Brief Engineering Assessment: Cost estimate for building fiber optics to key anchor institutions

Prepared for the National Association of Telecommunications Officers and Advisors and the Schools, Health, and Libraries Coalition
September 2009

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1. Introduction

The following is a brief engineering assessment of the cost of building fiber optics to America's key anchor institutions: schools, health care facilities, and libraries.

The cost and completion time of large-scale fiber optic deployments depend on a wide range of factors, including overall program management, access to the public right-of-way, the quality and quantity of available labor, coordination between the builder and the entities being connected, supply of materials, and the integration of the physical and electronic portions. Successfully operating a fiber network also requires effective governance, a business model, and qualified entities performing maintenance, moves, adds, and changes.

Good planning practices can reduce the risk inherent in large-scale infrastructure projects and help the project owners complete the project cost-effectively and in a way that best suits the people to be connected and served. This document 1) outlines strategies for network deployment, 2) briefly illustrates key cost factors, and 3) provides case studies and approximate deployment costs.

2. Network Costs

Averaged over a large sample size, it is probably suitable to estimate $50,000 as a national goal for per-site construction cost of large networks serving community anchors such as schools, libraries, and government facilities. As this report suggests, the designers of the network should seek opportunities to take advantage of existing fiber and other infrastructure.

However, this cost would be limited to areas where sufficient density (i.e., sites per fiber mile) exists—*urban, suburban, or small town areas where two or more sites, on average, can be reached per mile of fiber.* It would also assume the existence of a national or regional backbone to interconnect the various resulting fiber "islands" (many of which are not currently fiber-connected by any carrier) to provide true fiber speed universally.

Finally, this cost is for a minimum level of "transport-only" networking. In order for a new community anchor network to provide added value over incumbent networks, it is worth analyzing the level of redundancy, network management, and other value-added features that community anchor users require. Depending on the level of network intelligence required, the additional cost may average an additional $25,000 to $50,000 per site.

3. Strategies to Control Construction Costs

A number of strategies have been found to effectively reduce the cost of a network deployment and increase the likelihood of success:

1) Maximize economies of scale
2) Be flexible in choosing specific technical solutions
3) Coordinate network intelligence with users' needs

Maximize Economies of Scale

Constructing a network requires coordinating many moving parts—everything from determining the needs and vision, creating a design, and acquiring funds, to facilitating procurement, selecting contractors, obtaining right-of-way access, preparing the right-of-way, obtaining permits, performing construction, performing restoration, overseeing the work, testing the network, and activating users.

Constructing fiber also requires coordination with entities that are indifferent to or opposed to the network—for example, incumbent telecommunication companies, power providers, and utility companies that control utility poles and conduit and are potential competitors. Those companies may require a new network provider to pay—not only to create space for its fiber optics, but to optimally relocate other utilities on the poles or create other "improvements" in a process known as "make-ready," which may lead to high cost and delay.

Construction may also require negotiation of franchise, right-of-way, pole attachment, and building-entry agreements—in our experience, most local governments that control many of these areas are highly motivated to facilitate the entry of new broadband providers into their communities.

Although the number of separate facets and issues definitely grows with the size of the network, they tend not to grow more than linearly with the number of sites and entities. Therefore, the larger the network implementation and the larger the user base, the less complexity there is per user—and the more optimal is the use of resources.

It is also significant that a larger "player" in the right-of-way tends to have more leverage over other entities in the right-of-way, such as other utilities, regulators, and building owners. Therefore a project that serves an entire city or region, with powerful stakeholders in government, may be better able to move roadblocks than one that will serve only a few buildings or one type of user. For example, a larger entity may be able to have a skilled and experienced group of government professionals dedicated to "expediting."

In addition to the political advantages of being a larger entity, most network construction projects have shown economies of scale for most aspects of planning, buying, and building networks (see below—Cost Factors). From a merely logistical perspective, the program manager of a large-scale project can reassign workers to other tasks if there are unexpected impediments in a particular area. In a smaller-scale project, the workers may need to stand idle, or the plan redesigned.

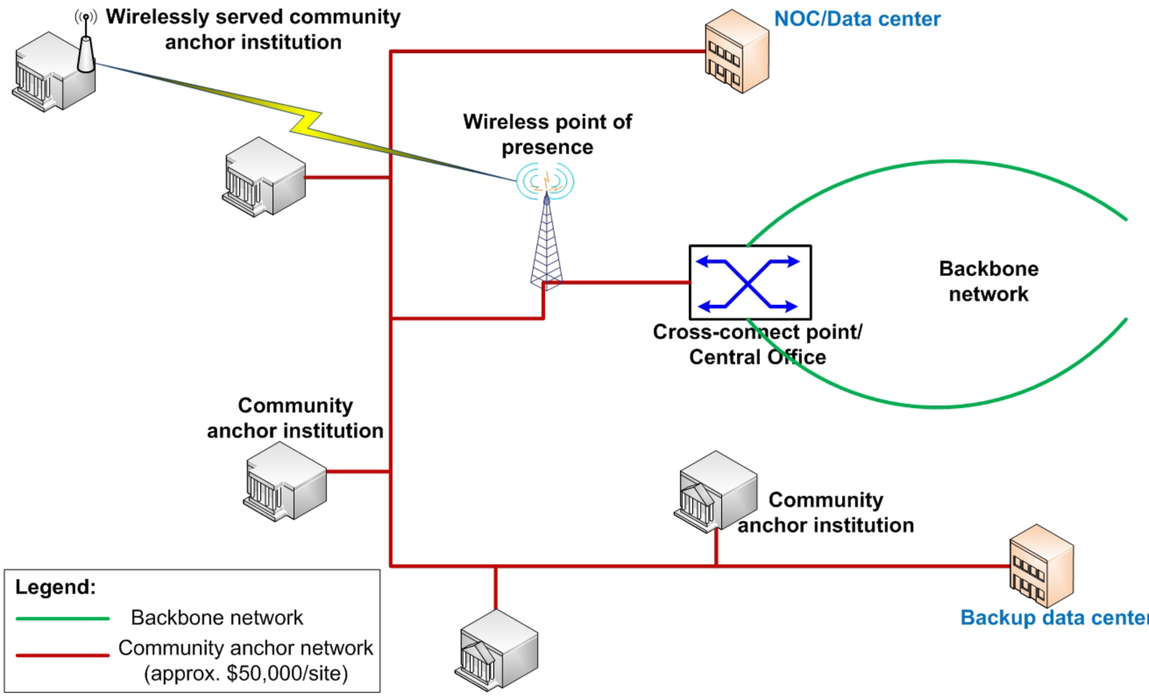
Be Flexible in Choosing Specific Technical Solutions

In almost any fiber optic construction project, there are "outlier" locations that cost significantly more than others or create exceptional risk of delay or other uncertainties. This can be because of distance, anomalous construction circumstances (obstructions, road or rail crossings, historical area, or other conflicting construction), or uncooperative building owners.

Because of these outliers, it is not unusual, in the first stage of a fiber project, to have 50 percent of the proposed construction cost assigned to serve the most costly 10 percent of the locations. It would be more beneficial to the project to cost-effectively and expeditiously serve the first 90 percent of locations, however, and serve the costly 10 percent in a second phase.

One solution is to have a "Plan B," such as a wireless system or a virtual private network, to accommodate those difficult locations, at least for a temporary period (Figure 1). Depending on the location of the locations to be served, adding a construction "Plan B" can reduce the construction cost of a network first phase by 50 percent and significantly reduce the risk of delay. It may also be possible that the extra time could be used to find other users or partners that would make fiber construction more cost effective, on a per-user basis, to the outlier locations.

Figure 1 – Community Anchor Network



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Coordinate Network Intelligence with Users' Needs

Networks are growing in the features and flexibility they offer, and a cost estimate and design should incorporate the appropriate level of features and "smartness." Owning and operating the physical network and electronics, end-to-end, gives the operator wide latitude, including the ability to dedicate levels of physical and electronic redundancy to sites, have complete knowledge of the degree of network security, determine where and how to connect to the Internet and other outside networks, manage intrusion detection, and determine how quickly service will be restored if fiber is cut or other problems emerge. It also enables the operator to determine what service and capacity levels to offer and perform its own upgrades on network architecture and electronics.

Some networks operate multiple networks within each network—offering public safety grade, medical/HIPAA grade, private network, and public network security over the same physical platform. The type of service can be assigned at the port or user interface at the site. Some network operators are also combining their services with other value-added services customized to the user group, including data and server mirroring across a metropolitan area or national network, hosted virtual presence or video conferencing, turnkey telecommuting and telemedicine, national Intranet access, direct access to state and federal networks, and peering with service providers. Other networks are firmly limited to "transport only," providing only a "pipe" and perhaps Internet access, with the users responsible for any other needed features.

When the network designer and operator understand the unique needs of their users and customers, the network design can incorporate particular features, such as data centers, ring topology, options for very high capacity links, and network segmentation. When these needs are known up-front, the network operator can incorporate those features and a reasonable upgrade path, yet not require costly over-engineering. The network operator can also consider the needs of its users in subsequent generations of network electronics upgrades and reconfiguration.

The network designer must include the cost of the added network intelligence, beyond mere transport. Depending on the degree of need and architecture, the additional cost of the intelligence can be 25 percent to 100 percent beyond the cost of the construction and site electronics.

4. Cost Factors

Any planner or designer with years of experience in fiber optic projects will report a wide range of unit costs for construction. However, understanding some general factors will help understand and anticipate these costs.

Labor

Labor forms the majority of the cost of construction—approximately 50 to 80 percent. Therefore the quantity of fiber strands and cables, a materials cost, is typically a secondary consideration.

Labor costs are highly variable. Affluent areas have significantly higher labor costs in all categories, for example. And while poor economic conditions may lead construction companies to reduce their fees,[1] the companies may increase their bid rates if there is suddenly high demand for immediate construction. In general, large-scale ventures have an advantage in managing costs, because construction companies feel comfortable offering lower rates when they expect to profit from the volume and duration of a project.

Mobilization of Contractors

There is considerable time and expense in beginning construction work. Even with a completed design, the network builder must develop detailed specifications, find a potential pool of contractors, issue bid documents, review bids, select contractors, order materials, and prepare the right-of-way. The network builder will also need to go through its procurement process and legal reviews. The added expense is usually borne by the entity managing the network build—directly through the staff and engineering time, and indirectly through costs built into the rates of the building contractor.

Therefore, to the extent that it can have a single start and be managed through a single entity, a network project can minimize the time and expense spent on mobilization.

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[1] "Strategies to Control Construction Costs: More Bang for the Stimulus Buck as Firms Clamber for Contracts," Eric M. Weiss, the Washington Post, April 8, 2009, http://www.washingtonpost.com/wp-dyn/content/article/2009/04/07/AR2009040703828.html, accessed September 13, 2009.

Aerial Versus Underground

Typical construction is a mixture of aerial and underground techniques, in part because aerial construction also is more vulnerable to extreme weather, particularly in wooded areas and areas with frequent ice and high winds.

In many cases, a network can be built more cheaply using aerial utility poles. This is particularly true when the poles are not crowded, and when the network builder has ownership of the utility poles (construction by power and utility companies). Best case, aerial construction can be completed for $25,000 per mile. Aerial construction may be more expensive when poles are crowded or when the utility pole owner charges high rates for access. Worst-case costs can be $100,000 per mile (which usually would lead a network owner to build underground or over another route).

Underground construction also has a wide cost range. In areas where restoration is not important and long continuous runs are possible (e.g., rural areas, in dirt, on the side of interstate roads), "plowing" the fiber into the ground is an inexpensive option—approximately $70,000 per mile. In more built-up areas, directional boring is necessary, because it is less destructive to the right-of-way and requires less restoration. Boring is more expensive, approximately $90,000 to $400,000 per mile. Boring also limits the amount of cable and conduit that can be built. (Two 2-inch conduit is a typical limit, corresponding to four medium-sized fiber optic cables.)

Density of Sites

As noted above, unit construction costs are per mile, not per site. A high density of sites enables more sites to be reached per mile of construction. Again referring to economies of scale, if more participants can connect to a given mile of fiber, the per-site cost of a network falls substantially.

Ability to Use Existing Infrastructure

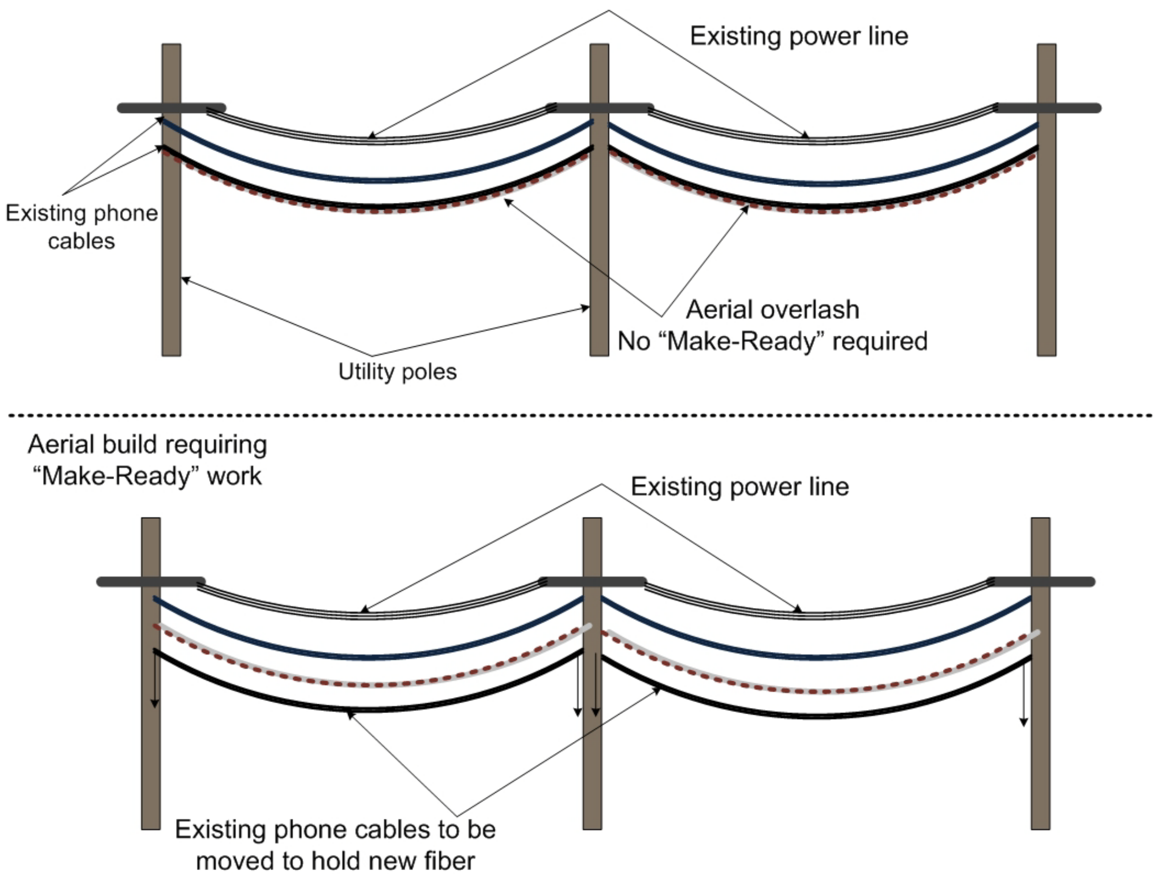
Where it is available, using existing cable infrastructure and pathways offers a range of benefits. There are a number of options for using existing cable infrastructure.

Some communications providers have excess fiber strands. Fiber count in cables ranges from 6 to 24 near residences and individual businesses to more than 1,000 on backbone routes. The cost of a 6-count fiber cable is $2,000 per mile, while an 864-count cable is $50,000 per mile, implying a marginal cost of approximately $50 per fiber per mile. Actual costs for fiber purchase or lease, of course, reflect market costs and depend on the total availability of fiber over the route–and are thus, typically, considerably higher; however, fiber lease or purchase may be a serious consideration over routes where construction is difficult or costly and considerable fiber has already been installed (e.g., river crossings, tunnels).

Utility pole attachments can be loaded with multiple fiber cables in a process called overlash. Overlashing enables a network provider to attach to utility poles without taking up more space (Figure 2). Overlashing requires the permission of the entity being attached and is limited to the loading capacity of the attachment. Some communities have the right of attachment to cable company cables on poles as part of the cable franchise agreement.

Using overlash eliminates make-ready costs and reduces construction costs to approximately $13,000 to $20,000 per mile.

Figure 2 – Overlash Construction Reduces Cost and Utilization of Utility Poles



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Some entities (utilities, service providers, governments) have conduit available for purchase, lease, or trade. Pulling cables through available conduit costs $20,000 to $50,000 per mile, instead of $90,000 to $400,000 for new construction.

Redundancy and Survivability Needed

The specific requirements of the network (e.g., public safety grade, mission criticality, cost of outages) will determine the physical and electronic architecture of the network. For availability above 99 percent (fewer than eight hours of downtime per year), a building will generally need two redundant physical paths from the network to its location, along with an electronic infrastructure to accommodate failure of a fiber route or an electronic component, and backup power of sufficient duration. The network will also need to provide a 24-hour network operations center, a fiber repair crew, intrusion detection, and backup management and recovery facilities.

If network users do not require this level of availability, the network operator should determine their actual current and future requirements, and which subset of survivability and redundancy tools are needed.

Ideally, any needs for physical redundancy will be included in the initial project design. In a network designed with redundancy in mind, each portion of the network is constructed as part of a ring and economical construction is possible. In our urban case study (Section 4), the fiber cost for each site is approximately $23,000, including ring fiber construction.

On the other hand, when redundancy is constructed after the fact, it requires a custom cable pathway, usually doubling (or more) the construction cost.

5. Case Studies

Urban Case Study

One urban community designed and constructed a fiber optic network to reach community anchor and government facilities. It has the following characteristics:

- designed for public safety grade, with almost all fiber in rings;
- the right to overlash fiber to other aerial fiber optic cable in the right of way and to use existing telephone conduit, where it is available
- a citywide footprint, with no location more than ½ mile from existing fiber
- 24x7 network operations center
- On-call fiber repair staff
- In-house engineering and design
- 250 locations connected
- Typical construction costs of $8 per foot aerial and $12 per foot underground
- Individual users segmented into separate virtual private networks
- Available speeds per user from 2 Mbps to 1 Gbps
- Point-to-point services available if fiber is not cost-effective

When the community sought to expand to 220 additional community anchor sites and establish new sub-networks for secure public health and government applications, the city designed additional fiber and rings and planned to enhance its NOC. The cost to expand was estimated at $5,300,000 for the fiber optic cable (providing redundant rings to almost all users), $4,500,000 for network electronics at the new community anchor sites, and $4,900,000 for new core electronics, new network management systems and network intelligence.

On a per-site basis, the average cost for fiber was $24,000, the site electronics was $20,500, and the core electronics, management systems, and network intelligence was $22,300, for a total of approximately $67,000 per added community anchor site.

Small City Case Study

A representative small city constructed a network with:

- Fiber optic ring to key locations, single path to others
- Construction and operation by municipal power utility, which owns all utility poles and has existing underground conduit for most underground routes
- 73 mile of fiber and 84 sites
- Hub buildings inside power substations
- Services from 100 Mbps to 1 Gbps per site
- Repair and maintenance by city

The cost for fiber optic construction was $26,000 per mile for aerial, $173,000 per mile for underground, and $2,208,000 total. The cost of network electronics was approximately $1,000,000.

The average fiber cost per site was $26,300, $38,200 including electronics.