
60 Percent Video Penetration
(In dollars)

Network Component	Single Item Cost	Total Cost per Home Passed
Central Office Equipment		
Video switching, and control	200/card 100/home	101
Broadband multiplexer, optical transmitter	2,240, 100	40
Voice multiplexer, opt. trans. opt. receiver	1,000, 50, 50	1
Power (central office only)	10/watt	2
Total		140
Feeder		
Single mode fiber	0.10/meter	15
Cable sheath	2/meter	6
Cable installation	12/meter	36
Inner duct	1.15/meter	3
Splice, connector	15, 25	4
Total		64
Remote Terminal (Serving Area Interface)		
Broadband multiplexer, detector	2,240, 120	38
Remote video switching	200/card	11
SLIC (4 subscriber/card) and WDM	112.5/broadband upgrade card, 462.5/narrowband card, 35 WDM	235
Voice multiplexer, opt. trans. opt. receiver	75, 60, 40	105
Power (RT only)	15/watt	74
Controlled environment vault	60,000	59
Total		523
Distribution		
Single mode fiber	0.10/meter	80
Cable sheath	1/meter	40
Cable installation	4/meter	39
Inner duct (per meter)	0.75	7
Connector	25	25
Pedestal/manhole terminal	100	13
Total		204

FIGURE 6.1 (Continued)
INVESTMENT COST
FTTH - Active Double Star
1.5 Hours On-Demand Viewing Per Week
60 Percent Video Penetration
(In dollars)

Network Component	Single Item Cost	Total Cost per Home Passed
Drop		
Fiber, sheath (per meter)	0.10, 0.85	58
Cable installation (buried)	1/meter	24
Splice, connector	15, 25	40
Total		122
Subscriber Premises		
CPE (voice only)		167
Optical transmitter, optical receiver	60, 40	
ISDN chip	15	
Digital - Analog converter	7	
WDM	35	
Cabinet	10	
CPE (video upgrade)		(79 (0.6*131)
Multiplexer	35	
Video codec	80	
Cost of second drop	16	
Hookup and installation	50/home	50
Video subscription (60%)	50/home	30
Power	50/watt	300
Total		626
Total network		1,683
Headend and Jukebox		77
Overall Total		1,760

Source: RAND Corp.

FIGURE 6.2
INVESTMENT COST
FTTH - Passive Double Star
60 Percent Video Penetration
(In dollars)

Network Component	Single Item Cost	Total Cost per Home Passed
<u>Central Office Equipment</u>		
Video switching, and control	200/card 100/home	105
Broadband multiplexer, optical transmitter	1,180, 200	164
Voice optical receiver, WDM	55, 35	11
Power	10/watt	10
Total		290
<u>Feeder</u>		
Single mode fiber	0.10/meter	105
Cable sheath	2/meter	42
Cable installation	12/meter	36
Inner duct	1.15/meter	3
Splice, connector	15, 25	28
Total		214
<u>Distribution</u>		
Single mode fiber	various	14
Cable sheath	1/meter	28
Cable installation	4/meter	39
Inner duct, splice	0.75/meter, 15	9
Fiber splitter, terminal	25/port, 100	34
Total		124
<u>Drop</u>		
Fiber, sheath (per meter)	0.10, 0.85	63
Cable installation (buried)	1/meter	24
Connectors	25	50
Total		137
<u>Subscriber Premises</u>		
CPE (voice only)		182
Optical transmitter, optical receiver	60, 40	
ISDN chip	15	
Ranging protocol chip	15	
Digital - Analog converter	7	
WDM	35	
Cabinet	10	
CPE (video upgrade)		101

FIGURE 6.2 (Continued)
INVESTMENT COST
FTTH - Passive Double Star
60 Percent Video Penetration
(In dollars)

Network Component	Single Item Cost	Total Cost per Home Passed
Multiplexer	25	
Video codec	80	
Video coder	40	
Cost of second drop	24	
Hookup and installation	50/home	50
Video subscription (60%)	50/home	30
AC power outlet, battery backup	50/watt	300
Total		663
Overall Total		1,428

Source: RAND Corp.

FIGURE 6.3
INVESTMENT COST
FTTH - Narrowband Network
(In dollars)

Network Component	Current Cost	Future Cost	Cost per Home Passed Current	Cost per Home Passed Future
Central Office Equipment				
Optical transmitter, optical receiver	750,300	60, 40	1	1
Multiplexer	11,000	1,000	15	1
Power	10/watt	10/watt	1	1
Total			17	3
Feeder				
Single mode fiber	0.20/meter	0.10/meter	5	2
Cable sheath	1/meter	2/meter	3	3
Cable installation	12/meter	12/meter	36	36
Inner duct	1.15/meter	1.15/meter	3	3
Splice, connector	40, 75	15, 25	2	1
Total			49	45
Remote Terminal (Serving Area Interface				
Optical transmitter, optical receiver	750,300	60, 40	1	1
Multiplexer	11,000	1,000	15	1
Line interface unit	193,600	83,600	265	114
Subscriber line card	1,070	110	1,498	154
WDM	100	35	140	49
Power	15/watt	14/watt	45	45
Controlled environment vault	60,000	60,000	59	59
Total			2,023	423
Distribution				
Single mode fiber	0.20/meter	0.10/meter	160	80
Cable sheath	1/meter	1/meter	40	40
Cable installation	4/meter	4/meter	39	39
Inner duct	0.75/meter	0.75/meter	7	7
Connector	75	25	75	25
Pedestal/manhole terminal	100	100	13	13
Total			334	204
Drop				
Fiber, sheath (per meter)	0.20, 0.85	0.10, 0.85	69	58
Cable installation (buried)	1/meter	1/meter	24	24
Splice, connector	40, 75	15, 25	2	2
Total			95	84

FIGURE 6.3 (Continued)
INVESTMENT COST
FTTH - Narrowband Network
(In dollars)

Network Component	Current Cost	Future Cost	Cost per Home Passed Current	Cost per Home Passed Future
Subscriber Premises				
CPE (voice only)		167	1,182	167
Optical transmitter, optical receiver	60, 40			
ISDN chip	15			
Digital - Analog converter	7			
WDM	35			
Cabinet	10			
Hookup and installation	50/home	50/home	50	50
AC power outlet, battery backup	50/watt	50/watt	150	150
Total			**1,382**	**367**
Overall Total			**3,900**	**1,126**

Source: RAND Corp.

FIGURE 6.4
INVESTMENT COST
FTTC - Digital Loop Carrier System
(In dollars)

Network Component	Current Cost	Future Cost	Cost per Home Passed Current	Cost per Home Passed Future
Central Office Equipment				
Optical source, optical receiver	750,300	60, 40	1	1
Multiplexer	11,000	1,000	15	1
Power	10/watt	10/watt	1	1
Total			**17**	**3**
Feeder				
Single mode fiber	0.20/meter	0.10/meter	5	2
Cable sheath	1/meter	2/meter	3	3
Cable installation	12/meter	12/meter	36	36
Inner duct	1.15/meter	1.15/meter	3	3
Splice, connector	40, 75	15, 25	2	1
Total			**49**	**45**
Remote Terminal (Serving Area Interface				
Optical source, optical receiver	750,300	60, 40	1	1
Multiplexer	11,000	1,000	15	1
Line interface unit	193,600	83,600	265	114
Subscriber line card (20% second drops)	67	28	89	37
Power	15/watt	15/watt	36	36
Controlled environment vault	60,000	60,000	59	59
Total			**465**	**248**
Distribution				
Copper pairs and cable	variable	variable	29	29
Cable installation	4/meter	4/meter	42	42
Inner duct	0.75/meter	0.75/meter	7	7
Splices	1.67/splice	1.67/splice	2	2
Pedestal/manhole terminal	50	50	6	6
Total			**86**	**86**
Drop				
Drop cable	0.50	0.50	28	28
Cable installation (buried)	1/meter	1/meter	24	24
Splice, connector	1.67/splice	1.67/splice	2	2
Total			**54**	**54**

FIGURE 6.4 (Continued)
INVESTMENT COST
FTTC - Digital Loop Carrier System
(In dollars)

Network Component	Current Cost	Future Cost	Cost per Home Passed Current	Cost per Home Passed Future
Subscriber Premises (incl. second drop)				
Protective block	30	30	36	36
Hookup and installation	80/home	80/home	96	96
Total			**132**	**132**
Overall Total			**803**	**568**

Source: RAND Corp.

FIGURE 6.5
INVESTMENT COST
FTTC - Fiber/Copper Narrowband Network
(In dollars)

Network Component	Current Cost	Future Cost	Cost per Home Passed Current	Cost per Home Passed Future
Central Office Equipment				
Optical transmitter, optical receiver	750,300	60, 40	23	2
Multiplexer	5,000	500	109	11
Power	10/watt	10/watt	10	10
Total			**142**	**23**
Feeder				
Single mode fiber	0.20/meter	0.10/meter	30	15
Cable sheath	2/meter	2/meter	6	6
Cable installation	12/meter	12/meter	36	36
Inner duct	1.15/meter	1.15/meter	4	4
Splice, connector	40, 75	15, 25	8	3
Total			**84**	**64**
Pedestal (optical network interface)				
Optical transmitter, optical receiver	750,300	60, 40	368	84
Multiplexer	5,000	500	875	88
Line interface (framer)	20	10	14	7
Subscriber line card	50	22	70	31
Power - 8-hour backup supply	50/watt	50/watt	150	150
Total			**1,477**	**311**
Distribution				
Single mode fiber	0.20/meter	0.10/meter	14	7
Cable sheath	1/meter	1/meter	14	14
Cable installation	4/meter	4/meter	39	39
Inner duct and connectors	0.75/meter, 75	0.75/meter, 75	45	20
Pedestal/manhole terminal	300	300	37	37
Total			**149**	**117**
Drop				
Drop cable	0.50	0.50	28	28
Cable installation (buried)	1/meter	1/meter	24	24
Splice, connector	1.67/splice	1.67/splice	2	2
Total			**54**	**54**

FIGURE 6.5 (Continued)
INVESTMENT COST
FTTC - Fiber/Copper Narrowband Network
(In dollars)

Network Component	Current Cost	Future Cost	Cost per Home Passed Current	Cost per Home Passed Future
Subscriber Premises (incl. second drop)				
Protective block	30	30	30	30
Hookup and installation	80/home	80/home	80	80
Total			**110**	**110**
Overall Total			**2,017**	**679**

Source: RAND Corp.

FIGURE 6.6
INVESTMENT COST
Fiber Backbone Coaxial Cable Network
60 Percent Video Penetration
(In dollars)

Network Component	Single Item Cost	Total Cost per Home Passed
<u>Headend Equipment</u>		
Distributed video channels	243,100	10
Optical transmitter	2,500	3
Power	10/watt	1
Total		14
<u>Feeder</u>		
Single mode fiber	0.10/meter	1
Cable sheath	2/meter	6
Cable installation	6/meter	18
Inner duct	1.5/meter	3
Splice, connector	15, 25	28
Total		29
<u>Optical Network Interface</u>		
Optical receiver	500	1
Amplifier, accessories housing	1,750, 100	2
Power	15/watt	5
Total		8
<u>Distribution</u>		
Cable plant	1.6/meter	36
Field electronics	250	22
Passive components	10/connector 50/splitter	19
Underground installation	4/meter	68
Underground circuit	0.75/meter	13
Power	1,000 per 3.2 km	15
Total		173
<u>Drop</u>		
Cable tap, connector	10, 10	20
Cable plant	0.20.meter	5
Cable installation (buried)	1/meter	11
Total		36

FIGURE 6.6 (Continued)
INVESTMENT COST
Fiber Backbone Coaxial Cable Network
60 Percent Video Penetration
(In dollars)

Network Component	Single Item Cost	Total Cost per Home Passed
Subscriber Premises		
Addressable converter	100	60
Hookup and installation	50/home	30
Second converter	100	18
Total		**108**
Overall Total		**368**

Source: RAND Corp.

FIGURE 6.7
INVESTMENT COST SAVINGS PER HOME PASSED
FTTH - Active Double Star without Switched Video
(In dollars)

Network Component	With Switched Video	Without Switched Video
Headend Equipment		
Distributed video equipment	9	9
Video jukebox	68	
Total	77	9
Central Office Equipment		
Video switching, and control	101	20
Broadband multiplexer, optical transmitter	40	13
Voice multiplexer, opt. trans., opt. receiver	1	1
Power	2	1
Total	**144**	**35**
Feeder		
Single mode fiber	15	3
Cable sheath	6	6
Cable installation	36	36
Inner duct	3	3
Splice, connector	4	1
Total	**64**	**49**
Remote Terminal (Serving Area Interface)		
Broadband multiplexer, detector	38	13
Remote video switching	11	5
SLIC (4 subscriber/card) and WDM	235	212
Voice multiplexer, opt. trans. opt. receiver	105	105
Power	75	60
Controlled environment vault	59	59
Total	**523**	**454**
Totals		
Total distribution, drop loop, CPE	**952**	**902**
Total electronics	**1,311**	**1,015**
Total nonelectronics	**449**	**434**
Overall Total	**1,760**	**1,449**

Source: RAND Corp.

Analyzing Construction Costs

Rehabilitation

As previously noted in Chapter 6, the FTTC Fiber/Copper Narrowband Network is a good model application for a rehabilitation project. The FTTC bus architecture is currently being deployed by Ameritech, Bellsouth, and NYNEX. The key supplier to these networks is Raynet.

Raynet has also performed studies to estimate the installed first costs of both FTTH and FTTC architectures. One such study compares "star-to-the-curb" and bus architectures. A community of 116 homes was chosen for the study with 160 active telephone lines. Twenty-nine pedestals were required. Two buses of two fibers each were required. For "star-to-the-curb" twenty-nine fibers were required (one fiber for each pedestal). For the distribution portion of the network, costs and prices appropriate to 1993 volumes were projected in 1989 dollars. Raynet estimated the "star-to-the-curb" installed first cost for the distribution portion of the network at $1,243 a line, and estimated $885 for the same portion of the bus architecture. Raynet claims the lower cost bus system requires a smaller number of fibers, consequently reducing the cost of splicing. Other fibers are not terminated until required for additional services such as video; and the noninvasive coupler does away with the need for splicing at the service access point.[1]

New Construction

The majority of the subscriber loop telco installations involve new construction and the active double star is the most popular architecture being deployed. Most industry experts agree that FTTH will prove economical for POTS only in new construction scenarios by the 1993 to 1995 time frame. FTTH for POTS plus video for existing networks will not be cost effective until much later, sometime between 1995 and 2000. The reason for this estimation is based on the fact that it will be cheaper to provide POTS over fiber and video over a separate coaxial cable network until that time frame. A significant demand for other broadband services aside from cable TV must be realized before a single fiber network for both broadband and narrowband services will be viable.

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[1] Ibid.

CHAPTER 7

QUESTIONS FOR RATE CASES AND OTHER PROCEEDINGS

The questions contained in the three following sections are intended to function as guides to the types of data a commission may need in assessing the broadband deployment plans of jurisdictional utilities and are not necessarily formal discovery questions.

Questions for Telephone Companies

1. Have you or do you plan to deploy coaxial cable or fiber-optic cable in the loop plant for provision of broadband services? A) If so, how much of new construction spending will be for fiber cable in feeder loop plant and how much for subscriber distribution and drop portions of loop plant (annually for the next five-ten years)? B) Is the plan to use fiber-optic cable for feeder and some portion of distribution cable (for example, between the SAI and RT or pedestal) and coaxial cable for the last segment to the subscriber premises? C) If not, what is the relative use of fiber-optic and coaxial cable that is contemplated? D) How much would be spent on associated electronics for central office equipment, remote terminals, pedestals, and subscriber premises equipment owned by the telco? E) What new telco broadband service are contemplated? F) What is the time frame for construction of such facilities? G) How many customers per year do you plan to provide broadband service to for the next five to ten years?

2. Is the primary motivation for your deployment of broadband loop plant for provision of entertainment video services or other broadband services? What are the other broadband services and what are your demand estimates in terms of new revenues per household from broadband services five years into the future?

3. How much do you estimate that the per-subscriber deployment costs of broadband "capable" loops will be (regardless of whether they are actually used for broadband services)? A) What do you forecast the trend in these costs will be (separate by EF&I and OAM)? B) How do these costs compare with copper?

4. The following provides clear demarcation points for residential subscriber loop plant between feeder (CO to SAI) and distribution (SAI/RT/pedestal) and drop portions of subscriber loop plant. Assuming a network configuration of this type, and assuming as well that a digital CO and digital SLC are in place, for the following categories of loop plant, please classify those which are necessary for provision of broadband services (such as cable television), and not for other narrowband services (that is, traditional or new narrowband services): A) For equipment and devices located at CO, RT, pedestal and subscriber premises: WDM, channel selectors, lasers, O/E and E/O conversion devices, optical bridgers, optical connectors, optical mix, channel banks, signal transmitters, receivers, detectors, codecs, line cards, and so on. B) For transmission facilities in feeder, distribution (shared vs. dedicated) and drop: coaxial cable and fiber-optic cable.

5. Would there ever be a need for using coaxial cable in subscriber loop plant unless broadband services to residential customers are contemplated? Is coaxial cable deployment contemplated for anything other than video services?

6. Under what conditions would you deploy fiber-optic cable in dedicated portions of subscriber loop plant? A) Why? B) At what point in the future would fiber optics for dedicated subscriber loop plant prove to be cost justified over copper? 1) For new construction? 2) For rehabilitation? 3) For growth? C) What is the contemplated useful service life of broadband loop plant for feeder and distribution portions? D) How does this compare to new narrowband facilities lives (book and tax lives)?

7. How do you classify fiber-optic and coaxial cable costs when they are used in subscriber loop plant? A) What would it take to separate them into shared feeder, shared/dedicated distribution, and drop categories for tracking purposes? B) How about electronics and equipment and devices used for broadband services like cable television? C) Do you plan to alter your system of bookkeeping to be able to track such costs between those required for narrowband services and those required for broadband service capability?

8. What are the per-subscriber costs for each residential broadband service trial currently underway? A) What are such costs forecasted to be as deployment continues? B) What demand and revenue forecasts have you made for broadband services? C) What is the source of funds for construction and how are they accounted for?

Questions for Cable TV Operators

1. Do you plan to upgrade your system with fiber-optic cable or have you already done so? A) If yes, in what part of your cable network is fiber-optic cable being installed or planned? B) Why?

2. Is your system fully addressable so that you may identify and bill specific households for premium services? A) Is it two way-addressable so that your customers may enjoy pay-per-view- type services? B) If not, when do you expect to upgrade to two-way addressability?

3. Do you plan further network upgrades for some type of two-way signaling and services(s) such as videotex (for example, shopping-at-home), distance learning, data, audiotex or voice? When do you expect to be able to perform such upgrades to offer such services? (Please be as specific as possible)

4. Are you involved in any field trials of new two-way services? A) Do you have any planned? B) If yes, is the local telephone company involved also? C) How are you interconnected with one another? D) Do you have any network schematic diagrams or illustrations of two-way service configurations? E) What type of equipment is required for two-way services on your cable system? F) How much does it cost per subscriber? G) What are your estimates of such costs (or even the trend) over the next five years?

5. Do you believe cable systems will ever evolve to the point of providing some types of two-way services for telecommunications, beyond that which will likely occur for pay-per-view video? A) Do you believe that on-demand video (for example, electronic video library instead of the local video tape store) is a viable service offering? B) If yes, when do you think it would be available to your customers? C) Is there a big future market for these types of services? D) How about two-way voice and data services?

Questions for Equipment Vendors

1. What systems and equipment do you have available for purchase by telephone companies to provide broadband telecommunications services, including traditional cable television-type service? A) Are your systems/equipment complete or must they be used in conjunction with another vendor? B) If so, what part do

you provide and is it necessary to enable a telephone company to provide cable television service?

2. Please answer the same questions in no. 1. above, assuming that the systems or equipment are for sale to cable television companies to provide two-way signaling for voice or data telecommunications services. A) Do your current or planned systems or equipment enable a cable television company to provide two-way voice or data telecommunications service(s)? B) If so, when would such systems/equipment be available in the market to cable television companies? C) What would be required for them to use your systems/equipment assuming you do not provide the entire two-way service capability?

3. What are the facilities and configurations which you recommend in the systems/equipment discussed in your answers to no. 1. and no. 2. above? A) Do you have any schematic diagrams or other illustrations of the services, systems, and equipment referred to in no. 1. and no. 2. above?

4. For each system and/or piece of equipment mentioned above, what is the sales price(s) and service agreement price(s)? A) Are these current or estimated future prices? B) What are the price trends anticipated for these systems/equipment over the next five years (personal opinion and estimates are acceptable)?

5. Have you made any sales or do you have orders for the systems/equipment made above? A) Without revealing customers, how many orders or in-service systems/equipment do you currently have? B) How many do you expect to have over the next five years?

6. Are you currently involved in any field trials with telephone companies to provide cable television service and/or cable television companies to provide two-way data or voice service(s)? A) If yes, are these field trials for business or residential customer service? B) If they are residential, what are your estimates of the costs of providing these types of services on a per household basis? C) What do you anticipate will be the trend in these per household costs in the future?

APPENDIX

This appendix contains tables of cost data found during our survey of publications on cost data. We used the RAND data as an example in our model because their data was the most disaggregated. However, data from other studies will still fit within our model, but they didn't disaggregate their costs to the same degree as RAND.

Projected Per Household Fiber Costs, POTS-Only, 1987-2000
(Constant Dollars)

	1987	1990	1995	2000
Central Office				
Switch	$375	$375	$300	$240
Cross-connect	$150			
Mux-Transm'r	$30	$25	$15	$10
Feeder	$50	$40	$35	$30
Remote Terminal/CEV				
Demux-Receiver	$30	$25	$15	$10
Cross-connect	$150			
DLC	$180	$150	$80	$70
Res. Transceivers	$500	$400	$225	$175
Con'rs &/or WDMs	$400	$350	$175	$140
Enclosure	$170	$170	$120	$100
Distribution				
Fiber	$500	$400	$225	$175
Pedestal	$150	$125	$100	$100
Drop	$250	$225	$125	$125
Ntwk Interface Box	$800	$675	$325	$250
Total Costs	$3,735	$2,960	$1,740	$1,425
Total Loop Costs	$3,360	$2,585	$1,440	$1,185

Projected Fiber Costs, POTS-Plus-Video, 1987-2000
(Constant Dollars)

	1987	1990	1995	2000
Central Office				
Switch	$375	$375	$300	$240
Cross-connect	$150			
Mux-Transm'r	$30	$25	$15	$10
Feeder	$75	$70	$60	$55
Remote Terminal/CEV				
Demux-Receiver	$725	$600	$160	$150
Cross-connect	$150			
Video Dist. Switch	$525	$450	$400	$325
Res. Transceivers	$1,000	$900	$335	$260
Con'rs &/or WDMs	$800	$350	$175	$140
Enclosure	$250	$230	$150	$120
Distribution				
Fiber	$1,000	$400	$225	$175
Pedestal	$250	$175	$100	$100
Drop	$350	$225	$125	$125
Ntwk Interface Box	$2,100	$1,375	$625	$350
Total Costs	$7,780	$5,175	$2,670	$2,050
Total Loop Costs	$7,405	$4,800	$2,370	$1,810

Source: Probe Research

Projected Fiber Backbone Costs, Per Home Passed, 1988-2000

	1988	1990	1995	2000
Overlay Costs				
Transmitter	$19.33	$5.16	$2.58	$1.93
Fiber	$1.72	$1.72	$1.72	$1.72
Installation	$3.08	$3.08	$3.08	$3.08
Receiver	$6.44	$2.58	$1.55	$1.29
Total Overlay Costs	$30.57	$12.53	$8.92	$8.02
New or Rebuild Construction				
Savings				
Installation	$1.54	$1.54	$1.54	$1.54
Amplifiers	$3.68	$3.68	$3.68	$3.68
Total Savings	$5.22	$5.22	$5.22	$5.22
Incremental Fiber Costs	$25.36	$7.31	$3.70	$2.80

Cable Television Fiber to the Home, Cost Per Subscriber, 1990-2000
(Constant Dollars)

	1988	1990	1995	2000
Cable Penetration		65%	70%	78%
Fiber Backbone				
Transmitter		$7.87	$3.70	$2.48
Fiber		$2.63	$2.47	$2.21
Installation		$4.70	$4.42	$3.94
Receiver		$3.94	$2.22	$1.65
Total Backbone		$19.14	$12.81	$10.28
Distribution				
Transmitter		$763.64	$448.59	$192.25
Fiber		$305.45	$251.21	$192.25
Receiver		$763.64	$466.53	$256.34
Star Coupler		$38.18	$26.92	$19.23
Total Distribution		$1,870.91	$1,193.25	$660.07
Coax Drop		$100.00	$100.00	$100.00
Total Cost		$1,990.05	$1,306.06	$770.35

Source: Probe Research

Cable Television Fiber to the Home, Cost Per Home Passed, 1988-2000
(Constant Dollars)

	1988	1990	1995	2000
Cable Penetration		65%	70%	78%
Fiber Backbone				
Transmitter		$5.15	$2.58	$1.93
Fiber		$1.72	$1.72	$1.72
Installation		$3.08	$3.08	$3.07
Receiver		$2.58	$1.55	$1.29
Total Backbone		$12.53	$8.92	$8.02
Distribution				
Transmitter		$500.00	$312.50	$150.00
Fiber		$200.00	$175.00	$150.00
Receiver		$500.00	$325.00	$200.00
Star Coupler		$25.00	$18.75	$15.00
Total Distribution		$1,225.00	$831.25	$515.00
Coax Drop		$100.00	$100.00	$100.00
Total Cost		$1,337.53	$940.17	$623.02

Source: Probe Research

ATTACHMENT

Cost Projection Model for Combined Transport System

Experience Curve Concept

To investigate the potential evolutionary patterns for combined transport systems, a simple cost projection model was developed using the concept of experience curves.

Experience curves rely on the observation that over time and across many industries, constant dollar costs decline with accumulated experience, frequently described as volume doubling. This phenomenon is descriptive, in that it is empirical.

Using experience curves for predictive applications requires qualifiers. First, when applied to physical items the technique does not allow for improvements in functionality over time. This is of particular importance in the case of fiber optics. Systems today have many times the functionality of past systems, as well as lower costs. Also, the effect on costs is caused not by increased volume, but by increased investment in technology which leads to lower costs. Many product classes have "gotten off" the learning curve by failing to keep up in manufacturing and product technology. Finally, since the learning curve relies on accumulated experience, the power of its application declines when the rate of accumulation declines.

Cost Categories Included

In this investigation, components of several kinds of residential fiber optic systems have been priced out based on projected price levels for 1988 at high levels of aggregation. Major sections of the analysis were:

- Central office/head end. Equipment needed to support the video distribution systems, exclusive of local access studio equipment and other common items. Voice facilities were not included.

- TV switch and remote terminals. Equipment and site costs associated with TV switching when required. Site costs are estimated for remote terminals based on $100,000 per site.

- Optoelectronics. Electronic items needed for the system: lasers, light emitting diodes, detectors, couplers, etc.

- Cable and splices. Hardware costs associated with the passive cable plant. Includes cable, splices, splice housings, connectors, termination boxes, etc.

Source: Corning

- CPE and drop cable. Hardware costs associated with the final drop into the home. Includes drop cable, customer electronics, key pad, in-home distribution cable, etc.

A series of assumptions was made regarding projected penetration of these early high-cost systems. Relying on the predictive application of experience curve techniques and on the assumed volume, projected costs were established for units at the end of the forecast periods.

Sensitivity Analysis

In order to investigate the influence of changing assumptions, three variations of the basic model were completed. We rounded to the nearest full percent.

In the first case, the influence of early acceptance of the technology was simulated by increasing the early penetration from 10% to 25% of the new construction over the period 1990-1995. This had the result of lowering the early system costs by 13%.

Next the impact of improved later acceptance was evaluated by changing the later penetration from 2% to 5%. This had no impact on early costs but resulted in an improvement to the base case of 14% in later costs.

Next, the potential impact of improved technology as reflected in a better experience curve rate was simulated by lowering the rate about 6%. This resulted in an improvement in the early costs of 9% relative to the base case and of 14% in the later cost.

Finally, we did a simulation in which all three factors were assumed: increased early penetration, increased late penetration, and improved technology. This produced substantial gains: a 24% reduction in average per-subscriber costs in 1995 to $1,700, and a 23% drop in 2000 to $1000 compared to the base case. Cost reductions of this magnitude illustrate the potential beneficial impact of a regulatory policy framework that is especially effective in allowing the proliferation of combined transport systems.

Source: Corning

Summary of Results

Cost Per Subscriber

		1988	1995	2000
Base case				
Double star		$4,400	$2,100	$1,200
Single star		5,100	2,500	1,300
Bus		4,200	2,200	1,600
	Average	$4,600	$2,300	$1,400
Early penetration				
Double star		$4,400	$1,900	$1,200
Single star		5,100	2,100	1,300
Bus		4,200	2,000	1,600
	Average	$4,600	$2,000	$1,400
Later penetration				
Double star		$4,400	$2,100	$1,200
Single star		5,100	2,500	1,100
Bus		4,200	2,200	1,400
	Average	$4,600	$2,300	$1,200
Cost reduction rate				
Double star		$4,400	$1,900	$1,100
Single star		5,100	2,200	1,100
Bus		4,200	2,100	1,300
	Average	$4,600	$2,100	$1,200
Combined effect				
Double star		$4,400	$1,600	$1,000
Single star		5,100	1,800	1,000
Bus		4,200	1,800	1,000
	Average	$4,600	$1,700	$1,000

(Rounded to the nearest $100)

Source: Corning

Item and Description	Single Item Cost ($)	Average Cost	
		Per Subscriber	Per Home Passed
Headend Equipment			
Video Switching (64X64 Cards)	200/card	60	36
Multiplexer	6.4K	117	70
Microwave Modulator, Coder	2K, 50	246	148
Laser, PIN, WDM	2500, 50, 30	47	28
	Total	470	282
Fiber Backbone			
SM Fiber, Sheath (per meter)	.10, .05	10	6
Cable Installation	10.5	35	21
Inner Duct (per meter)	0.75-1.15	4	2
Fiber Splicing & Connector	20, 27.5	1	1
Power (per watt)	10	33	20
	Total	83	50
Optical Network Interface			
Multiplexer	6.4K	117	70
LED, PIN RCVR, WDM	50, 5.7K, 30	105	63
Video Coder, Codec, Modulator	40, 50	138	83
Reinforced Terminal	300	7	4
	Total	367	220
Coaxial Plant Upgrade			
Amplifiers	1000	219	131
Common Plant Sub-Total	Total	1139	683
Subscriber Installation Cost			
Addressable Converter	125	125	75
Hook-up and Installation	50	50	30
	Total	175	105
Overall Total		$1314	$788

Table 6-1: Average Cost per Subscriber for SCM Fiber Backbone
(Hourly viewing = 1.5, Subscriber penetration = 60%)

Source: Department of Engineering and Public Policy
Carnegie Mellon University

Item and Description	Item Cost ($)	Avg. Cost (600Mbps)		Avg. Cost (2.4Gbps)	
		Per Subscriber	Per Home Passed	Per Subscriber	Per Home Passed
Headend Equipment					
Video Switching (64X64 Cards)	200/card	66	40	60	36
Multiplexer, Coder	1K-10.5K, 50	228	136	191	114
Transmitter, PIN, WDM	50-500, 50, 30	26	16	11	6
	Total	320	192	262	156
Fiber Backbone					
SM Fiber, Sheath (per meter)	.10, .05	186	112	8	5
Cable Installation	10.5	141	85	35	21
Inner Duct (per meter)	0.75-1.15	11	7	4	2
Fiber Splicing & Connector	20, 27.5	41	24	2	1
Power (per watt)	10	33	20	33	20
	Total	412	248	82	49
Optical Network Interface					
Multiplexer	1120-10.5K	227	136	191	114
LED, Detector, WDM	50, 50-300, 30	26	16	3	2
Video Coder,Codec,Modulator	50,40,50	341	204	122	74
Reinforced Terminal	300-500	29	17	7	4
	Total	623	373	323	194
Coaxial Plant Upgrade					
Amplifiers	1000	203	122	219	131
Common Plant Sub-Total		1558	935	886	530
Subscriber Installation Cost					
Addressable Converter	125	125	75	125	75
Hook-up and Installation	50	50	30	50	30
	Total	175	105	175	105
Overall Total		$1733	$1040	$1061	$635

Table 6-2: Per Subscriber Cost for PCM/TDM Fiber Backbone
(Hourly viewing = 1.5, Subscriber penetration = 60%)

Source: Department of Engineering and Public Policy
Carnegie Mellon University

TYPICAL DISTRIBUTION/DROP COSTS (EXAMPLE FOR ONE-FIBER STAR)

Item	Cost Per Subscriber	Totals
Distribution Cable	$ .07/ft. x 1 fiber x 1500 ft.	105
Drop Cable	$ .40/ft. x 1 fiber x 150 ft.	60
Splices	$28/splice x 4 splices	112
Optical Connectors	$70/unit x 2 units	140
Drop Placement	$1.75/ft. x 150 ft.	262
Distribution Placement	$.08/ft. x 1500 ft.	120
Subscriber Interface Box	Mechanical + Power + Install. = 300	300
		1174

150 ft. drop, 1500 ft. distribution, 4 splice points, with singlemode fiber.

Source: United Telecom

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