Fiber Optics for Government and Public Broadband: A Feasibility Study

Prepared for the City and County of San Francisco
January 2007

Abstract

San Francisco leads the nation in innovative municipal public service and in private-sector technology innovation. These two phenomena intersect in the path-breaking potential to network every home and business with fiber optics. Fiber represents the holy grail of communications networking: unlimited capacity, long life, and global reach.

This Report evaluates the feasibility of City ownership of a 21st Century fiber network to spur private-sector innovation and competition -- and thereby offer revolutionary bandwidth and services to businesses and residents. The Report recommends a market-friendly model in which San Francisco enables multiple communication companies to compete over a City fiber infrastructure that would reduce barriers to entry.

The Report also integrates a fiber networking strategy for public safety, public health, educational, and other government use. Fiber deployment for internal City use represents an essential next step in government service. The City fiber network would serve as a backbone for networking to the community.

This project confirms San Francisco's status as technology and municipal innovator for the world, placing it among those few cities that have undertaken similar projects, including Amsterdam, Stockholm, Vienna, and Singapore. Other American cities look to San Francisco for leadership and collaboration opportunities on fiber networking

CTC
COMMUNICATIONS ENGINEERING & ANALYSIS FOR THE PUBLIC INTEREST

Columbia Telecommunications Corporation • 10613 Concord Street • Kensington, MD 20895
301.933.1488 • www.CTCnet.us

Table of Contents

1. Executive Summary 1

1.1 The Fiber Project: purpose and scope 1

1.2 Summary of Recommendations 3
1.2.1 Build a Fiber Network to Meet the City's Internal Communications Needs 3
1.2.2 Deploy a First Phase FTTP Network in the City's Enterprise Zone 4
1.2.3 Extend the Fiber City-Wide—With a Competition-Enhancing, Open Model 7
1.2.4 Build Fiber Assets Now for Future Projects 9
1.2.5 Evaluate Regional and Inter-Jurisdictional Approaches 10
1.2.6 Conduct Market Research to Complement this Report 11
1.2.7 Survey Potential Industry Partners to Complement this Report 11
1.2.8 Explore Private-Sector Partnerships for Infrastructure 12
1.2.9 Coordinate Infrastructure Construction With Sidewalk Renovations 12

1.3 Users and Stakeholders: How might the network be used? 12

1.4 The Broadband and Competitive Context 15
1.4.1 The City Lacks Competition in Provision of Broadband "Pipe" 15
1.4.2 Existing Networks Cannot Offer Very-High Speed Broadband 16

1.5 Report Methodology 19

1.6 San Francisco's Fiber and Wireless Projects Distinguished 22

2. Assessment of Internal City Needs 23

2.1 City Agencies 24
2.1.1 Department of Telecommunications and Information Services 24
2.1.2 Municipal Transportation Agency 30
2.1.3 Department of Public Health (DPH) 33
2.1.4 Public Safety Services Division 36
2.1.5 Public Utilities Commission 38

2.2 Selected Non-City Users 39
2.2.1 San Francisco Unified School District 39
2.2.2 City College of San Francisco 42
2.2.3 San Francisco State Univ.–Digital Sister Cities Collaborative Technology Lab 44
2.2.4 Pacific Gas and Electric Company 46

3. Potential to Leverage City Assets for FTTP 47

3.1 Infrastructure 49
3.1.1 Fiber optics 49
3.1.2 Conduit 50
3.1.3 Utility Poles and Pole Attachments 56
3.1.4 Other Physical Assets 57

3.2 Staff Resources/Expertise 58
3.2.1 Network Construction Oversight and Inspection 59
3.2.2 Network Integration 60
3.2.3 Network Monitoring 61
3.2.4 Network Accounting 61
3.2.5 Network Maintenance and Repair 62

3.3 Planned Capital Improvement Projects 62
3.3.1 Sewer and Water 62

3.3.2 Utilities 64
3.3.3 Road Construction and Repair 65
3.3.4 Public Transportation Construction and Repair 66

4. FTTP Case Studies 67

4.1 Seattle 67

4.2 Portland, OR 70

4.3 Amsterdam 71

4.4 Suburban Utah (“UTOPIA”) 74

4.5 Palo Alto 78

4.6 Jackson, Tennessee 81

4.7 Reedsburg, Wisconsin 83

4.8 Brief Descriptions of Selected International FTTP Initiatives 85
4.2.1 Stockholm 85
4.2.2 Denmark 86
4.2.3 Vienna 86
4.2.4 Paris 86
4.2.5 Cologne 87
4.2.6 Brisbane 87

5. Overview of FTTP Technologies 88

5.1 Background 88

5.2 Summary Comparison of FTTP Architectures 89

5.3 PON – Passive Optical Network 92
5.3.1 Architecture 92
5.3.2 PON Transport Equipment 93
5.3.3 Service Support 95

5.4 Active Ethernet 98
5.4.1 Architecture 98
5.4.2 Service Support 100

5.4 Point-to-Point Home Run Architecture 102

5.5 Comparison of Architectures and Recommendation 104

6. FTTP Design and Deployment Cost Models 108

6.1 Fiber Optic Plant Construction 108
6.1.1 Design Model Considerations 108
6.1.2 *Incremental Fiber Construction Cost Components* 112
6.1.3 Fiber Construction Cost Models 115
6.1.4 Fiber Construction Phasing Approaches 122

6.2 Network Transport Infrastructure and Electronics 126
6.2.1 Design Considerations and Assumptions 126
6.2.2 PON Architecture and Cost Estimates 129
6.2.3 Home Run Ethernet Architecture and Cost Estimates 130

6.3 Physical Hub Facility Infrastructure 131
6.3.1 PON Hub Facilities 131
6.3.2 Home Run Ethernet Hub Facilities 132

6.4 Incremental Subscriber Costs ... *133*

6.5 Summary of Cost Estimates ... *134*
6.5.1 Potential Cost Savings through Collaboration of Coordination ... 135

7. Open Access Overview ... 137

7.1 What is Open Access and Why is it Important? ... *137*

7.2 Alternatives for Open Access ... *141*
7.2.1 Open access at What Network Layer? ... 141
7.2.2 Open Access to Which Services? ... 150

7.3 Open Access in FTTP Architectures ... *151*
7.3.1 PON ... 151
5.2.1 Home Run ... 151
7.3.2 Active Ethernet ... 153

7.4 Considerations for Open Access FTTP Network Selection ... *153*

8. Internal Network Business Case ... 155

8.1 The Cost Benefits of a City-Owned Network ... *155*

8.2 The Functional and Technical Benefits of a City-Owned Network ... *156*
8.2.1 City-Owned Fiber Facilitates Control and Management ... 157
8.2.2 City-Owned Fiber Facilitates Availability and Reliability ... 158
8.2.3 City-Owned Fiber Offers Independence from Public Networks ... 159
8.2.4 City-Owned Fiber Enables Control Over Network Security ... 160

9. The Existing Broadband Landscape in San Francisco ... 161

9.1 User Groups ... *161*

9.2 Broadband Market Patterns in San Francisco ... *162*

9.3 Connectivity Options in San Francisco ... *164*
9.3.1 Voice ... 165
9.3.2 Cable Television/Video Programming ... 165
9.3.3 Data and Internet Connectivity ... 166

10. FTTP Financial Analysis ... 170

10.1 Retail Delivery Model ... *171*
10.1.1 Market Share ... 172
10.1.2 Financing Costs ... 173
10.1.3 Operating and Maintenance Expenses ... 174
10.1.4 Summary of Assumptions ... 177
10.1.5 Pricing ... 178
10.1.6 Cash Flow Results ... 178

10.2 Wholesale/Open Access Model ... *179*
10.2.1 Financing Costs ... 180
10.2.2 Operating and Maintenance Expenses ... 181
10.2.3 Summary of Assumptions ... 183
10.2.4 Cash Flow Results ... 183

10.3 Summary Comparison of Retail and Open Access Models ... *184*

10.4 Financing ... *185*
10.4.1 Access Fee Model ... 186
10.4.2 Property Owner Assessment ... 186

10.4.3 Cash Flow Results Under Potential Assessment Financing 186

11. Provider Perspectives 188

11.1 Comcast 188

11.2 RCN 189

11.3 AT&T 190

Appendix 1: Technical Description of Carrier FTTP and FTTN Architectures 192

Appendix 2: Columbia Telecommunications 196

Table of Figures

Figure 1: Proposed Enterprise Zone ... 6
Figure 2: Identified Communications Needs ... 24
Figure 3: MUNI RFID Conceptual Diagram ... 32
Figure 4: SFUSD Network Architecture ... 40
Figure 5: City College Fiber Ring Architecture ... 43
Figure 6: Sebastian Connectivity Overview ... 45
Figure 7: City Fiber Optic Cable In MTA MUNI Conduit and Manhole ... 52
Figure 8: MTA Conduit Under Street With Electric Trolley Line ... 53
Figure 9: MTA Railway and Trolley Bus Routes ... 54
Figure 10: City of San Francisco Public Facilities ... 58
Figure 11: DTIS Public Safety Outside Wire Division Fiber Splicer ... 60
Figure 12: Planned Water System Replacement Projects ... 64
Figure 13: Planned Undergrounding Areas ... 65
Figure 14: Access Network Overview ... 90
Figure 15: Generic PON Architecture ... 94
Figure 16: Active Ethernet Access Network Architecture ... 99
Figure 17: Voice, Data, and Video in an Active Ethernet Access Network Architecture ... 101
Figure 18: Point-to-point Home Run Architecture ... 103
Figure 19: Fiber Topology of Baseline Design Model ... 111
Figure 20: Typical Aerial Installation and Interconnection Internal Wiring ... 114
Figure 21: Candidate Backbone Fiber Topology ... 117
Figure 22: Sample PON Aerial Construction Fiber Design ... 119
Figure 23: Sample PON Underground Construction Fiber Design ... 120
Figure 24: Proposed Enterprise Zone ... 125
Figure 25: Conceptual FTTP PON Hub Site Equipment Configuration ... 130
Figure 26: Conceptual FTTP Home Run Ethernet Hub Equipment Configuration ... 131
Figure 27: Candidate FTTP PON Hub Site Layout ... 132
Figure 28: Candidate FTTP Home Run Ethernet Hub Site Layout ... 133
Figure 29: Example of Open Access to a Selection of ISPs ... 139
Figure 30: Layer 2 Ethernet Open Access to a Selection of ISPs ... 144
Figure 31: Layer 2 ATM Open Access to a Selection of ISPs ... 146
Figure 32: Layer 3 Open Access to a Selection of ISPs ... 149
Figure 33: Layer 1 Open Access to a Selection of ISPs ... 152
Figure 34: High-Speed Connectivity Adoption Curve ... 162

List of Tables

Table 1: Summary of Existing City Infrastructure Assets 48
Table 2: FTTP Access Technology Comparison 106
Table 3: San Francisco FTTP Design Model Cost Summary 135
Table 4: Potential Cost Savings Through Collaboration of Coordination 136
Table 5: Open Access Alternatives 142
Table 6: Access Network Solution Comparison 154
Table 7: Internet Use 164
Table 8: High-Speed Internet Use 164
Table 9: Internet Providers (partial) 167
Table 10: Residential Internet Offerings (partial) 168
Table 11: Business Internet Offerings (partial) 168
Table 12: Retail Model Income Statement 174
Table 13: Summary of Operating and Maintenance Expenses 175
Table 14: Recommended Staffing Levels (Technical) 176
Table 15: Estimated Staffing Requirements 176
Table 16: Base Case (Retail) Net Income and Cash Flow 178
Table 17: Reduced Market Share (Retail) Net Income and Cash Flow 179
Table 18: Open Access Model Income Statement 181
Table 19: Operating and Maintenance Expenses 182
Table 20: Estimated Staffing Requirements 183
Table 21: Base Case (Open Access) Net Income and Cash Flow 184
Table 22: Reduced Market Share (Open Access) Net Income and Cash Flow 184
Table 23: Comparison of Open Access and Retail Models 185
Table 24: Base Case (Assessment) Net Income and Cash Flow 187
Table 25: Reduced Market Share (Assessment) Net Income and Cash Flow 187
Table 26: Comparison of Financing Approaches 187

1. Executive Summary

1.1 The Fiber Project: purpose and scope

San Francisco has embarked on a pioneering program to facilitate provision of state-of-the-art communications services to citizens -- and simultaneously enhance the status of San Francisco as a technology-leader, business-leader, and thought-leader for the world. As part of that program, this Report presents an evaluation of the feasibility of construction and operation of a fiber-to-the-premises (FTTP) network for government and public broadband networking.

San Francisco leads the country and the world in the areas of progressive municipal innovation and private sector communications technology. This project serves to combine the two—and to address San Francisco's potential to enable essentially unlimited and open communications capacity to all residences and businesses.

Our competitor cities in Europe and Asia are increasingly adopting FTTP as the inevitable, essential broadband medium. Municipal FTTP projects are underway or under consideration in numerous major European and Asian cities including Paris, Vienna, Amsterdam, Stockholm, Zurich, Milan, Dublin, Singapore, and Hong Kong.[1]

FTTP is not driven by a need for more television channels; on the contrary, the incredible bandwidth possibilities of FTTP facilitate other goals: innovation, job growth, economic development, environment protection, education, and community development.

High-bandwidth broadband is widely-recognized a key driver of future economic competitiveness,[2] and is also regarded as a facilitator of political discourse and activity – the most important medium for communication and expression of political ideas since the advent of television.

FTTP is the holy grail of broadband: a fat pipe all the way into the home or business--but in the near future only available for a privileged few located in the limited areas of private-sector deployment.

But private-sector networks[3] are not meeting this growing demand for bandwidth and speed in an affordable manner.[4] Though there are private-sector FTTP deployments

---

[1] These projects span a wide variety of models, ranging from municipal ownership to public/private partnership to municipal attempts to stimulate private fiber builds. A number of these projects and their associated models are presented as case studies below.

[2] The calls for greater broadband deployment come from organizations as diverse as the U.S. Chamber of Commerce, AARP, the National Association of Chief Information Officers, and major equipment manufacturers such as Nortel and Cisco--all of whom recognize that the United States' position as a technological and economic leader require networks that enable growth applications such as teleconferencing, telecommuting, and distance learning.

[3] Reuters, "More Internet traffic, new broadband and mobile services, eating up bandwidth, creating need for optical gear," www.cnetnews.com, accessed September 28, 2006.

underway in some, limited areas of the United States, none is planned or foreseen for San Francisco.[5]

In this context of private sector disinterest, municipal FTTP would rank San Francisco among the world's most far-sighted cities -- by creating an infrastructure asset with a lifetime of decades that is almost endlessly upgradeable and capable of supporting any number of public or private sector communications initiatives. For example, it can:

- Promote private sector competition – by providing a platform for numerous competitors to quickly and inexpensively enter the San Francisco market and offer competing, differentiated broadband services and access.

- Facilitate democratic and free market values – FTTP would enable San Francisco to create an open*, standards-based Internet platform for all comers*-- at the same time as the cable and phone companies are entrenching their closed network models that preclude competitive access to the networks. The incumbents have publicly declared their intention to charge access tolls of third-party innovators and independent IP-based video providers.[6]

- Enhance digital inclusion by facilitating affordable access to this incomparable enabling resource for community groups, students, the elderly, and communities of need.

- Facilitate economic development by
  - Enabling small business creation and growth
  - Enabling job creation and the enhanced, multiplied economic activity that accompanies it
  - Supporting businesses with very high bandwidth needs, such as digital media and software development
  - Attracting and retaining businesses of all sizes
  - Enabling workforce education
  - Enabling telework and distributed work
  - Stimulating economic activity
  - Enhancing the City's reputation for visionary and pioneering projects

---

[4] The services and products available from private-sector providers in San Francisco are discussed in detail below.

[5] In the course of this project, CTC analysts met with representatives of the major wired broadband providers in San Francisco: AT&T, Comcast, and RCN. None of these companies currently has plans for deployment of FTTP facilities throughout the City, although AT&T has a small greenfield FTTP deployment in Mission Bay. The facilities they currently operate or foresee for the future are not comparable to FTTP. Their networks and products are assessed below. Verizon is responsible for the major, private FTTP projects underway in other parts of the country. San Francisco is not within Verizon's service area and, to our knowledge, Verizon has no plans to expand service, either through FTTP or other technologies, to San Francisco.

[6] See Lawrence Lessig, "Congress Must Keep Broadband Competition Alive," Financial Times, October 18, 2006, http://www.feetcom/cms/s/a27bdb16-5ecd-11db-afac-0000779e2340.html, accessed December 21, 2006.

- Promoting major development initiatives such as revitalization zones.

- Provide a highly-reliable, resilient backbone for existing and future wireless initiatives—improving performance and capacity through fiber "backhaul."[7]

- Support current and future public safety and government communications systems—both saving the City the enormous, unending cost of leasing circuits from telephone companies, and simultaneously providing a higher-quality, higher-capacity, more reliable, more secure transport for key City users such as law enforcement, fire, emergency management, and public health.

- Facilitate interoperable communications between San Francisco and other jurisdictions--in the Bay area and throughout the region.

1.2 Summary of Recommendations

The major recommendations offered by this Report include:

1.2.1 Build a Fiber Network to Meet the City's Internal Communications Needs

The City should continue and expand its successful practice of building and operating fiber for its own internal use. The City has already demonstrated significant success with this approach and currently operates approximately 50 miles of fiber optics, serving facilities such as the community colleges, the City government, and public safety agencies.

We recommend further deploying fiber to 250 selected City sites. Based on our assessment of the City's internal needs, we anticipate extensive use of this fiber network by first responders, schools, DTIS, the PUC, the Public Health Department and hospitals, and other City departments.

If the fiber is deployed through "conditioned" conduit on the model of the City's existing fiber network, we estimate a cost of $5.4 million for fiber. We estimate that the City's fiber investment would be recouped in nine years. Significantly, however, this fiber could likely not be used in the future as the backbone for an FTTP network because its use is conditioned on non-commercial purposes.

---

[7] The City's current fiber optic network cannot be used for a public broadband network because it was cost-effectively constructed using conduit that is "conditioned," meaning it cannot be used for non-City applications. This conduit was provided to the City by the private sector under cable franchise agreements (in the case of Comcast and RCN) or under other agreements (in the case of PG&E), generally under the condition that the conduit not be used for commercial or non-City purposes. These conditions are standard in similar agreements throughout the country.

If the fiber is deployed independent of the conditioned conduit, we estimate a cost of $12.3 million for fiber construction. Based on current lease expenditures, we estimate that the City's fiber investment would be recouped in approximately 22 years. It is essential to note that these numbers are extremely conservative estimates because they are based on only the City's current bandwidth use—not on future needs.[8] The City's needs are likely to grow exponentially in coming years, and lease fees are likely to follow suit. A City-owned fiber network would scale with the City's needs, with no additional costs for fiber.

Another way of understanding the value of City-owned fiber is to compare its financed cost to the alternatives. Assuming the City financed the cost of building the network (financing the fiber over 20 years and the electronics over seven years), the annual principal and interest (P&I) payment would be $1.59 million. In addition to the P&I payment, we estimate the annual operations and maintenance costs at $1.05 million per year. This results in an average cost per month of $881 for each of the selected sites. By comparison, comparable functionality from leased services would cost far more than that amount. AT&T's higher-end leased offerings such as OC3 and OptiMAN can address these capacity issues, but the lease costs are prohibitive. For example, fees for OptiMAN[9] service of one Gbps can exceed $10,000 per month per circuit. Assuming the same 250 sites we recommend for the City-owned network, the cost of this service (as an alternative to City-owned fiber) would be $30 million per year *ad infinitum* – compared to a one-time construction cost of less than $16 million (including both fiber and networking equipment) to build the entire City-owned network.

In addition to the obvious cost benefits, the advantage of fiber over existing leased circuits is dramatic: fiber is more reliable, more scalable, more adaptable to emerging needs and applications, and more future-proof. The City's technology lead for public safety communications makes a strong case that the City should not rely on carrier networks for public safety applications and users.[10] The City's public safety technology staff-members do not believe the City can rely on private carriers, who do not prioritize public safety support. For example, when Police Department facilities were connected over leased T1 circuits, it would take up to 48 hours for repairs by AT&T, an unacceptable delay for public safety.[11]

1.2.2 Deploy a First Phase FTTP Network in the City's Enterprise Zone

---

[8] Our payback analysis assumes savings on lease costs for T1 circuits. Significantly, fiber offers tens of thousands of times the capability of a T1 circuit—capability that could likely not be bought on the private market.

[9] Monthly lease fees are dependant upon a variety of factors including desired committed interface rate (CIR), whether repeaters are required, and contract term.

[10] CTC interview with Joseph John, Manager, DTIS Public Safety Services Division, October 5, 2006.

[11] Ibid.

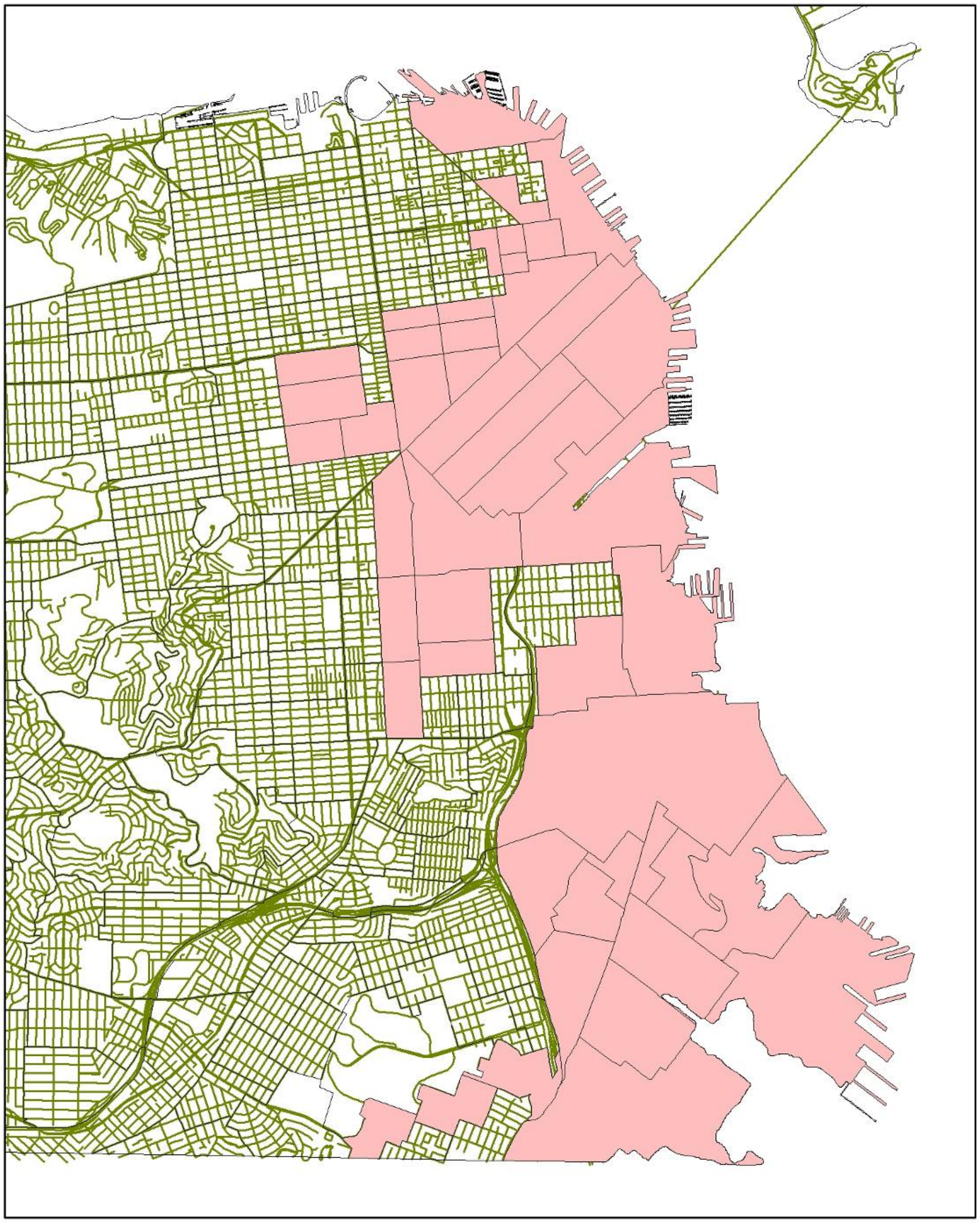
As an intermediate step between the internal fiber network and City-wide FTTP, CTC recommends that the City consider a first phase of FTTP deployment that would deploy fiber to all premises in the area designated by the City as an enterprise zone for purposes of state incentives toward development. This area has been targeted by the City in part because of the disproportionate level of poverty in the area.[12]

We estimate an incremental cost for FTTP construction in key development areas of approximately $150 million assuming a "wholesale" business model (that the City would own the fiber and lease access to multiple service providers, but would not itself provide communications services over the fiber) and Home Run Ethernet network architecture. This construction stage would include all businesses and residents in the proposed San Francisco Enterprise Zone as defined by the Mayor's Office of Economic and Workforce Development, constituting a total of approximately 12 square miles of economic development area including Hunter's Point, Bay View, South Bayshore, Chinatown, Mission District, Mission Bay, Potrero Hill, South of Market, Tenderloin, and Western Addition (Figure 1).

---

[12] CTC interview with Jennifer Entine Matz, Deputy Director Business Affairs, Mayor's Office of Economic and Workforce Development, December 14, 2006.

Figure 1: Proposed Enterprise Zone



1.2.3 Extend the Fiber City-Wide—With a Competition-Enhancing, Open Model

The Report concludes that the City could, at an additional cost of $410 million,[13] build fiber to every home and business in San Francisco – in a cost-effective manner that maximizes the first phase area and internal network described immediately above. In total, including all three phases of construction (internal network, pilot, and City-wide network), the complete construction and activation cost for the FTTP network would be approximately $560 million assuming a wholesale business model and Home Run Ethernet network architecture.

With respect to preliminary business plan, we conclude that a wholesale or "open access"[14] model offers the best balance of technology advancement, infrastructure, future proofing, and encouragement for private sector innovation-- and is thereby most likely to facilitate the goals of the City. Specifically:

- The model is likely to stimulate private efforts to offer diverse, cost-competitive services to residents and businesses. The strategy creates a platform for broadband competition and innovation by separating network ownership from service-provision.

- This model requires less City involvement in operations than does a retail model because it does not require the City to go into the business of providing communications services itself.

- The model leverages the considerable City's right-of-way knowledge and utility maintenance capabilities.

- The model is practical and entails less political risk as well as less financial risk.

- This model allows the customer to select the provider of their choice. In addition, by separating the service from the infrastructure, the current communications monopoly/duopoly is ended and incentives are reduced to limit available capacity and restrict access to and performance of Internet based applications.[15]

---

[13] These figures assume that the network would pass 100 percent of homes and businesses and would include connections to 50 percent of the premises passed—these connections would be installed only in the event that services were ordered—an assumption of 50 percent take-rate.

[14] This Report uses the terms "open platform" and "open access" to refer to networks that allow competing service providers to compete over network infrastructure at competitive prices, assuming: (1) the technical architecture or its configuration enable competing providers to operate without constraints imposed by the network owner for non-technical reasons; and (2) the technical architecture or its configuration precludes the network owner from manipulating or monitoring the content of the data transmissions sent and received by the providers' customers.

[15] In today's model, providers have incentives to discourage or encumber Internet based applications that are alternatives to traditional voice and video services.

- This model is also emerging as the preferred choice for major City FTTP projects in the United States and Europe. [16]

- This strategy also fits well with the technical model proposed below, which recommends a robust fiber architecture to be managed and maintained by the City with competitive service providers leasing capacity on the fiber.

- Finally, the wholesale model requires a smaller capital investment than does the retail model and the limited data available suggest that the wholesale model is more likely to maintain a positive cash flow--to generate enough revenue to meet its own annual expenses--than is the retail model. To maintain a positive cash flow, a substantial market share is required. There exist no empirical data that demonstrate that the City can expect to obtain and sustain the numbers necessary under a retail model.[17] Rather, our analysis suggests that, in a market like San Francisco, the probability of obtaining the required market share to maintain cash flow is higher with the open access model because multiple providers will promote and sell services—not just the City.[18]

To implement this business plan, we recommend an established, standards-based technology known as Ethernet for deployment of this network over a "Home Run" fiber topology. This technology enables the standard mass-produced Ethernet equipment used in homes and businesses to be used in a Citywide network. Home Run Ethernet is being deployed by the Amsterdam FTTP network and other municipal service providers. It is particularly attractive for a wholesale deployment, because it enables individual retail service providers to directly reach customers over dedicated fiber optic strands from FTTP hub facilities in each neighborhood.

Ethernet technology has increased in speed by a factor of more than 100 over the past ten years and remained approximately constant in cost. It has been widely-deployed in home networks, business networks of all sizes, and carrier networks. Its wide adoption at all levels of the industry and well-matured standards have resulted in low hardware costs, widespread availability of related expertise, and continued development of faster and more functional versions. It is likely to continue to improve in quality, decline in price, and be eminently upgradeable as bandwidth needs increase in the coming years.

---

[16] This model is preferred, for example, among many of the major cities that are implementing or considering FTTP, including Stockholm, Amsterdam, the Danish TRE-FOR Network, UTOPIA (suburban Utah), Seattle, and Portland, OR. An endorsement by many of these cities and others was signed in November, 2006 in the context of the International Network of E-Communities (INEC) Declaration on Open Networks. See www.i-nec.com, accessed November 29, 2006.

[17] As is discussed below, CTC therefore strongly recommends that the City undertake market research to try to determine potential market interest and penetration rates.

[18] It is important to note that the business case for FTTP is not limited to such easily-quantified matters as cash flow and capital investment—rather, the business case for such a network also includes the less quantifiable financial factors, including economic development, small business empowerment, job creation, livability, environment protection, education, increased sales tax and real estate tax revenues, increased property values and other factors that measure the overall benefit of a next generation communications infrastructure such as FTTP.

Ethernet supports a wide range of deployment architectures, including the Home Run fiber topology we recommend, which offers the greatest flexibility for technology selection, models for open access, and overall greater capacity. It also minimizes the practical and aesthetic impact on the public right-of-way relative to other communications technologies.

1.2.4 Build Fiber Assets Now for Future Projects

Opportunities for cost-effective installation of fiber arise each day as City crews work in the right-of-way. At a minimum, San Francisco should immediately adopt a future-looking policy to add to existing fiber and conduit infrastructure at every opportunity to build up critical mass. Every municipal project has the potential to provide long term cost savings on communications infrastructure.

Conduit and fiber are the key for future-proofing the City's infrastructure. There is a low incremental cost to install fiber or conduit during any capital improvement project or repair. We therefore recommend speedy adoption of a Citywide policy and detailed specifications for installation of fiber optics during any relevant capital improvement project or repair, including:

- Road construction or repair by the Department of Public Works (DPW)
- Sewer or water line replacement or repair by the Public Utilities Commission (PUC)
- Electrical work by the PUC
- Sidewalk repair and replacement by DPW
- Relocation to underground of aerial utilities by Pacific Gas & Electric (PG&E) and other utilities
- Other open trenching opportunities initiated by private utilities
- Any other circumstance under which any City department is working in the right-of-way.

Immediate adoption of a fiber-placement strategy would capture each of these opportunities.

Similarly, the City should develop uniform requirements and procedures for using commercial carrier construction to simultaneously install fiber or conduit, or negotiate conduit or dark fiber during permitting. Every private sector project in the right-of-way offers an opportunity for partnerships.

The City's PUC is developing a strategic plan for sewer replacement, for total replacement of the City sewer system over a 100-year period. First, the requirements and procedures should enable the City and commercial carriers to coordinate FTTP conduit construction with the sewer replacement. It is also potentially useful for the City to consider placement of FTTP or internal network infrastructure in storm sewers. However, it is important to note that a storm sewer system does not have ready access to the surface as often as is necessary for service to homes and businesses. As a result, sewers themselves have the greatest potential for internal network and FTTP backbone fiber, which do not require access to as many points on the surface.

1.2.5 Evaluate Regional and Inter-Jurisdictional Approaches

CTC recommends that San Francisco explore the possibility of multi-jurisdictional FTTP and Institutional Networking projects, in light of the possibilities of realizing economies of scale with respect to equipment, construction, operations, and services.

With respect to the City's internal communications needs, fiber interconnection with other Bay Area jurisdictions is likely to become more essential with the passage of time and almost certainly represents the next step in government networking. The City's public safety community is already working on microwave interconnection with neighboring jurisdictions,[19] and would gladly use fiber interconnection as a high-bandwidth means of linking to first responders in other Bay Area localities.[20] City-owned fiber to remote locations would also facilitate another key public safety goal: remote mirroring and backup of City data and a backup emergency communications center.[21]

With respect to FTTP, other West Coast cities raise the possibility of tying West Coast cities together with fiber and of maximizing economies of scale and negotiation leverage by collaborating on FTTP projects. The Cities of Seattle, WA and Portland, OR[22] have expressed an interest in collaborative approaches with San Francisco--both note the potential leverage a combined approach would give this group of cities in negotiations with potential providers or vendors.[23] Both have suggested an immediate joint meeting among the senior staff-people working on each city's FTTP project.

A comparable effort is underway in Europe, where some of the major cities planning FTTP projects have undertaken an effort through Eurocities to link "smart" cities throughout Europe.[24]

---

[19] CTC interview with Joseph John, Manager, DTIS Public Safety Services Division, October 5, 2006; Ian Hoffman, "Proposal Tuned in for Radio Network," Oakland Tribune, July 25, 2005.

[20] CTC interview with Joseph John, Manager, DTIS Public Safety Services Division, October 5, 2006. A comparable, major regional interoperability project is underway in the Washington, DC metropolitan area, where 19 jurisdictions are interconnecting their public safety networks over fiber-optics under a grant from the US Department of Homeland Security (DHS). DHS funding for urban area projects is generally premised, among other things, on regional approaches**.** "A giant leap for first response," Washington Technology, November 27, 2006.

[21] CTC interview with Joseph John, Manager, DTIS Public Safety Services Division, October 5, 2006.

[22] Specifically, the Seattle Office of Broadband and the Portland Office of Cable and Franchise Management, both of which are lead agencies on their cities' FTTP project.

[23] The perspectives of these cities are presented below.

[24] Eurocities is a consortium of 123 major cities in 32 European countries. Eurocities' "Broadband Manifesto" calls for widespread deployment of fiber and for "Trans-National, Interconnected Open Broadband Networks." Eurocities Broadband Manifesto: Ensuring the Infrastructure for the Knowledge Economy, http://www.telecities-

Both Seattle and Portland have expressed interest in such a model on the West Coast of the United States, and potentially beyond. Seattle's Broadband Director presented that vision in a speech to the Washington, DC metropolitan area Council of Governments: "we should consider what it would take to connect Seattle to Portland and Portland to San Francisco and San Francisco to the Washington, DC area, and from there to the world."[25]

1.2.6 Conduct Market Research to Complement this Report

We recommend following up on the results of this Report with in-depth market research of both the residential and business markets. Market data can assist to refine the business case presented in this document by replacing assumptions with statistically-accurate data.

We would recommend a combination of surveys and interviews to estimate market potential**.** The data gathered in this process can be further leveraged at a later time for marketing purposes—both for marketing retail services and for marketing to potential private-sector partners or lessees.

General analysis should focus on discerning patterns and trends. In addition, any subgroups of interest (such as demographic groups) should be individually examined to illuminate areas of similarities and differences. Statistical tests appropriate to the research questions and format of data should be used to identify significant relationships between variables and significant differences between subgroups. Any open-ended responses should be coded and tabulated.

The results will yield qualitative data that can be of significant value.

1.2.7 Survey Potential Industry Partners to Complement this Report

CTC recommends that the City undertake a process to determine the interest of the private sector in leasing City fiber under the model proposed here or otherwise participating in the process of expanding fiber networking throughout the City. This Report already documents the potential interest in collaboration of two of the City's existing wireline broadband providers as well as of Pacific Gas & Electric.[26] Further detail could be elicited either through a formal information request (such as a Request for Information) or an informal survey and interview process. Either of these processes would also enable the City to encourage creative proposals and expressions of interest

---

prague.cz/download/prezentace/broadband_manifesto_eurocities_eplanatory_notes.pdf, accessed December 13, 2006.

[25] Tony Perez, Director, Office of Broadband, City of Seattle, speech presented to the Metropolitan Washington Council of Governments Broadband Regional Forum, Washington, DC, October 30, 2006.

[26] The perspective of these providers, Comcast and RCN, is discussed below, as is the perspective of PG&E.

from a wide variety of potential partners, including financiers, equipment manufacturers, construction firms, systems integrators, Internet service providers, and the public.

Among other areas, such a process could elicit such information as:

- Availability in the current market of financing for municipal fiber construction, including potential terms and conditions
- Specific pricing for construction, equipment, and integration services
- Interest in leasing dark fiber on the part of existing and potential service providers, both facilities-based and not, as well as financial parameters
- Public and community group interest in FTTP

1.2.8 Explore Private-Sector Partnerships for Infrastructure

CTC recommends exploring a partnership with service providers with existing conduit in the public right of way. Specifically, both Comcast and PG&E have significant conduit infrastructure and spare conduit. Presently the City has access to spare Comcast and PG&E conduit, but under strict conditions, such as that it not be used for non-governmental purposes.

If the City is able to reach agreement on another level of collaboration with one of these providers, it may be possible to significantly improve the economics of a City fiber build.

1.2.9 Coordinate Infrastructure Construction With Sidewalk Renovations

The City is in the process of replacing sidewalks. The sidewalks are potentially an asset in FTTP construction. For example, the Amsterdam FTTP network is locating the majority of its fiber optic cable infrastructure underneath city sidewalks.

CTC estimates that up to ten percent of underground construction costs, approximately up to $23 million, could be saved by installing FTTP cables in coordination with sidewalk renovation. The savings would require a change in the sidewalk renovation program, requiring that the renovations be coordinated with a fiber optic build plan, both in timing and that the areas repaired be geographically contiguous. The current plan is to replace City sidewalks over 25 years, and this plan would require accelerating the repair to the FTTP build schedule.

1.3 Users and Stakeholders: How might the network be used?

How might the network be used? A few brief case studies illustrate FTTP’s inexhaustible possibilities for innovation and public benefit.

- **Targeted Neighborhood Economic Development:** The enterprise zone includes the area known as Multi-Media Gulch, which contains a number of high-tech companies responsible for numerous San Francisco jobs. The City's economic development planners envision filling the old buildings and warehouses in the neighborhood with numerous other high-tech businesses and local workers by offering them bandwidth they can't refuse. Fiber bandwidth would draw software companies, video production houses, digital media shops, and application service providers. As the City's economic development planners see it, in the national and global competition for businesses, fiber would add incomparable connectivity to the City's existing attractions: culture and cachet.

  Where go businesses, there follow jobs. The City's economic development planners envision that the businesses attracted by fiber will bring sustainable spillover benefits throughout the enterprise zone, in the form of jobs, retail and restaurant offerings, and real estate appreciation.[27]

- **Small Business:** Giant Killer Robots is a small, entrepreneurial, local firm that specializes in creating digital effects for major Hollywood films. Born and raised in San Francisco, this 10-year old company needs ultra-high speed broadband to seamlessly integrate its Canadian office with its headquarters in San Francisco—and to send its high-bandwidth product to its film studio clients in Los Angeles. In the current market, such a connection is likely to cost hundreds of thousands of dollars per year if leased from the phone company—an impossible expense for a small business. In the absence of affordable, very-high speed broadband, Giant Killer Robots is reduced to sending hard drives by overnight mail to its customers and remote office—a competitive disadvantage as well as a bar to innovation. A San Francisco fiber network would enable Giant Killer Robots to negotiate with multiple providers to get the service it needs at a price it can afford—and would enable it to continue to operate and innovate in San Francisco without suffering a competitive disadvantage.

  FTTP would also enable Giant Killer Robots to realize a business and community goal: much of the work of this digital media company can be done by a lightly-trained technician working from home over a very high-speed connection. Many of Giant Killer Robots' competitors outsource this work to Asia or other areas where such connections are available. Giant Killer Robots foresees a scenario in which it can hire, train, and oversee local workers who can participate from their homes over fiber and contribute to the company's success--and the City's economy.[28]

- **Public Health**: The City's Public Health community requires a mesh of true broadband connections among hundreds of public and private health care

[27] CTC interview with Jennifer Entine Matz, Deputy Director Business Affairs, Mayor's Office of Economic and Workforce Development, December 14, 2006.
[28] CTC interview with John Vegher, co-owner and co-founder, Giant Killer Robots, November 14, 2006.

locations throughout the City. Radiologists in different locations could simultaneously view and discuss x-rays. Surgeons could video-conference to watch and advise colleagues during emergency surgery from distant locations. Multi-lingual translators could be available over video-conference to translate and interact with patients throughout the City, not just in the primary hospitals where such translators currently work. According to the City's Public Health Department, the Department receives more than 100 requests per day for remote access to the translators who, among them, translate 23 languages. This public health vision is not wishful thinking—all these applications are possible today but for the lack of connections and capacity at a manageable price. The proposed FTTP network could offer such connections—in a secure manner that ensures patient privacy and contains this aspect of the increasing cost of health care.[29]

- **Education:** Balboa High School is located near the Excelsior District in the Mission Terrace neighborhood. A Balboa teacher oversees CAST, a youth video production program for 16 to 18 year olds. The students produce programming that expresses their visions for their lives, their ideas and hopes, their views of world issues, and their thoughts on current events. Balboa High School was built in the late 1920s and the last upgrade to the technology system was 11 years ago. Internet speeds are less than 54 Kbps and permit little more than sending small documents and email. To upload video to a broadcast site requires high bandwidth—which the school cannot afford. The City's FTTP project would enable the CAST students to upload their productions to broadcast sites and to download videos and applications for their production efforts.[30]

- **Public Safety**: The City's public safety technologists view fiber as critical for public safety communications and anticipate rapidly increasing needs for fiber. The alternative to City-owned fiber, leased circuits, cannot be used for public safety--not because of cost, but because of reliability, time to repair, and availability. The City's technologists foresee emergency events in which public safety networks fail to operate because private-sector communications providers simply do not have the incentives to support public safety needs first and foremost as does the City.[31]

  Fiber could make possible expansion and increased capacity of the City's wireless 800 Mhz public safety network to high-use special events that require bursts of extra capacity – such as a Superbowl or World Series. It could facilitate mirroring and remote backup of City public safety data and staff at a remote, earthquake-safe location. It could enable interoperable communications among the fire, police, and emergency response personnel of multiple jurisdictions with whom San Francisco first responders cooperate. It could dramatically boost the speed and reliability of any future public safety wireless network by providing

---

[29] CTC interview with David Counter, Chief Information Officer, John Applegarth, IT Manager, and Almir Guimaraes, IT Manager, San Francisco Public Health Department, November 9, 2006.
[30] CTC interview with George Lee, Balboa High School, December 2006.
[31] CTC interview with Joseph John, Manager, DTIS Public Safety Services Division, October 5, 2006.

fiber backhaul. From the standpoint of public safety, these applications are not seen as optional--they are necessary and the fiber to implement them is viewed as an essential investment.

- **Next Generation Network Development:** The technologists of San Francisco have noted the emergence of a Next Generation Internet. This chrysalis-stage project leverages next generation fiber networks to enable reliable, high-bandwidth peering over short and long distances in the service of public, educational, and community goals. Using national, university-based fiber networks, these visionaries are working to create collaborative production and distribution tools over high-bandwidth connections. FTTP would enable connection to this national network from numerous San Francisco sites (such as high-tech non-profit/community organizations, homes of interested residents, public broadcasting facilities, and technology businesses).[32]

- **Community Development and Service:** The Bay Area Video Coalition currently services 1,000 young San Franciscans each week, assisting them to develop careers and skills through visual arts and production. BAVC envisions using the FTTP network to distribute and remotely produce its clients' projects. Even more creatively, BAVC envisions using fiber to disseminate visual data regarding pollution levels. This innovative project collects and distributes vital health information over a media-linked application. In BAVC's vision, donated mobile phones will measure pollutant levels and transmit them wirelessly to a central server that will instantaneously create video mapping and narratives of high-pollutant areas. Fiber backbone would enable seamless transmission and aggregation of the data and wide dissemination to the public.[33]

1.4 The Broadband and Competitive Context

This Report evaluates the existing broadband market in San Francisco and describes how current and planned networks cannot meet needs for affordable, very high-speed broadband.

1.4.1 The City Lacks Competition in Provision of Broadband "Pipe"

Despite industry protests, it is increasingly apparent that the current American market precludes true broadband competition because of the impracticability of construction of numerous broadband physical networks. While there may be significant competition in provision of programming and services such as telephone, email, and video—there is not significant competition in provision of "pipe" -- the infrastructure over which all of those services operate.[32] Moreover, to the extent that service competition exists, a market is

---

[32] CTC interview with Joaquin Alvarado, San Francisco State University, December 14, 2006.
[33] CTC interview with Ken Ikeda, Executive Director, BAVC, December 7, 2006.

distorted if the infrastructure provider can manipulate the quality of competing services over the connections the provider controls to the end customer. In a context in which network owners have been permitted by the FCC and the courts to "close" their networks to competition,[34] competitors can reach customers only by building their own facilities—at prohibitive cost that precludes the emergence of multiple competitors. This situation is akin to a scenario in which the national road network is owned by UPS and closed to competitors--in order to provide service, FedEx, DHL and other package deliverers would be forced to build their own network of roads and highways--a prohibitive bar to competition. The result in the communications context is comparable: a broadband monopoly or duopoly of incumbent cable and telephone companies.[35]

Even using this closed model, the incumbents do not plan to build FTTP throughout San Francisco's neighborhoods, with the exception of small scale trials in new developments. In fact, none of San Francisco's existing wired providers has significant FTTP plans anywhere in the country. At best, these incumbent providers will move incrementally to expand capacity, but they are constrained in their investment choices by the capital markets, which reward short-term profits and punish long-term expense for investments like FTTP. As was noted recently in a recent Strategy Analytics study:

> Unlike local governments, which can justify investing in expensive FTTH technology on the grounds that it may benefit the public or stimulate economic growth, telcos and other shareholder-owned companies face intense pressure to limit costs and show near-term returns on investment. This financial pressure will continue to make FTTH difficult to rationalize in the near term.[36]

1.4.2 Existing Networks Cannot Offer Very-High Speed Broadband

The incumbent communications carriers proffer many products in San Francisco that they describe as "broadband." Perhaps these products are broadband under the (widely rejected) definitions accepted by the Federal Communications Commission (FCC). But the FCC accepts as "high-speed"[37] connections that are only marginally better than dial-

---

[34] Under recent rulings, the owners of DSL, cable broadband, and FTTP systems have been permitted to close their networks to competitors – a deviation from the common carrier rules under which the telephone networks have long operated and under which numerous competitive Internet Service Providers (ISP) offered service over dial-up modems. As a result, many of these ISPs have ceased to offer Internet service—because they cannot access the distribution networks, at any price.

[35] Even less service exists in much of the country. Amazingly, significant areas of rural America have no broadband options other than satellite service, which is costly and cumbersome. Satellite technology has proven itself a competitor for delivery of one-way video and radio, but it is significantly inferior to fiber optics -- and even to cable modem or DSL service -- for Internet and interactive services. Satellite broadband cannot match cable and DSL for bandwidth, it is far more costly, and satellite transmission entails a latency and delay issue that makes widespread Internet use unlikely utilizing existing technologies.

[36] Jim Penhune and Martin Olausson, "Fiber To The Home in Europe: Will Municipalities or Markets Drive Growth?," Strategy Analytics, November 10 2006.

[37] The FCC defines "high-speed" as "connections that deliver services at speeds exceeding 200 kilobits per second (Kbps) in at least one direction" and defines "advanced services" as "connections that deliver services at speeds exceeding 200 Kbps in both directions." "Federal Communications Commission

up, and that offer insignificant fractions of the speed that fiber can deliver using current technologies.[38]

The networks operated by cable and telephone companies are limited in their technological capabilities and do not offer the kinds of speeds and capacity possible with FTTP.[39] Both industries are further limited in their reach: cable serving primarily the residential market and AT&T serving some business and residential areas but limited by its technology.

1.4.2.1 The Cable Companies: Comcast and RCN

San Francisco has two cable television operators: Comcast Cable, whose "footprint" includes all residences in San Francisco; and RCN Communications, who operates a system that covers approximately one tenth of the City and provides service to approximately 31,000 households. Both RCN and Comcast offer broadband at speeds defined by the FCC as "high speed."[40] Both operate high-quality, reliable hybrid fiber/coaxial systems that can compete against other offerings in today's marketplace. Both, however, operate systems that are limited by their lack of fiber—even with advanced electronics and software, these systems cannot keep pace with the potential speeds of fully-fiber networks such as that proposed in this Report. The cable systems are limited by the inherent shortcomings of the coaxial cable that runs from their nodes into the home. An additional limitation arises from the shared nature of cable modem service—bandwidth within a neighborhood is shared rather than dedicated. As a result, speeds may be significantly decreased by one's neighbors' simultaneous use of their cable modems.

The cable companies traditionally have serviced the residential market and they have a very limited footprint with respect to the business areas of the City, as is generally true throughout the United States. Their limited commercial impact has not made an

---

Releases Data on High-Speed Services for Internet Access," FCC Website, http://www.fcc.gov/Bureaus/Common_Carrier/Reports/FCC-State_Link/IAD/hspd0705.pdf, accessed October 3, 2005.

[38] In Europe and Asia, significant fiber projects are underway to offer worst-case symmetrical speeds of 100 Mbps—500 times the speed the FCC considers satisfactory.

[39] Even advertised speeds may be illusory or inconsistent. The New York Times recently noted that some "customers do not get the maximum promised speed, or anywhere near it, from their cable and digital subscriber line connections. Instead, the phrase 'up to' refers to speeds attainable under ideal conditions, like when a DSL user is near the phone company's central switching office." Matt Richtel and Ken Belson, "Not Always Full Speed Ahead," The New York Times, November 18, 2006.

[40] Subscribers may be able to get cable modem speeds in San Francisco of "up to" three to six Mbps and, under ideal circumstances (none of one's neighbors using cable modem service at the same time), a couple of Mbps upstream. Fractions of those speeds would not be unusual at peak hours. Using current technologies, cable modem can theoretically provide as much as 20 or 30 Mbps downstream and 10 Mbps upstream under ideal circumstances but these circumstances are rare and the product, if available, is likely to be pricey.

appreciable competitive impact on the availability or price of higher quality and speed broadband products for business.

1.4.2.2 The Phone Company: AT&T

AT&T is the incumbent local exchange carrier in San Francisco, where it offers Digital Subscriber Line (DSL) services to most of the City and leases enhanced circuits to government and businesses at higher prices. Small and medium sized businesses may have difficulty affording these circuits.

DSL represents a relatively low-bandwidth form of broadband -- a network of roads, not superhighways.[41] DSL does not even have the capabilities of a cable modem network because it is based on lower-bandwidth infrastructure. DSL runs on telephone network copper wires, which simply cannot handle the same capacity as fiber or even as Comcast or RCN's hybrid fiber/coaxial (HFC) networks. As capacity requirements increase, DSL is likely to fall further behind cable.[42]

AT&T does not plan to build FTTP, although it has deployed an FTTP trial system in the Mission Bay greenfield development.[43]

AT&T has announced a strategy for upgrading its existing copper systems to fiber-to-the node (FTTN), known by the AT&T brand, "Project Lightspeed." This technology is actually the next generation of DSL technology and is extremely limited in capacity – even for today's existing applications. To our knowledge, only a few, very limited areas actually received Project Lightspeed service as of the end of 2006.[44] AT&T has not committed to a date certain by which even this limited technology will be widely-deployed in San Francisco.[45]

---

[41] AT&T's new "naked DSL" product (so-named because it can be purchased alone rather than in a more costly "bundle" with other products) provides speeds of only 786 Kbps downstream and approximately half that upstream. A higher-end DSL product offers 1.5 Mbps downstream and half that upstream at a higher price. Ryan Kim, "AT&T to offer 'naked' DSL for far less than before," San Francisco Chronicle, January 16, 2007, http://sfgate.com/cgi-bin/article.cgi?f=/c/a/2007/01/16/BUGT4NJ0OI1.DTL, accessed January 23, 2007. Theoretically, DSL can provide as much as 15 Mbps downstream and a few Mbps upstream under ideal circumstances (such as close proximity to AT&T's central office) but these circumstances are rare and the product is likely to be pricey.

[42] The limitations of DSL are demonstrated by the efforts of Verizon to supplement its old copper phone networks with new FTTP networks in limited metropolitan areas within its existing footprint, which does not include San Francisco.

[43] CTC interview of Ken Mintz, AT&T Area Manager, External Affairs, November 14, 2006; "AT&T says won't need fiber-to-the-home network," Reuters, December 5, 2006, http://today.reuters.com/news/articlenews.aspx?type=internetNews&storyID=2006-12-05T152035Z_01_N05255779_RTRUKOC_0_US-ATT-LINDNER.xml&WTmodLoc=InternetNewsHome_C2_internetNews-1, accessed December 21, 2006.

[44] Brian Santo, "The Smell of Money," CED Magazine, November 16, 2006.

[45] CTC interview of Ken Mintz, AT&T Area Manager, External Affairs, November 14, 2006.

Project Lightspeed's century-old copper technology can carry only a few video channels at once—and likely no more than one High Definition channel at a time. The theoretical data capacity of this architecture is up to 25 Mbps per customer but AT&T's current stated plan is to offer only one to six Mbps downstream and up to one Mbps upstream. The remainder is required to offer video.

Even if AT&T does upgrade to this architecture in San Francisco, its limitations are likely quickly to be reached. From a technical standpoint, Project Lightspeed is a short-term solution in a market where bandwidth needs are growing exponentially and high, symmetrical capacity is increasingly needed for small businesses and for popular emerging applications like gaming, video-gaming, video-downloads, and video-conferencing. AT&T's 100 year-old copper plant is not capable of meeting these needs in the medium or long-run.[46]

1.4.2.3 4G Wireless

4G is the term applied to promising new wireless technologies, many of which offer sustained data speeds of a few Mbps or more per user. These include technologies with standards developed by working groups of the Institute of Electrical and Electronics Engineers (IEEE) and known by IEEE standards numbers 802.11 (WiFi), 802.16 (WiMAX), and 802.20. 4G also includes new generations of wireless technologies planned by the current cellular providers.

4G receives significant cultural and press attention, but the excitement over this technology should not blur the fact that 4G, no matter how promising, does not currently represent a broadband technology that is comparable to fiber. 4G does not have comparable capacity to fiber, versions of 4G using unlicensed spectrum may be limited in range and subject to interference, and 4G is largely untested as a widespread broadband medium – a technology still in development.

1.5 Report Methodology

This Report was prepared by Columbia Telecommunications Corporation (CTC) in late 2006 at the request of the San Francisco Department of Telecommunications and Information Services (DTIS) and pursuant to the San Francisco Board of Supervisors'

---

[46] AT&T provided CTC with extensive comments regarding this report, and noted that "FTTN is a proven technology that provides access to high-speed Internet connections and other services. This deployment does not involve trenching streets or driveways. The copper wires that will service the new broadband signal are, in fact, capable of delivering a strong, next-generation IP network to residential homes. AT&T's interactive, next-generation network effectively uses copper wire to cover the last 3,000 to 5,000 feet." (Ken Mintz, "Re: AT&T California insights, context and clarifications related to 'Fiber Optics for Government and Public Broadband: A Feasibility Study'", March 1, 2007). CTC stands by its analysis that this FTTN technology is insufficient to meet San Francisco's needs and, in any event, has not been deployed in San Francisco.

Resolution urging an evaluation of municipal fiber construction, operation, and potential provision of services and leasing of facilities to independent providers.[47]

Pursuant to the direction of the Resolution, a range of strategies were evaluated, including:

- San Francisco as a competitive, retail communications service provider – the City would own communications infrastructure and offer competitive services over that infrastructure in competition with the private sector

- San Francisco as an infrastructure owner only – the City's role would be to build, maintain, and lease communications facilities so as to facilitate a reduction or removal of barriers to market entry for new and enhanced connectivity services

- San Francisco as an infrastructure owner and service provider to itself – the City would seek to meet its own internal needs rather than waiting for as-yet unrealized, affordable, commercial services.

To adequately evaluate those and other options, CTC's staff of engineers and analysts undertook the following tasks:

- Extensive in-field data-gathering in San Francisco, including
    - Field work to assess internal City fiber construction and maintenance capabilities
    - Site visits to major City communications facilities
    - Field review to survey and inventory existing City-owned communications assets, including existing fiber rings
    - Physical plant evaluation throughout the City and with the staff of DTIS' Public Safety Outside Wire group
- Meetings with City, MTA, and PUC officials, including a wide variety of representatives of public agencies

---

[47] Resolution No. 617-04 was authored by Supervisor Tom Ammiano and unanimously adopted by the Board of Supervisors on October 5, 2004. Among other things, the resolution urges DTIS to analyze and report on:

- Other local governments that own and/or operate broadband facilities
- "The feasibility of the City providing services directly, as well as leasing facilities to independent providers"
- The City's existing broadband resources
- A potential plan for "a City-owned high-speed communications system, including recommendations for the types of facilities and the amount of bandwidth the City should install, and the timing and placement of such facilities" and associated costs and business models
- Use of strategies to maximize existing City broadband resources and construction including sewer replacement projects and other "construction and excavation activities"

These issues are addressed by this Report. The other areas of inquiry raised by the Resolution, including public and commercial market research, are outside the scope of this Report as it was commissioned by DTIS.

- Meetings and follow-up correspondence with interested citizens and businesses in the context of a number of interviews and public meetings CTC conducted over the course of this project
- Meetings with owners of potentially-useful assets for development of communications networks, such as Pacific Gas & Electric (PG&E)
- Meetings with, and other research regarding, existing communications providers in the County to determine the existing availability of services; to assess the factors that prevent or delay further private sector deployment of communications in the City; and to determine the level of interest in leasing capacity on a City-owned fiber network. CTC met or spoke with the following facilities-based providers:
    - Comcast
    - AT&T
    - RCN
- Meetings with representatives of academic and intellectual communities.

This Report was released in draft form in January 2007 and was held open for public comment until the end of July 2007.

1.6 San Francisco's Fiber and Wireless Projects Distinguished

This FTTP Report has often been related to the ongoing San Francisco TechConnect Wireless project. Despite the obvious similarity—both projects seek to enhance broadband availability throughout the City—it is important to note the significant differences between the two projects, because they do not supplant or compete with each other; rather, ***these technologies inherently serve to enhance and complement each other***.

- Bandwidth: fiber optics offer theoretically infinite bandwidth (also known as throughput, speed, capacity) while wireless offers far lower speeds that, though impressive, cannot support some of the ultra-high speed applications made possible by fiber.

- Mobility: the key advantage of wireless cannot be mirrored by fiber; wireless offers mobility and connectivity during movement. As has been noted, one can't build fiber to the ambulance, to the bus, or to every laptop in a public park.

- Speed to deployment and related cost: wireless can be deployed far faster than fiber given the significantly lesser volume of infrastructure necessary and the relatively small amount of construction necessary in the public rights-of-way, if any. Fiber construction is burdensome and time-consuming because it involves building a physical asset down every right-of-way in the City, either on utility poles or underground. For the same reasons, the initial capital costs for wireless networking are far lower than those for FTTP.

  The obvious flip-side of this distinction is that fiber is a long-term asset with a life of decades (and, as a result, is very cost-effective in the long-run) while wireless is a short-term technology. Existing WiFi radios, for example, will likely have to be replaced in three to five years as technology changes and components age.

2. Assessment of Internal City Needs

As part of this study, CTC was directed by DTIS to meet with designated City and County of San Francisco (City) agencies and with non-City institutions to determine existing communications needs and to determine what needs could by met by fiber optic-based communications services.

Under the direction of DTIS, CTC met with seven City agencies and with five non-City institutions selected by DTIS.

The key network connectivity needs identified from interviews with City agencies are:

1. increased performance networking for existing and emerging technology applications
2. increased connectivity speed to support new applications (video, homeland security, intelligent transportation systems)
3. maintenance of high reliability standards (especially for public safety, security monitoring, utility monitoring)
4. maintenance of high security standards
5. reduction of recurring fees
6. high speed connectivity to hundreds of additional locations, including outdoors and at key public transit facilities and utility infrastructure
7. high speed connectivity to mobile users
8. unified network management
9. ability to operate and manage network independently of other agencies

For their part, non-City institutions report that they need:

1. high performance networking for existing and emerging applications
2. increased connectivity speed to support growth in new applications (distance learning, digital media production, IT recovery, data backup, centralized servers, textbook download, Web-based student information and administrative software)
3. fast and reliable Internet connectivity (Internet connectivity provides primary connections between administratively separate institutions and to the public, and to entities outside the city)
4. increased reliability of network links
5. expansion of existing fiber optic connectivity

We also met with Pacific Gas & Electric (PG&E), who report the following interests:

1. interoperability with government communications
2. high-speed connectivity with mobile users
3. reliable monitoring of infrastructure
4. partnership with City and County to obtain fiber capacity for PG&E
5. data collection from customers.

Figure 2: Identified Communications Needs

2.1 City Agencies

2.1.1 Department of Telecommunications and Information Services

2.1.1.1 Overview

The Department of Telecommunications and Information Services (DTIS) is the primary provider of voice and data services for City departments. The mission of DTIS is “to be an enterprise information and technology services organization that provides proactive leadership in the use of technology and information solutions to improve the City’s operations and service delivery.”

CTC interviewed with Archie Lee, Network Architect, Chris Vein, Executive Director, and Brian Roberts, Senior Regulatory and Policy Analyst.

DTIS provides departments with:

- Intra/Internet connectivity;
- Network management
- Application and database services;
- Data center operations;
- Public safety system support;
- Desktop support;
- Telephone services
- Email;
- HR/Finance application;
- Telecommunications Billing;
- Geographic Information Services (GIS)
- Government access cable television programming; and
- Data Storage, Backup, and Recovery.

DTIS charges the cost of its services to City departments based on its direct costs and has published a description of its rates and rationale for the rates.[48]

DTIS serves over 25,000 end-users in 378 buildings with a budget of $74,792,290 budget. DTIS has a staff of 270.

DTIS provides data services to agencies over Ethernet local area networks within facilities. The most common data links between facilities are either T1 circuits leased from AT&T or FiberWAN Ethernet services provisioned over DTIS fiber. FiberWAN is discussed in more detail below.

Prior to the FiberWAN project each department connected to the City's datacenter using leased services. Departments typically bought routers and connected to their other facilities and to the data center using T1s. Larger departments often have their own networks with department datacenters for their specific applications. These department datacenters connect to the City's datacenter using leased lines.

Therefore, if a person within CCSF uses the Internet or data or resources at other facilities, then, depending on the person's agency or location, he or she is using either FiberWAN or a leased AT&T service.

DTIS provides telephone service through its own PBX switches, which in turn connect to trunk lines provided by AT&T. At the moment, FiberWAN is not used for voice service, although FiberWAN is capable of supporting packet-based voice-over-IP services with upgrades to the telephone electronics of the City, and FiberWAN is also capable of supporting PBX-based services over separate fiber pairs from the Gigabit Ethernet service.

DTIS operates over 1,500 leased AT&T circuits between its buildings at a cost of approximately $2.5 million per year. Over 600 are T1 circuits, accounting for

[48] *FY2006-2007 Rate Handbook*, Department of Telecommunications and Information Services.

approximately $1.4 million. Eleven circuits are DS3 or greater capacity, totaling approximately $200,000 per year.

DTIS is responsible for backhaul of the public safety radio system. It provides the service over private fiber or microwave links.

DTIS is deploying surveillance cameras in crime hotspots to gather evidence once a crime has been committed. The cameras use wireless, fiber optic, and copper backhaul for video back to the CECC. DTIS sees the deployment of video applications such as crime surveillance as a application demand for fiber optic communications.

DTIS operates a Citywide fire alarm system and public safety telephone system. Both networks operate using City-owned copper lines installed in AT&T conduit and the City's attachment space on joint use poles. The fire alarm system locates red pullboxes throughout the City, including City facilities and school buildings. The fire alarm system allows citizens to report fire incidents without using the public switched telephone network. Fire alarm alerts are received at the CECC where first responders are dispatched to the incident. In addition to the fire alarm system, public safety telephones are located throughout the City in blue call boxes, often in conjunction with the fire alarm system.

The public safety telephone system operates on separate City-owned copper lines, also terminating at the CECC. The City operates and maintains a MITEL private switched telephone network that provides four-digit dialing between phones and is independent of the public switched telephone network. To accommodate multiple public safety phones at one facility or to aggregate phone lines throughout the city at Fire Stations, the City uses T1 multiplexers to aggregate multiple phone lines over a single pair of copper lines.

There are approximately 400 public safety telephone lines and 2000 fire alarm boxes within the City. Both public safety systems consist of approximately 300 miles of copper plant, of which approximately 200 miles is aerial and 100 miles is underground. DTIS maintains and manages the system internally.

The City has access to AT&T conduit for the fire alarm system and public safety telephone system that expires in 2011. DTIS is concerned that the City will have to pay lease charges for the conduit after the agreement expires. DTIS is exploring alternate transmission means for the two copper systems including fiber optics, the public safety radio system, and 4.9 GHz public safety wireless communications.

2.1.1.2 Fiber Network

DTIS is implementing a City-owned fiber optic data network to serve many of the City's facilities. One of the services DTIS will provide over the fiber network is an Ethernet based wide area network for data known as "FiberWAN." FiberWAN enables the City to migrate away from leased data connections and provide DTIS with the ability to expand its current data and voice services while also creating a more unified network platform for network management and operations.

FiberWAN also provides Internet connectivity over redundant Internet connections. FiberWAN recently obtained a Class B public IP address space to facilitate its user to connect to the Internet.

The core of the FiberWAN network consists of Cisco Catalyst 6500s operated in a 10 Gbps Ethernet ring. At the data center, a 6509 connects the servers and other equipment to the core. At each of the other core sites a 6506 connects the sites to the core. Another 6509 at each site connects other municipal sites to the core network in a gigabit ring formation with up to three sites connected to two backbone core sites. At each site a Cisco Catalyst 3550 provides connectivity to the network.

FiberWAN uses the Multiprotocol Label Switching (MPLS) protocol to provide a multitude of services to the various departments in the City. MPLS was also chosen to allow Departments to connect between their facilities having FiberWAN manage their connections of using their own end equipment to manage connectivity.

Each department connects to the City's data center. Each department can connect with other departments by way of the data center's existing networking equipment and security policies. Each department is considered a trusted network if FiberWAN controls their security policies. For departments who control their own security policies, their networks are treated as semi-trusted.

FiberWAN uses Storage Area Networking (SAN) technology for storing databases and information from the City's network. The SAN is located in the City's data center. As part of the City's upcoming 311 Call Center, the City will be installing a smaller SAN to store information locally. FiberWAN will use their network to provide connectivity from the 311 Center SAN back to the larger SAN for added redundancy.

DTIS subscribes to a Data Recovery Service from IBM to protect City databases and applications. The City uses a VPN connection over the Internet to connect to the service. DTIS is exploring building a second datacenter to serve as a redundant datacenter site and to load balance the server demand at the data center.

DTIS' first fiber installation occurred in 2001 when the City constructed a public safety fiber optic network largely in PG&E conduit. The fiber ring connects six public safety sites using 96 count fiber.

Since the installation of the initial public safety loop, DTIS installed fiber to connect the City College of San Francisco campuses. DTIS was selected for this project when City College did not receive a responsive bid to an RFP for a fiber optic network between its own facilities. While deploying fiber for City College's use, DTIS installed additional fiber for the rest of the City's institutional networking needs. Using a combination of MTA conduit and rights to conduit from other sources, DTIS deployed a 216-count fiber ring. DTIS has also committed to providing physical maintenance for the City College network for the next 10 years. Subsequent to this project, DTIS installed fiber to connect several of the City's public safety radio tower facilities.

DTIS is using the additional fiber capacity installed in the City College network plus the fiber from the initial public safety network to connect City institutions to the FiberWAN. DTIS constructs additional fiber for public safety and other institutional needs as requested by various departments and as funding becomes available.

As of FY2007, 26 sites were served by FiberWAN. Of the current $2.5 million per year paid by the City in leased circuits, $650,000 are accounted for by circuits where both links terminate at the FiberWAN sites and are thus candidates for further reduction of AT&T lease fees.

Moreover, many additional City sites are in proximity to FiberWAN cable plant and may be connected with a few city blocks or less construction of fiber optics. As many City facilities are in physical clusters, adding one new site creates cost opportunities to add its neighbors to the network as part of the same project.

DTIS charges City agencies a minimum rate of $120 per month for FiberWAN service at a 1.5 Mbps rate, comparable to an AT&T T1 circuit, available for $175 to $350 per month. It is important to note that the FiberWAN connection is designed to connect the site simultaneously to any and all Citysites and the Internet via a "cloud" service, while the T1 circuit travels only from one site to one other site. As a result, many sites are able to replace several separate T1 circuits with one FiberWAN connection.

FiberWAN savings are more significant for larger-capacity connections. A 10 Mbps FiberWAN connection at $340 per month compares to a $900 to $1000 AT&T connection. A 40 Mbps FiberWAN connection at $575 a month compares to a $750 to $2000 AT&T DS3 connection.

DTIS seeks to expand FiberWAN and provide services to more City facilities. Expansion to new sites can be accomplished with additional fiber construction, addition of edge electronics at the new site, and, if necessary, modular expansion of existing FiberWAN core equipment.

FiberWAN provides a physical plant, electronics, and operational solution scalable to all City institutions. Because almost half the communications conduit has conditions on its use, FiberWAN is currently limited to City and educational use; however, it provides a framework for potential expansion to other institutional and enterprise users.

2.1.1.3 Fiber Optic Outside Plant Expertise

DTIS has formed a Fiber User Group that meets regularly to discuss upcoming fiber optic projects. The User Group consists of City departments using the fiber optic network. At the request of departments, DTIS performs price quotations for additional fiber optic construction. DTIS performs its cost estimations in house.

DTIS has an outside plant team that constructs, maintains, and operates the City's copper and fiber optic infrastructure. The team consists of line crews that maintain the outdoor plant and construct additional plant, three fiber optic splicers, and project management staff. DTIS also has the ability to increase its staffing levels during fiber construction projects.

In the event of a fiber optic cut, the Cisco network monitoring software signals the CECC and City's data center of an outage. The network monitoring staff alerts DTIS of the outage. DTIS staff then drives the fiber route to determine if a visible incident (such as road construction, fire, water main break) caused the incident. If the incident can be located DTIS informs its splicers of the location and send them out to repair the fiber damage. If the location of the fiber cut if not noticeable, DTIS will perform an OTDR test on the fiber from the closest location to determine the approximate location. The network had demonstrated high resiliency and survivability. The public safety fiber optic network has had only two outages since construction was completed in 2002.

DTIS performs its own underground construction consists of small digs performed by hand, consisting of connecting various conduit systems that are available to the City. Aerial construction is performed in the City's attachment right space and is attached to the City's existing cross arms where existing. Aerial and underground fiber are both dielectric cable. Strand is used during aerial construction. The majority of fiber optic plant constructed by DTIS has been underground.

2.1.1.4 Available network infrastructure

Through franchise agreements and other agreements, DTIS is able to use conduit and fiber from a range of sources and service providers. The specifics of the agreements are described below. The providers are:

1. UCC
2. Metropolitan Transportation Agency (MTA)
3. RCN Communications
4. Comcast
5. Pacific Gas & Electric
6. City Auxiliary Water Supply System (AWSS)

The City received fiber from UCC from a settlement regarding construction permits. DTIS prefers using UCC conduit where available as there are no restrictions on the use of the conduit. Much of the eight-duct bank is unused.

Approximately 40 to 60 percent of the City's fiber optic network operates within MTA conduit. DTIS and MTA have an MOU for fiber construction within MTA conduit.

Under the terms of the agreement, MTA allows DTIS to construct fiber within their tunnels and conduit. In return DTIS provides MTA with 12 dark fibers over its network. MTA and DTIS have fiber in MUNI tunnels and under 90 percent of the electric bus routes. The MTA fiber is not subject to restrictions on its use.

The City has access to RCN and Comcast conduit under the terms of the franchise agreements. The City's use is limited to public, educational and governmental applications.

PG&E is typically DTIS' last resort when determining which system of conduit to use for routing, The City has the right to use any conduit that PG&E is not using, but PG&E requires that the City pay PG&E to have their line crews supervise any construction within PG&E conduit.

DTIS worked with AWSS, the auxiliary water supply system project to install conduit during an expansion of the system to provide high pressure water lines for the Fire Department. DTIS is working on getting the PUC to incorporate conduit construction into water and sewer capital improvement projects.

The available conduit is discussed in more detail below.

2.1.2 Municipal Transportation Agency

MTA is the City entity responsible for public transportation. MTA operates a subway system, electric trolley and conventional buses, streetcar lines, and operates Department of Parking and Traffic (DPT).

CTC met with Kylie M. Grenier, the MTA IT Program Manager.

The main needs of MTA are:

1. Fiber to dozens of new locations, including radio repeater sites, sites associated with the new SFGo Intelligent Transportation System initiative, and at DPT sites away from its existing communications infrastructure that require surveillance cameras.
2. Fiber optic cable in the MTA-owned MUNI subway and streetcar communications conduit. Although DTS has installed fiber in some MUNI conduit, much of its conduit does not contain fiber.
3. Moving existing facilities from leased T1 connections to FiberWAN to reduce monthly recurring charges.

MTA is currently developing a master plan describing its IT and communications needs.

MTA has constructed cable conduit and fiber in its MUNI tunnels and underneath many electric trolley routes. This infrastructure is not subject to conditions from use by the City for services to homes and businesses.

The MTA operates fiber it obtained from two separate sources. MTA has older fiber that it installed, and it has fiber installed by DTIS. Currently, DTIS is installing twelve fibers in MTA conduit for MTA use, wherever it installs fiber in MTA conduit, under the terms of a 2004 MOU between MTA and DTIS.

MTA currently spends approximately $200,000 per year on 145 leased circuits, including two DS3s and 30 T1s. It has network connections to dozens of locations. In addition, there are several new needs that will require adding more sites and more capacity.

MTA is currently working with the DTIS' fiber user's group to identify and document MTA's fiber network, and activate new sites on the DTIS FiberWAN.

MTA's first priority is to connect its larger facilities over fiber, such as 1 South Van Ness Street and 875 Stevenson Street, and then switch over smaller sites depending on their proximity to the existing FiberWAN fiber. MTA's long term goal is to connect all transportation facilities, including maintenance yards, substations, control centers, and offices, with fiber optics.

The MTA is in the process of using a Department of Homeland Security (DHS) grant to replace and add cameras within the MUNI tunnels. The project includes updating cameras from black and white video to color, adding cameras at key locations and using DSL for backhaul of the network (Internet DSL from AT&T). MUNI would like to migrate the cameras to its fiber optic network, but are unable at this phase of the project due to the deadlines associated with the grant. There are approximately, two cameras per facility. MTA also wants to operate surveillance cameras at MTA office facilities, additional MUNI stations, power substations, and other transportation facilities.

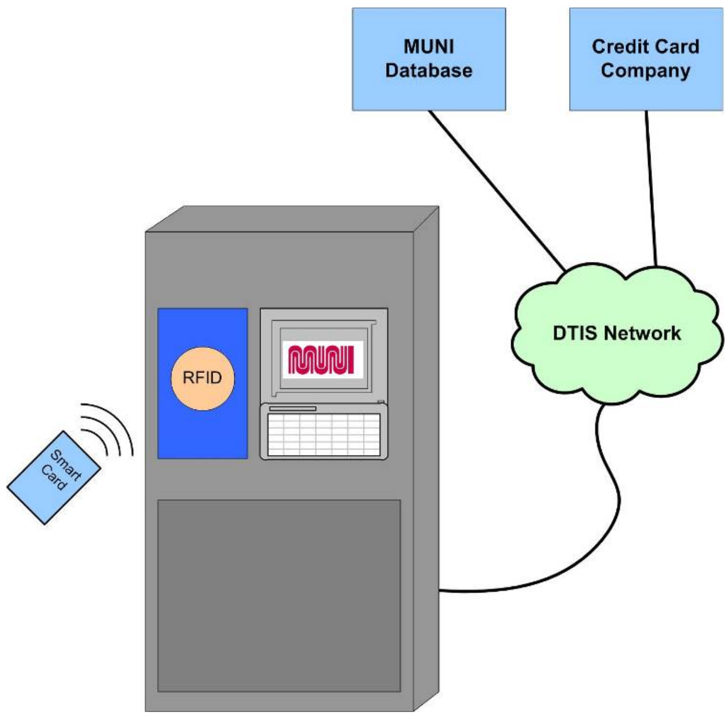
MTA would also like to upgrade its existing subway control systems, which include train control, track switching, and train traffic detection. As part of the control system upgrade, MTA is also looking at constructing a new control center for the MUNI system, which will need significant fiber optic resources.

Another significant application is the automatic vehicle location (AVL) system used to electronically track MTA's 1,100-vehicle fleet. The AVL system operates wirelessly over cellular spectrum at $30 per month per vehicle. MTA is considering migrating the system to a city-owned system using the 800 MHz land mobile radio spectrum.

MTA operates several traction power substations throughout the city to provide electricity to the City's transportation system. MTA is interested in obtaining fiber optic connectivity to each site for video surveillance as well as Supervisory Control and Data Acquisition (SCADA). SCADA systems will allow the MTA to remotely monitor and control the various components of each substation.

MTA has a plan for upgrading and expanding the MUNI's fare collection equipment such as ticket vending machines and fare gates. New fare collection equipment will require additional backhaul for credit card point of sale equipment as well as the ability to access MUNI databases for ticketless fare collection using RF smart cards in the future.

Figure 3: MUNI RFID Conceptual Diagram



MTA would also like to add passenger information systems to subways stations and rail and bus stops to provide riders with additional information such as estimated time of arrival. The video or transit information would require backhaul to a central database.

The MTA is looking at improving its wireless communications by deploying a new 800 MHz digital trunked radio system. The new 800 MHz system would provide voice and data communications to approximately 3,000 MTA users as well as provide backhaul for the MTA automatic vehicle location system. The radio system would be separate from the City's existing public radio system and would require extensive backhaul communications, potentially provided over FiberWAN or over fiber installed together with FiberWAN fiber.

SFgo is a DPT initiative that is deploying an Intelligent Transportation System (ITS) throughout the City. SFgo include applications such as:

- improved traffic and pedestrian signals;
- traffic surveillance cameras;
- upgraded signal controllers; and

- variable message signs.

SFgo will require significant backhaul requirements to implement the project throughout the City. MTA is looking at using its own fiber resources, constructing additional fiber, and leasing fiber from DTIS to provide the backhaul needed to support the project.

2.1.3 Department of Public Health (DPH)

CTC met with DPH CIO Dave Counter, and CTOs John Applegarth and Almir Guimaraes.

DPH provides a full spectrum of health services in the community ranging from emergency services to long-term care. In its range of responsibilities and abilities, DPH is a microcosm of the national health care system.

The combined IT budget for DPH is $20 million per year, from an overall $1.1 billion per year budget.

DPH envisions sharply increasing data communications needs. Telemedicine requires transmission of enormous images and files. Real-time video and high-resolution imaging is needed to enable patients to be treated and diagnosed. Patients may be in hospitals, clinics, or laboratories. Medical practitioners may be in hospitals, clinics or at their practices. A new long-term care facility will require that patients be able to be examined or treated within their “care homes.”

Once images and files are shared, they will need to be stored in a secure and reliable manner. Data must be able to be stored in primary and redundant facilities and readily backed up over the network.

Taken together, DPH envisions requirements for more than 1 Gbps of connectivity per site, not only between the hospital and major hub facilities, but to any and all satellite facilities, which may include clinics, labs, pharmacies, and home care facilities. Communications will need to be flexible to accommodate moves in facilities and introduction of new telemedicine services.

At the moment the only commercially available service that serves this need effectively is the AT&T OptiMAN service. At the time of this report, that service is only consistently available in the downtown business district and costs over $16,000 per month, or $192,000 per year. The service will be needed at hospitals, clinics, as well as at potentially hundreds of community-based organizations and institutions that provide public health services.

DPH has divided its IT functions into two functional areas, hospital based and community based. The Hospital Based applications tend to be used within the hospital campus and hence tend to be accessed and provides over local area and campus networks.

The Community Based applications tend to have more widely-distributed users and require wide area network (WAN) connectivity. The CTOs are each assigned to one of the two functional areas.

Although each functional area has quite different needs and operate in unique environments, they do have common issues with available connectivity services. For example, for both areas, DPH reports that the limited performance and cost-effectiveness of available commercial services constrains potential applications, and the costs of more advanced services are prohibitive. Some examples of more advanced services that DPH requires include: real-time on-line data connectivity of 1 Gbps or more to "hub-sites" and satellite facilities. This facilitates seamless access and sharing of secure data across hospitals, clinics, and physicians. Sharing of data access is an essential component of quality of care and cost containment. It encourages time management efficiencies, departmental specialization and better utilization of specialized equipment. Additionally, it permits remote diagnosis, inventory control and management and coordination of pharmaceutical needs.

Hospital Based

San Francisco General (SFG) shares facilities with the City, serving one million square feet of facilities in an eight-block area. Also housed in the complex is the long-term care hospital. SFG has an affiliation agreement with the University of California Research Department and contracts through the City for physicians. The hospital supports 50 Cisco based networks with 60 data closet and fiber infrastructure throughout the campus. The network equipment is upgraded on a three to four year lease cycle. A Cisco wireless LAN is employed in clinic areas. The OC3 is leased from SFG to the data center. Separation of data from the university and other institutions supported on campus is critical.

Community Based

DTIS manages the contracts. There is a need to communicate with over 400 different community-based and administrative sites. The IT community hub is located at 1380 Howard Street. It consists of a 155 Mbps closed connection, 50 Mbps to SFG and1.5 Mbps to 50 other sites. The costs for the AT&T leased circuits are: $6,000 per month each end for SFG connection, and $300 per month for each 1.5 Mbps connection. There is a DS3 (45Mbps) to the Internet that is currently at 45 percent of capacity today (20 Mbps).

A dedicated fiber for backup of data files and a data recovery system for "at-risk" locations is desired. The existing capacity of the T1 circuits limits capability of backups and other applications. The new hospital Laguna Honda is located on bedrock so it will be a new data site. Several hundred physicians from Mt. Zion, Mission Bay, VA, UCSF and other facilities can back up data from multiple systems with access to a dedicated fiber.

Telemedicine Explosion

In telemedicine, high data transport is necessary. PAC images are one to two GB files or larger and CTC scans are 20 GB files or larger. There is a need for more than a static image transfer. Commercial circuits, if available, are too expensive. T1s, T3s, OC3s do not have the required capacity and the connection charges are over $16,000 per month.

Physician specialization increases the off-site data requirement. There is a strong need for on-line, real-time connectivity with sufficient capacity to support remote diagnostics. Radiology and Out-Patient Clinics need fiber connectivity to support remote reading and diagnostics. Direct VPN access into emergency rooms will balance ER loading and maximize the ability to admit patients efficiently. Pharmacy orders can be transmitted to clinics to expedite service delivery.

New Long-Term Care Facility

DPH desires a Fiber-to-the-Resident project to 1,200 care homes at its new long-term care facility. This would enable each home to choose voice, video, and data providers and services that meet their specific needs. The project could be a "pilot" for a city-wide "open access" model because it would include public provided fiber infrastructure and subscriber choose of provider and services. There would also be a potential to test an all IP based delivery vs. analog for cable televisions service as well.

Interpreter Service Application

DTIS is involved in a video-based interpreter service pilot program. The project is in conjunction with Highland-Alameda Hospital. This hospital was the first hospital in the country to have a videoconferencing interpretation system. The hospital provides point-to-point translations in 23 languages. Better physician/patient communication results in an increase in standard of care to patients of the Bay Area. Liability is reduced when miscommunication (lack of comprehension) is avoided. Deployment is straightforward. A video station can be deployed anywhere on the network. The hospital reports:

● Increased patient satisfaction – Wait times are drastically reduced, and patients are happy to have visual communications with the interpreter.

● Better use of interpreters – Less time is spent on each request, because interpreters need not travel between the center and the clinics.

● Cost efficiencies across sites and organizations are realized when translations services are shared.

Higher bandwidth is needed in order to expand the service to 400+ agencies in the Bay Area. Involving more agencies in the services increases the quality of Bay Area patient care and contains health care costs for patients.

2.1.4 Public Safety Services Division

The Public Safety Services Division of DTIS maintains and operates the City's public safety systems, including mobile radio, telephones, and data communications for police, fire and rescue departments. Applications include computer assisted dispatching (CAD), AVL, records management systems (RMS), and local, state, and federal database queries.

CTC spoke with Joseph John, the Director of the Division. The Division is developing fiber assets as budgets and grants are made available. The Division pays the DTIS outside plant team to design and construct fiber. The DTIS network team activates the fiber and operates the data portion of the Division's services.

The Division envisions greatly increased capacity needs driven by widespread use of video and geographic information systems (GIS) by first responders, dispatchers, emergency managers, and City decision makers. As the communications are needed for critical first responder and homeland security roles, they must be highly available and secure. The Division reports that it experienced 48-hour outages when it was served by AT&T T1 circuits.

The Division believes that fiber is a critical need, and that its need for fiber will continue to increase. The Division believes that 1) leased circuits are not well suited for public safety due to lack of reliability, time to repair, and availability, and 2) unlicensed WiFi communications is also not reliable enough or capable of providing needed capacity for its need. The Public Safety Division requires a secure and reliable fiber and wireless platform.

Public Safety's first goal is to connect each of the City's facilities to City fiber. Fiber optic connectivity could provide bandwidth for a number of public safety applications including video surveillance, fire and security alarms, emergency telephones, and site access.

In addition to needing fiber at the City's facilities, Public Safety also would like fiber optics at all of the City's non-governmental critical infrastructure sites, such as PG&E substations, and transportation centers. Again, the fiber would support video, alarms, emergency and first-responder communications.

Public Safety envisions the fiber providing backhaul communications for wireless communications, specifically, a combination of the existing 800 MHz narrowband land mobile radio system with a 4.9 GHz broadband network overlay to provide a secure and reliable network for first-responder voice and data applications.

Public safety applications used by the City include:

- Computer Aided Dispatch (CAD);
- Automatic Vehicle Location;
- GIS;

- Records Management System (RMS); and
- Local, State, and Federal law enforcement database queries.

As discussed earlier, DTIS operates a Citywide fire alarm pull box system and the Mayor's Emergency Telephone System (METS), which is a public safety telephone system. Both systems currently operate on copper lines in AT&T conduit.

Public Safety recommends replacing migrating the pull boxes and METS to fiber optics and/or wireless communications. Public Safety also recommends replacing the existing METS telephone switch with a VoIP switch. The upgrades would enable the systems to continue operating after agreements with AT&T expire and also potentially improve their flexibility and performance. Notably, these systems continued operating in the aftermath of the 1989 World Series earthquake, when most other systems failed because of damage or extended power loss.

San Francisco and the other Bay Area jurisdictions are in the process of deploying a point-to-point microwave system to connect each jurisdiction's public safety radio system with radio gateways, which will allow radio communications between different radio systems. The project is funded by an Urban Area Security Initiative (UASI) Critical Infrastructure grant from the Department of Homeland Security and must be completed by the end of 2006. Public Safety would like to eventually construct fiber optics between each jurisdiction and use the microwave as redundant links.

Public Safety has already deployed several surveillance cameras in high crime intersections to deter criminal behavior, monitor the scene, and record any crimes in progress to aid in apprehending and prosecuting criminals. Public safety reports that the program has been successful so far and has plans to deploy additional cameras throughout the City. Each high crime area requires fiber optics to provide backhaul for the cameras to handle the bandwidth necessary for surveillance video.

Public Safety sees remote access to City networks by employees and the ability to telecommute as a great benefit. Public Safety notes that many employees live out of city; therefore connectivity from anywhere is crucial especially in the event of an incident that limits accessibility in and out of the City. High quality remote access requires robust, high-speed Internet connectivity, as well as high speed connectivity within the City networks.

Currently, dispatchers make decisions based on low speed, data such as voice and text; however, in the future, Public Safety expects to use high resolution photos, 3D photos, full motion video, and other bandwidth intensive transfers to improve the response time of the City's first responders. Public safety envisions that video will eventually enable the dispatcher to see video of the 911 caller as well as enable the dispatcher to click on a GIS map of the location of the call and view video from nearby surveillance cameras or from first responders on the scene.

2.1.5 Public Utilities Commission

The Public Utilities Commission (PUC) is the City agency responsible for fresh water, wastewater, and municipal power for the City of San Francisco. CTC met with Hans Loffeld, the PUC director of information technology.

The PUC uses a variety of licensed wireless and leased communication lines to provide backhaul between its main facilities. The PUC obtains T1 lines through DTIS to provide connectivity between PUC headquarters, two sewer treatment plants, the water distribution maintenance yard, and the Lake Merced pump station. Another sewer treatment plant is connected by a high frequency point-to-point Gigabit Ethernet microwave link. The Commission is exploring using more point to point wireless links for increased bandwidth.

To monitor and maintain the utility systems, the PUC has deployed a Supervisory Control and Data Acquisition (SCADA) system for remote monitoring and control of pump stations, reservoirs, and electrical substations. The SCADA system uses wireless RF or leased lines for backhaul.

Although PUC obtains its wide-area circuits through DTIS, it manages its own IT systems, including the SCADA system. It currently does not own or operate its own wide area network fiber. The PUC has a limited quantity of conduit available for communications in the City.

The PUC expressed interest in fiber optic connectivity between its locations for day-to-day operations as well as backhaul for the SCADA system. The PUC would like its own dark fiber within the City fiber optic network to deploy its own managed network. PUC suggested an arrangement under which it pays for building entrance construction costs and provides use of its own conduit as an in-kind payment.

One of the major applications driving increased bandwidth at PUC facilities is PUC's interest in surveillance video. Few of the PUC's existing links provide adequate capacity for full motion video.

PUC is also planning on making available GIS information and maps to field personnel. PUC will require a broadband wireless communications service to provide IT resources to its mobile workforce and are planning to coordinate with the DTIS Citywide WiFi initiative.

The PUC is in the process of developing a sewer master plan with a draft expected in the summer of 2007. The plan for sewer replacement is to double the replacement schedule of the sewer system from every 200 years to 100 years, which roughly equates to twice the sewer replacement that the City currently performs annually.

Replacement is planned by a location-by-location basis depending on the condition of the sewer system. Once the sewer system master plan is approved there is the possibility that

that the replacement schedule can be expedited. PUC wants to develop fiber optic installation specifications for fiber to accompany sewer and water replacement.

Steve Medbery with the PUC, Director of Environmental Regulation and Management reported that the PUC was very open to any proposals for collaboration with a fiber construction project, as long as the proposal did not affect the PUC's ability to maintain and operate the sewer system. The PUC also agrees that any coordination of street cutting would be beneficial to the City as it would minimize the impact on residents. The PUC recommended that any contractor who installs conduit for the City be able to respond quickly to install conduit as soon as the PUC performs a street cut.

2.2 Selected Non-City Users

Public, non-profit, and academic users have distinct yet significant communication needs. At the direction of DTIS, CTC interviewed public entity users selected by DTIS to determine their communications needs and future applications.

2.2.1 San Francisco Unified School District

The San Francisco Unified School District (SFUSD) provides public pre-kindergarten through high school education for approximately 60,000 students. The school system operates over 160 educational facilities.

For wide area network connectivity, SFUSD uses the State of California's telecommunications services contract (CalNET) with AT&T to procure network connectivity between the schools and the District Office. In addition to CalNET, which provides a reduced cost for telecommunication services, the School District also receives E-rate funding for reimbursement of a percentage of the cost of their networking connections. The reimbursement to SFUSD from the E-rate program varies by period. The schools use state contract amounts to prepare their budget. E-rate reimbursement and state contract amounts are combined to reduce costs by 50 percent.

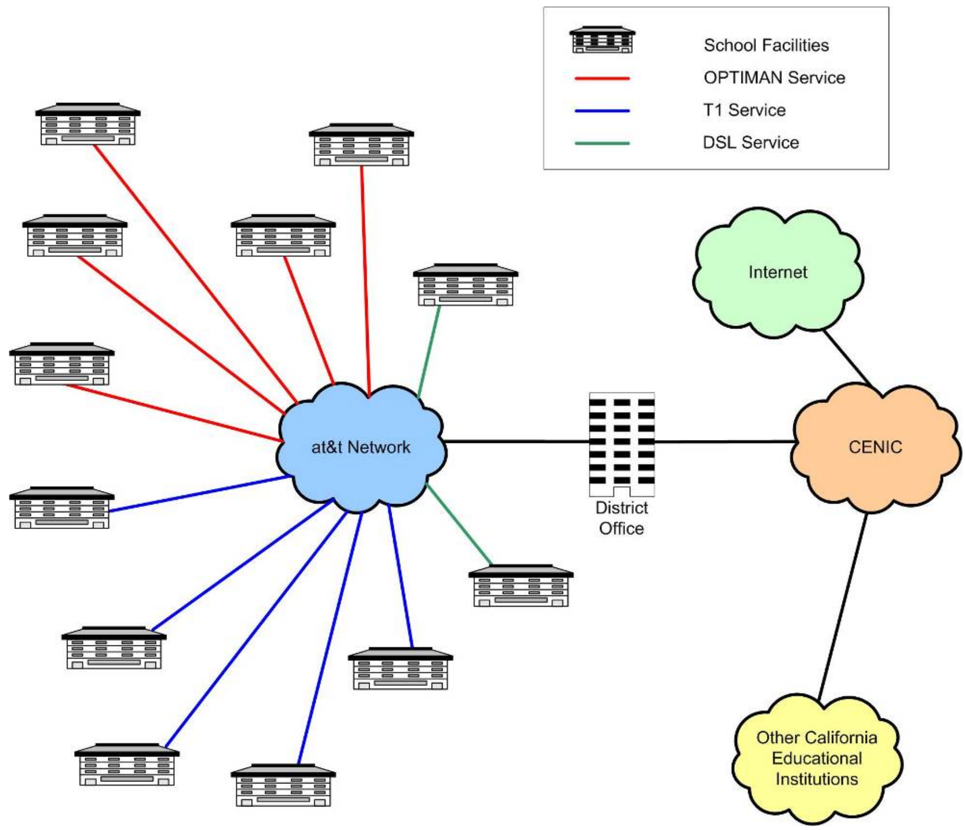
SFUSD finds E-rate reimbursement and state contract amounts cost-efficient and would be interested in using City fiber only if it is comparable or better in cost.

SFUSD believes that it is critical that students have access to high-speed Internet at their homes.

Approximately half of the School sites are connected by AT&T's OptiMAN service, which provides fiber optic Ethernet based connectivity at 10 to 100 to 1,000 Mbps depending on the traffic needs of the individual school site. The majority of the remaining School sites are connected using T1 lines, and a few smaller facilities use DSL modems for connectivity.

SFUSD's main Internet connection is provided by the Corporation for Education Network Initiative in California (CENIC). CENIC provides a 150 Mbps connection to the Internet as well as access to its intranet, which connects SFUSD to other educational institutions in California. The School District also maintains a 10 Mbps backup Internet connection from AT&T in the event of an outage. SFUSD filters its Internet connection at the District Office before providing connectivity to the other School facilities.

Figure 4: SFUSD Network Architecture



SFUSD is in the process of moving many of its localized servers and applications to a centralized data center at the District Office in order to improve monitoring and maintenance, backup, and recovery. As the School System moves to a more centralized application approach, more bandwidth will be needed between the District Office and the School facilities to support those applications.

To backup remote and centralized services and data, the School system has implemented a centralized data backup and recovery system. The backup system is moving the School System's backup system from localized tape backup to a centralized server based system. The backup system requires connectivity between the schools and the District Office during off hours for backup.

Many of the School System's applications are moving to more bandwidth intensive web-based applications. Applications run by the School System include:

- Human resources and payroll
- Student information systems
- Special education information systems
- Truancy and attendance systems

SFUSD is increasing its use of media based applications. One application is distance learning. One potential deployment is real time distance learning to provide educational access to students across the School District. One example would be providing access to students to Advanced Placement classes that are not offered within their own high schools. Another potential application would be online computer based classes for additional education credit. Distance learning classes are still in the early implementation stages as the logistical and policy issues still need to be worked out before wide scale implementation. The school system sees their connection to CENIC may provide additional distance learning access to other educational resources throughout the State in the future.

Another media application the School System foresees in the future is digital educational materials in the form of educational videos, textbooks, and other resources. The school system envisions being able to download educational resources from publishers instead of the traditional textbook approach.

Video surveillance is another potential video application that may require additional bandwidth over the School District's network. The School District has deployed some cameras at School facilities but has no immediate plans for a District wide centrally monitored video surveillance system.

The School District is also in the pilot stages of a VoIP system that is operating in two elementary schools currently. The pilot program has been successful so far and SFUSD has plans to migrate to VoIP for sites connected to the OptiMAN service.

SFUSD is fairly autonomous from other government entities within the City. The School District communicates most with the Public Library system, but this connection is performed over the Internet. The School system does not see an overwhelming need to connect to other governmental agencies as long as they have high-bandwidth Internet connectivity.

In terms of connectivity to its students, the School District believes it is essential that all students have high-quality Internet access. The School District would support fiber optic connectivity to all its students, but is more focused on ensuring that all students have access to broadband Internet connectivity rather than the type of connectivity. Digital inclusion is an extremely important issue for the School District and it has programs in place to provide donated or discounted computers to in need students.

2.2.2 City College of San Francisco

The City College of San Francisco (City College) provides higher and continuing education as well as many community outreach programs. The Citywide college system consists of over 100,000 students, 1,000 staff, and 2,000 faculty members. The college operates nine campuses throughout the City, and reports a need for high capacity and reliable communications between facilities.

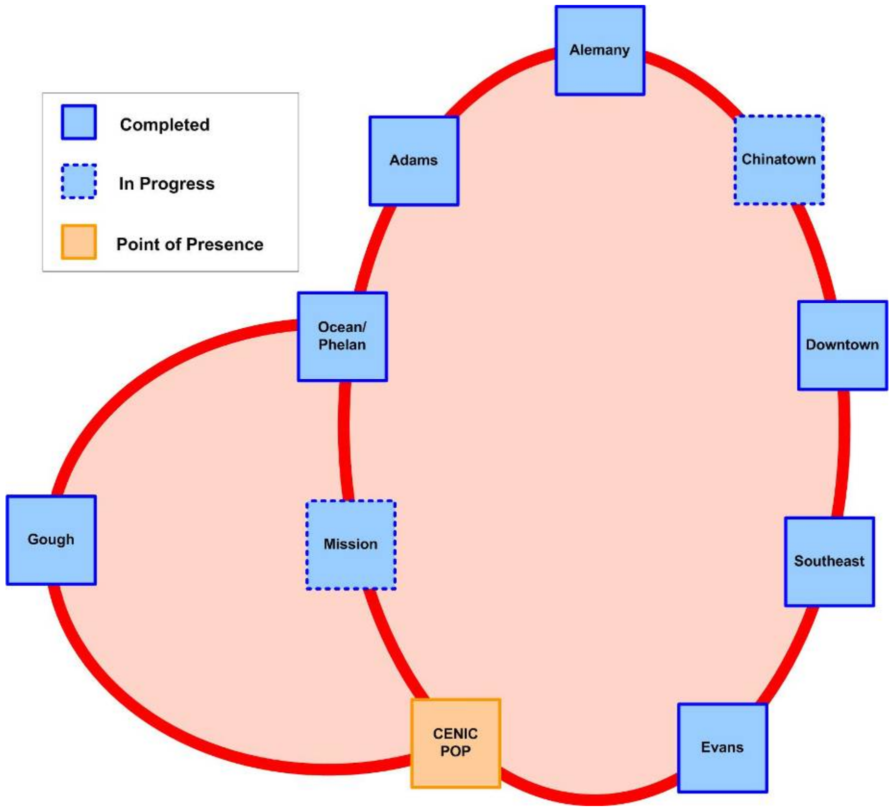
CTC met with Tim Ryan, the Network Manager for the City College.

The City College operates or plans to operate several applications requiring high-capacity fiber optic network links between its campuses and the Internet, all of which may benefit from the fiber optic network:

- Distance learning
- Data backup and recovery
- Video on Demand
- Traditional video broadcasting
- Developing an incubator center for start-up companies as a potential employment opportunity for graduates
- Use of computer labs and IT resources during off-hours for community outreach programs
- Grid Computing
- Distributed Supercomputing
- IEEE Global Quilt Research
- Expansion of high bandwidth applications and lessons into the daily curriculum

The City College recently completed a collaborative fiber optic project with the City to construct a fiber optic network between its nine campuses and a point of presence (POP) for the Corporation for Education Network Initiative in California (CENIC), where the City College connects to other educational and research institution and receives its Internet access. Internet access is through a 100 Mbps connection that is 50 percent utilized at peak time.

Figure 5: City College Fiber Ring Architecture



Through the partnership, the City College obtained a 12-strand, 36-mile ring that connects the campuses and the CENIC POP. Fiber was installed by DTIS in conduit available to the City under franchise and other agreements. The City operates some strands within the same cable sheath.

During construction of the ring, the City College explored linking their network to the other educational institutions within San Francisco, but the bond measure funding the construction did not allow funding to be spent on interconnecting the City College to other entities. The City sees connecting to additional sites as a potential need of their network.

The City College has found the following benefits from its fiber optic network:

- Reduced cost relative to leased T1 circuits
- Reduced network complexity
- Increased reliability (prior to fiber, City College had two T1 links that were unreliable)
- Scalability of bandwidth for the future
- Carriage of the VoIP phone system

After transitioning its wide-area network to the fiber optic ring, the City College received a $750,000 grant from the National Science Foundation (NSF) to develop fiber optic and advanced networking educational programs at the City College. The College has designated two strands of its fiber optic network for new programs.

2.2.3 San Francisco State Univ.–Digital Sister Cities Collaborative Technology Lab

San Francisco State University (SFSU) is a four-year college that was founded in 1899. SFSU enrolls more international students than any other master's degree-granting institution in the United States. Overall, SFSU enrolls 2,016 international students representing 94 countries.

CTC spoke with Joaquin Alvarado, Director for the Institute for Next Generation Internet. Mr. Alvarado is also the Director of Academic Programs for the College of Extended Learning at SFSU.

The University's interest in the project stems from its desire for cost-effective access to high bandwidth. They are launching a development lab project called the Digital Sister Cities Collaborative Technology Lab (Digital Sister Cities Lab). The Digital Sister Cities Lab is located on the SFSU campus, but is moving to a new campus downtown. The Digital Sister Cities Lab is intended to develop and promote collaborative tools that advance the growth of the "Next Generation Internet," which entails gigabit connections to users for interactive applications.

The Digital Sister Cities Lab will have similar development labs in each of the sister cities for this project including Paris, Dublin, and Toronto. Each digital sister city is obtaining a 10 gigabit Ethernet connection to the other sister cities. SFSU is obtaining its connection through the CENIC POP which is located at 200 Paul Street.

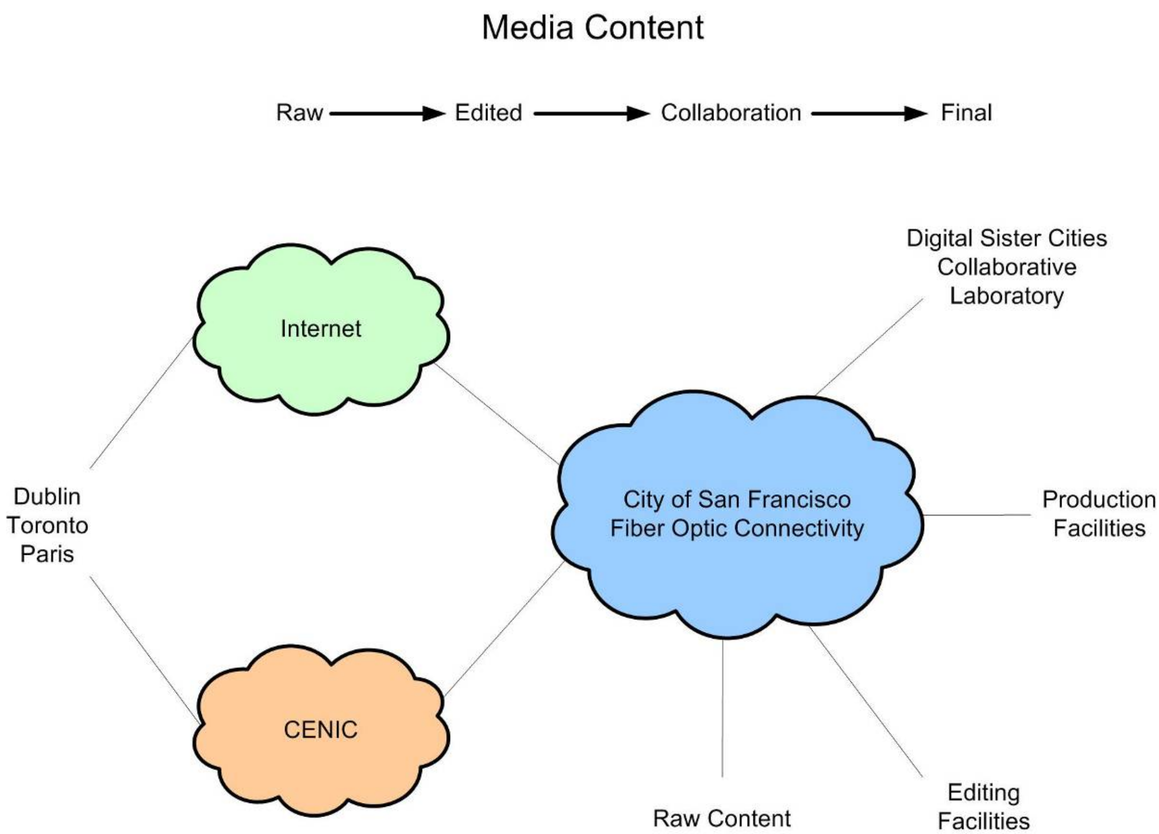
The first application under development is Sebastian, a software tool for creative professionals to globally collaborate on film and video production. The tool will enable users across the world to stream high definition video, discuss the project, and edit the video instantaneously. Sebastian can improve upon the current technique of sending large media files over the Internet, which often takes hours, and discussing the video over the telephone.

Using Sebastian, for example, a film production company in San Francisco could subcontract special effects or do a location shoot in Toronto and at the end of each day review the footage with the producers or directors in San Francisco and make decisions or edits in real time.

Once Sebastian is complete, the Digital Sister Cities Lab plans to allow the public into their lab to use the tool for media production. The goal is to provide a tool that helps smaller production companies in San Francisco compete with the larger production companies while keeping their businesses in San Francisco.

According to SFSU, the real obstacles to the project are 1) creating a tool that is easy to use and 2) getting the connectivity necessary to transmit the data live. With Sebastian, the first issue will be addressed. Fiber optic connectivity between potential users will be able to address the second issue. Fiber optic connectivity within the City, in conjunction with high speed Internet connectivity, can reduce barriers to participation of a range of collaborators both within the San Francisco community and with their counterparts in other cities.

Figure 6: Sebastian Connectivity Overview



The Digital Sister Cities Lab sees fiber optic connectivity as the key to success in this project and other high bandwidth applications of the future. For this and similar ventures to be successful, there will need to be fiber optic connectivity available at a reasonable cost to participants. As fiber optic connectivity becomes more available, there will be more businesses and individuals able connect and innovate together.

SFSU reports that several San Francisco production companies have agreed to participate in the project. Located in the Presidio, Lucas Films is in the process of developing other high bandwidth applications for media production. Bringing Lucas Films into the project would require extending fiber optics to their location.

Even without Sebastian, the Digital Sister Cities Lab sees benefits to fiber connectivity, such as the ability to move footage back and forth quicker and without having to decrease the quality of the video.

The Digital Sister Cities Lab believes that with more companies interested in these high bandwidth applications and more fiber available to consumers, the cost of fiber optic connectivity will decrease to meet the demand.

2.2.4 Pacific Gas and Electric Company

Pacific Gas and Electric Company (PG&E) provides gas and electric utility services to the residents and businesses of San Francisco. The utility itself has substantial communications infrastructure within the City. AT&T is the main service provider for communications needs within San Francisco that cannot be served by PG&E infrastructure.

PG&E has been installing fiber for many years in the City. It has conduit to all businesses and residences served by underground utilities. It has fiber optics to most of its offices, warehouse, and substation facilities. PG&E is continuing to expand its fiber where budget permits. PG&E does not locate power and communications cable in the same conduit. PG&E constructed the City E911 fiber and makes its conduit available to the City for government use.

PG&E has more than 15,000 vehicles in large service area to support and maintain its power systems. PG&E's communications needs mirror those of the City's public safety, public service, and MTA. Their communications operation ranges from non-critical data collection from their users and infrastructure to emergency communications system wide in the event of a service outage. PG&E has some first-responder obligations, including de-energizing and sectionalizing its system during emergencies.

A key need for PG&E is interoperable communications throughout their service area, especially during an emergency when it is necessary to communicate with first responders and emergency operations centers.

Voice communication has traditionally been the critical communication need. However, as the communications and technology landscape has changed, data communications and streaming video are becoming just as important as traditional voice communications.

PG&E has partnered with IP Networks for a data and Internet offering for high-end business users. PG&E leases access to their fiber infrastructure to IP Networks, who offers the retail service to customers. PG&E reports that it is continuing to look at ways to expand this offering.

PG&E is extremely interested in further dialogue with the City regarding aggregation of communications needs, leasing and sharing of fiber assets between entities, and sharing conduit and other resources. The representatives of PG&E stated that they would be supportive of the City deploying fiber to meet internal needs and possibly leasing access to selected providers.

3. Potential to Leverage City Assets for FTTP

This Section of the Report documents the City's existing infrastructure in order to further a general understanding of potential assets that can be leveraged for the fiber projects.

CTC's experience demonstrates that communities frequently own assets in key locations that can greatly reduce network deployment costs. Similarly, there exist opportunities for cost-effective fiber deployment using the County's existing utility infrastructure and future infrastructure construction to realize economies of scale.

San Francisco's government and institutions have invested in communications infrastructure, have negotiated access to valuable cable pathways and fiber optics in franchise agreements, and have access to communications services from commercial providers. Government and institutions have skilled network and outside plant staff and have developed operational procedures to run the existing networks and to plan for future needs.

DTIS is in the process of building a private fiber network for use by government departments. It is installing the fiber in conduit obtained in franchise agreements and in conduit built by City departments. The City is taking the dormant value of these assets and returning the value to the City in the form of increased network performance and reduction of monthly recurring charges to communications.

DTIS is using only a small fraction of the available assets in its current deployment. The remaining assets may be used to expand the DTIS network to more City departments or potentially expand services to non- City institutions, to businesses and to residents.

The assets include:

1. Fiber optic cable
2. communications conduit
3. utility pole attachments
4. staff expertise

Table 1 details the existing City infrastructure.

Table 1: Summary of Existing City Infrastructure Assets

Fiber	***Provider/Source***	***Description***	***Comments***	***Conditions***
	RCN	can request up to 350 fiber drops for governmental use	not located in all parts of the City	limited to public, educational, governmental use
	CCSF	216- count fiber optic network	some of the fiber is reserved for CCSF and MTA	varies depending on conduit restrictions
	MTA	fiber optics constructed for SF Go project	used for connecting traffic intersections	none
Conduit	***Provider/Source***	***Description***	***Comments***	***Conditions***
	UCC	eight-duct high capacity bank	limited areas	none
	MTA	built under rail and electric bus lines, and for SF Go project	40-50% of City fiber is in MTA conduit	none
	RCN	provided by franchise	limited availability of conduit	limited to public, educational, governmental use
	Comcast	provided by franchise	limited availability of conduit	limited to public, educational, governmental use
	PG&E	unused conduit	between public buildings throughout the city	no cables can be installed exclusively for third parties
	AWSS	conduit installed for CCSF fiber project	interconnects other conduit systems	unrestricted
	at&t	conduit supports METS and fire pullbox system	limited to public safety networks; expires 2011	public safety systems only
Other	***Provider/Source***	***Description***	***Comments***	
	City Buildings	250+ City facilities	potential hub locations	none
	City Land	parcels located throughout the City	potential hub, cabinet and vault locations	none
	Towers and Tall Buildings	public safety radio locations	potential locations for additonal wireless equipment	none
	Staff Resources	270 DTIS staff and other agency staff	network operations, management, construction, and integration expertise	none

In addition, further assets can be built more economically if they are coordinated with planned capital improvement projects, such as sewer and water upgrades, utility construction, road construction and repair, and public transit construction and repair.

3.1 Infrastructure

The City has developed a significant amount of communications infrastructure through master planning, project coordination, construction, and asset management. Infrastructure that facilitates communications deployment includes fiber optics, conduit, utility poles and pole attachments, and other physical assets such as buildings and other fixtures.

The following sections describe the assets available to the City for further communications deployments.

3.1.1 Fiber optics

The City has constructed several fiber optic segments to serve the City's internal needs. Fiber optics serve government use in the downtown and in many neighborhoods. Although fiber optic cable runs within a few blocks of most major City buildings, there are some portions of the City that do not have City fiber optics nearby. Moreover, most of the facilities located near the fiber have not been connected—only 26 City buildings are currently directly connected to the fiber.

Most of the City fiber is installed underground. Because some of the fiber is installed in conduit (PG&E, Comcast, RCN) that is restricted to government or educational use, or not available for use by third parties, the general rule is that the installed City fiber is restricted to governmental and educational use (or "conditioned"). The conduit ownership may change from block to block. According to DTIS staff, no attempt was made to avoid "conditioned" conduit.

After the construction of the public safety loop, the City College of San Francisco issued an RFP for a fiber optic network between its facilities. DTIS was awarded the contract to construct the City College network while also deploying fiber optics for other City networking needs. Using the agreement with MTA and the City's rights to conduit, DTIS constructed a 216-count fiber ring, dedicating some of the fibers to the City College. The fiber is housed in both conditioned and non conditioned conduit.

DTIS is using the fiber installed concurrently with the public safety, City College, and radio backhaul projects for the City's fiber based data network "FiberWAN." DTIS constructs additional fiber for public safety and other institutional needs as requested by various departments and as funding becomes available, generally for "lateral" construction to locations from the backbone. All of the City's existing fiber optic routes currently have sufficient capacity to support additional facility connections and applications. All future fiber optic construction projects are planned to consist of 312-strand fiber optic cables or higher.

In addition to the PG&E, City College, and DTIS-built fiber projects described above, the City has the right to use four fiber optic strands in the fiber optic backbone of RCN's cable system. In addition to backbone fiber, the City could also request up to 350 fiber drops from RCN's backbone to City facilities. The City's use of the RCN fiber is limited to governmental purposes so the City may not offer services to third party providers or the public. The fiber is not frequently utilitzed, in part because it is located only in the Mission, Outer Mission, and Noe Valley portions of the City.

Several municipal departments have their own fiber optic resources for specific agency needs. MTA has twelve fiber optic strands wherever DTIS builds fiber optic cable in MTA cable pathways in the MUNI tunnels or in the electric trolley right-of-way. MTA also has 24 additional fiber strands within the MUNI tunnels, and is building additional fiber to support its SFgo project.

3.1.2 Conduit

The City has access to conduit within the City. Through franchise agreements and other agreements, DTIS is able to use conduit and fiber from a range of sources and service providers. The challenge is to combine conduit and fiber from different sources to form a cohesive network. In some places, the City also owns its own conduit infrastructure and constructs conduit to link various conduit assets together.

The providers are:

7. UCC
8. Metropolitan Transportation Agency (MTA)
9. RCN Communications
10. Comcast
11. Pacific Gas & Electric
12. City Auxiliary Water Supply System (AWSS)

UCC

The City received conduit from UCC after they violated the terms of their construction permits. DTIS prefers using UCC conduit where available as there are no restrictions on the use of the conduit. There is also high capacity—an eight-duct bank which is mostly unused. However, UCC conduit exists only in limited areas of the City so it must be interconnected with conduit from another source.

MTA

The MTA constructed conduit beneath its electric bus routes and within the MUNI tunnels to serve the agencies' on communications needs. As part of a memorandum of understanding with DTIS in 2004, DTIS and other City agencies have the right to access a portion of the MTA conduit for installing fiber optic cables. Under the MOU, DTIS must also install fiber optic cable for the MTA while installing its own fiber. DTIS estimates that 40-60 percent of the City's fiber currently resides in MTA conduit.

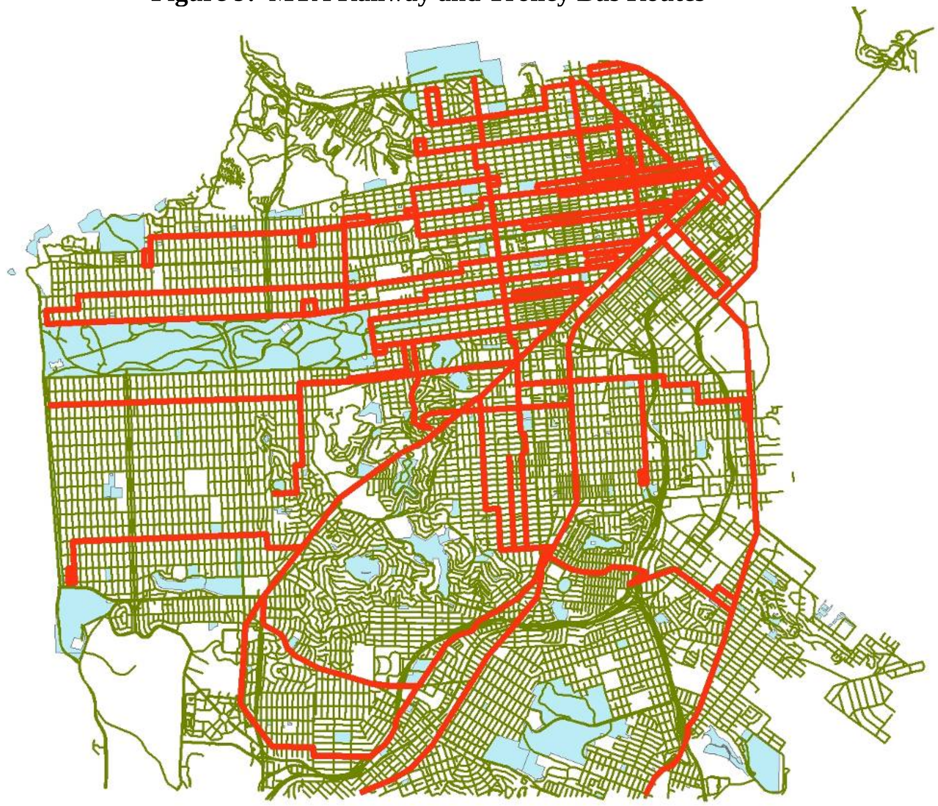
Conduit banks under the electric trolley lines are four 4" PVC accessible in MTA manholes. Where it is installed, fiber optic cable is pulled through mini-duct within the conduit (Figure 7).

Figure 7: City Fiber Optic Cable In MTA MUNI Conduit and Manhole

Figure 8: MTA Conduit Under Street With Electric Trolley Line

There are 16 electric trolley lines and five underground MUNI lines. The total mileage of both systems is 110 miles with coverage of many San Francisco neighborhoods (Figure 9).

Figure 9: MTA Railway and Trolley Bus Routes



Comcast

Under the cable television franchise agreement between Comcast and the City, Comcast is required to install a spare conduit for the City's use in any area where Comcast has installed conduit since 1996. In areas where Comcast already has conduit, Comcast must make any available conduit available to the City.

The City has access to the Comcast conduit and can use the Comcast conduit to provide communications services to government, educational, and public access agencies. The City may not use Comcast conduit to provide communication services to third party entities.

The franchise agreement requires that all Comcast underground conduit permit applications include drawings identifying the conduit to be installed for the City. The City conduit must be marked for ready field identification, be at least two inches in diameter and installed with a pull-string inside, and must be connected from one underground vault to another. Comcast is also required to provide as-built drawings to DTIS and the Department of Public Works.

RCN

The City's RCN franchise agreement provides the City with use of conduit. The RCN conduit is limited to public, educational, and governmental use. RCN was required to provide up to 539 linear miles of one two-inch conduit. The two-inch conduit can be upgraded to larger or more conduit in exchange for less miles of two-inch conduit. However, relatively little of it was built—RCN built to only 10 percent of the City, mostly in the Mission, Outer Mission, and Noe Valley areas.

The main location of City interest on the RCN system is the 200 Paul Street Internet cross-connect point. In that area, the City uses one to two miles of RCN conduit for entry to the facility. Unfortunately, relatively little of the completed RCN construction was underground, so there is little conduit actually available to the City. Much of the available conduit is standalone conduit built to take advantage of joint trenching opportunities. RCN is in the process of selling its San Francisco operation to Astound Broadband.

Pacific Gas & Electric

Under the conditions of an agreement between PG&E and the City, the City has the right to use existing empty PG&E conduit. The agreement is part of a broader settlement between PG&E and the City. Under the agreement, the City can use conduit to 26 buildings, plus an additional two buildings each year from 2002 through 2011. The City may substitute other buildings or other routing, provided the total conduit provided is of comparable value to the building conduit reflected in the agreement.

The City has placed miles of fiber in this conduit and still has a substantial allotment available. PG&E has an extensive conduit network as it provides electricity to the homes and business within the City. Approximately 50 percent of the City's electrical plant is in underground PG&E conduit. PG&E stated that they have constructed underground conduit into most of the homes and businesses within the City of San Francisco.

The conduit is restricted to use for connectivity by the City between "public buildings," defined as "any building occupied, in whole or in part, by [the City], the [SFUSD], The San Francisco Community College District, the San Francisco Housing Authority, the Redevelopment Agency of the City, the San Francisco Port Authority, or the San Francisco Airport." The fiber installed may serve non-City parties under certain circumstances—these are that "in no case shall Fiber Optic Communications Facilities be installed, maintained, or used in PG&E Conduit pursuant to this Agreement for use solely by third parties," that PG&E be able to obtain information about the City's use, and that the City obtain "third-party's written contractual agreement to indemnify, defend, and hold harmless PG&E against any loss, damage, expense or liability." This implies that other parties may use fiber within cables that travel between Public Buildings under the above terms, but that those parties cannot have their own dedicated cables within the PG&E conduit.

The City is required to pay fees for preparation of the conduit, including "fishing and cleaning," and for PG&E supervision of installation. DTIS prefers not to use PG&E conduit if other conduit is available because of the additional cost.

In addition, the City installed inner duct for a separate 96-count fiber optic ring for 911 services in 2001, described above in Section 3.1. The fiber was acquired as part of a bid process. The ring comprises approximately 44,000 feet.

AT&T

AT&T and the City entered a 50 year agreement, in 1961, for use of AT&T conduit for deployment of the City's fire pull box and METS systems. Like PG&E, AT&T has an extensive conduit network throughout the City. The City is currently using approximately 100 miles of AT&T conduit in support of the METS and fire alarm system.

DTIS is concerned about the agreement expiration date in 2011 and the likelihood that DTIS will no longer be able to use AT&T's conduit or that they will not be allowed to migrate to newer fiber optic cables within the same conduit. As a result, DTIS has begun exploring other options for connectivity including fiber optics, 4.9 GHz wireless, and the public safety radio system.

AWSS

DTIS has also taken advantage of capital improvement projects (CIPs) to construct conduit at an incremental cost to the overall CIP. DTIS worked with AWSS, the auxiliary water supply system project, to install conduit during an expansion of the system to provide high pressure water lines for the Fire Department.

3.1.3 Utility Poles and Pole Attachments

Half the City has aerially constructed utilities, meaning that electric and communications facilities are located on utility poles. The majority of the poles are under the authority of the Northern California Joint Pole Association (NCJPA). The NCJPA manages the use of joint use poles and distributes access and the costs of using a joint use pole.

In support of the fire alarm system and the METS, the City currently has approximately 200 miles of copper plant strung among the poles in the City. For public safety purposes, the City has the right to the space between the electrical space and communications space on any joint use pole within the City. On most poles where the City currently has infrastructure, the City has added cross arms in its space to support its infrastructure.

The City is currently not a member of the NCJPA, but would need to join if the City had the desire to attach equipment or fiber to joint use poles. Because the NCJPA regulates much of the joint use of poles, the City does not foresee obstacles to joining the NCJPA and attaching to the existing joint use poles in the City. From its experience in constructing fiber, DTIS feels the current aerial construction process and cost of receiving a pole attachment agreement is fairly simple and inexpensive.

The cost of pole attachment is regulated by State of California tariff system. A more significant cost relates to pole preparation, which items such moving utilities and replacing poles and is referred to as “make ready” costs. Make ready obligations are generally assessed by the pole owner after a multi-party field inspection (“ride out”) with the existing users of the poles. The City has little control over make ready costs; as a result, these costs create significant uncertainty.

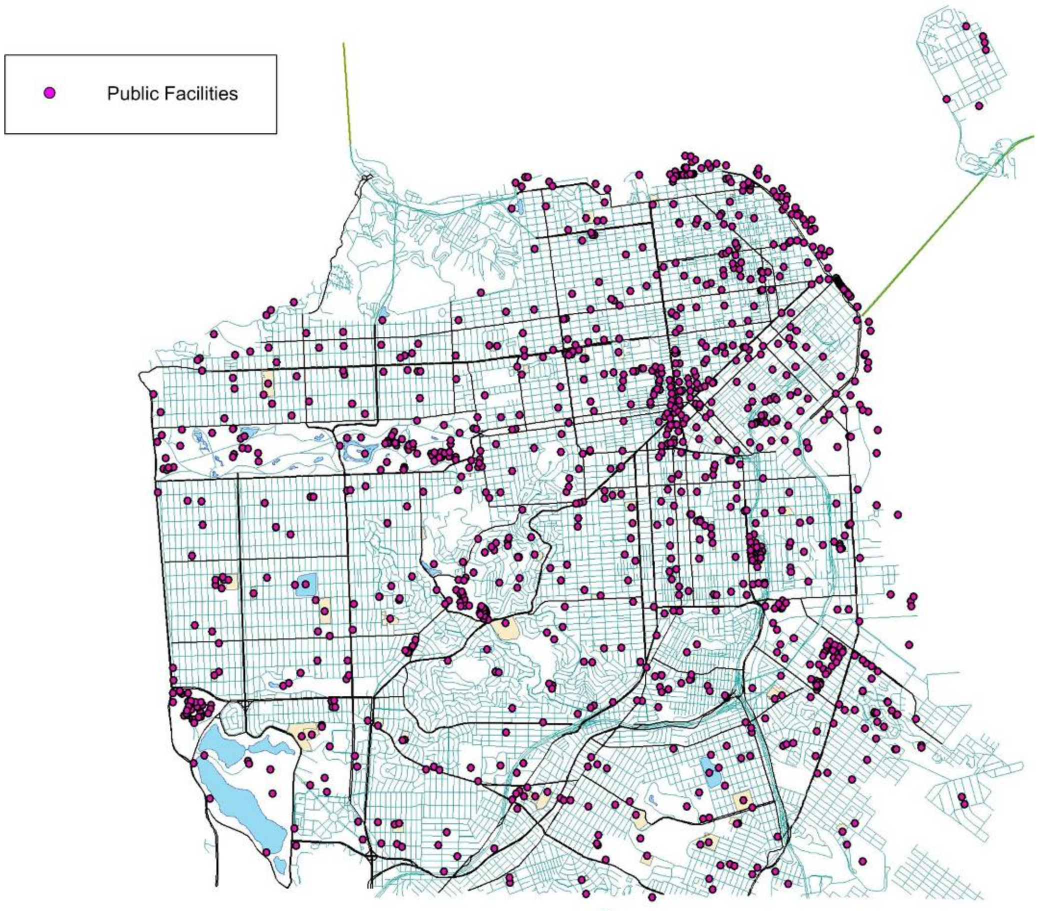
3.1.4 Other Physical Assets

The City has significant physical infrastructure assets including buildings, communications towers, and a microwave system. Each asset may serve as an integral part of a Citywide communications network.

City Buildings

The City has over 250 public facilities such as office facilities, schools, health clinics, recreation centers, and other governmental facilities. Government buildings are potential secure locations for the storage of electronic equipment for a municipal network, with adequate access to power and heating, ventilation, and air conditioning (HVAC). The ability to house equipment at these locations may decrease the need to place equipment in the public right-of-way, facilitate the maintenance and operations of a fiber optic network, and physically secure network assets. As is discussed below, approximately 20 hub facilities will be required for a municipal network serving all residences and businesses in the city, and access to secure facilities will significantly reduce the cost and complexity of building a network.

Figure 10: City of San Francisco Public Facilities



In addition to buildings, the City also has government land which may be suitable for the placement of fiber optic equipment, potentially in shelters or environmentally controlled vaults.

City Towers

The City uses a combination of tall buildings and towers to provide coverage and capacity for its public safety radio system. The City has also instituted a microwave system to support the communications between radio sites. These facilities potentially provide a location for mounting additional wireless equipment to support mobile connectivity in conjunction with a fiber optic network.

3.2 Staff Resources/Expertise

City personnel are constructing, maintaining, and supporting a variety of communications networks throughout the City. Their expertise is an invaluable asset that can be leveraged to plan and guide future fiber optic communications projects.

The roles of DTIS network staff can be seen as a variation of the roles undertaken by a large facilities-based Internet service provider, including attending to needs of customers, making physical connections, managing network electronics, connecting to outside service providers, keeping information secure, hosting information, managing infrastructure and growing the network to serve increasing demands.

In addition, because it serves the unique needs of a large city government, DTIS has acquired specialized expertise. This includes the need for the highest availability and reliability for public safety, operation of a public safety radio system, compliance with stringent information security requirements, and overseeing franchising.

DTIS staff can potentially form the core of a larger team that implements a Citywide network serving a large percentage of residents and businesses. Alternately, DTIS can potentially act as expert overseers of outside contractors performing this role.

In CTC's judgment and experience, DTIS compares favorably to the most sophisticated cities in the United States with respect to internal staff capabilities and experience regarding fiber networking.

3.2.1 Network Construction Oversight and Inspection

DTIS has performed and/or overseen the construction of the City's existing fiber optic communications network. DTIS' highly-capable Public Safety Outside Wire Division is responsible for performing construction estimates for additional fiber optic plant, constructing conduit and installing and splicing fiber optics, and overseeing large scale fiber optic and conduit construction projects. The Division has approximately ten people who do line work and underground construction. The Division has three people qualified to do fiber optic splicing as well as an in-house fusion splicer. During larger construction projects the Division has the ability to increase staff to meet demand.

Figure 11: DTIS Public Safety Outside Wire Division Fiber Splicer

The Division generates fiber optic and conduit construction quotes in-house using their expertise in existing City conduit and fiber optic cable, and their experience on similar construction projects for the City.

Once quotes and funding have been secured, the Division often digs its own trenches for conduit, pulls fiber optic cable, and splices and terminates fiber within buildings. By leveraging the existing conduit for City use, the Division can typically keep underground construction projects to a less than a half a mile, depending on the location of the added building.

For large scale fiber optic construction projects, the Public Safety Outside Wire division oversees the construction to ensure the project meets the contract designed specifications. For example, the Division planned and oversaw construction of the City College fiber optic network for DTIS.

3.2.2 Network Integration

As discussed above, DTIS staff is in the implementation phase of a City-owned and operated fiber optic wide area network, FiberWAN. Dozens of sites are being added to the network. DTIS has activated a network core and is connecting the core to City departments at the sites. DTIS connects to existing network hardware at the sites if it is compatible, or installs new switches.

DTIS connects FiberWAN to the facility local area networks and to the City's IT resources. It is responsible for the City's connection to the Internet, security, and intrusion detection. It maintains separate networks within FiberWAN for each department. It designs redundancy into the network, designs network electronics, and makes plans for scaling the network. It makes possible remote connectivity to the network through VPN and other means. It makes possible connections from FiberWAN to other government and educational networks.

3.2.3 Network Monitoring

The City monitors both the network equipment and fiber optic components of the City's FiberWAN project and the public safety network. As part of the fiber optic construction project, the City was also awarded a contract to monitor the City fiber ring for 10 years.

Network monitoring occurs at two separate City locations. The dual monitoring system provides redundancy in the City's monitoring operations. The network is monitored 24 hours a day, seven days a week for fiber faults or equipment failure.

In addition to the fiber optic network, the City also monitors the public safety radio system, fire alarm system, and METS. The aggregated monitoring allows multiple systems to be monitored by a single entity, thereby reducing staffing needs.

3.2.4 Network Accounting

DTIS is responsible for billing other City agencies for their telecommunications and data connections. In the summer of 2006, DTIS began implementing a new Teleweb system for billing purposes. The system will allow the users in various departments to use a web interface to view their telecommunication charges. The new system will allow each department to manage their own telephony inventory, including wireless phones and pagers. The system will also provide greater management of the City's telecommunications expenses.

The City is also in the process of auditing the telephony inventory to remove unneeded circuits and update the current inventory. DTIS estimates there are approximately 3,000 to 4,000 circuits in the City. As part of the FiberWAN project, DTIS is now charging departments for data connectivity over City owned fiber optics. DTIS developed a rating system based on projected costs, but is working on refining the rate schedule for the FiberWAN connectivity.

There is currently no process in place for holding funds obtained through the chargeback process for network expansion. A process may be needed to ensure that the long-term capital costs of the network are covered.

3.2.5 Network Maintenance and Repair

In the event of a fiber optic cut, the Cisco network monitoring software signals the CECC and City's Datacenter of an outage. The network monitoring staff alerts DTIS of the outage. DTIS staff then drives the fiber route to determine if a visible incident (such as road construction, fire, or water main break) caused the incident. If the incident can be located, DTIS informs its splicers of the location and sends them out to repair the fiber damage. If the location of the fiber cut is not noticeable, DTIS tests the fiber from the closest location using specialized equipment (an OTDR) to determine the approximate location.

The public safety fiber optic network has had only two outages since construction was completed in 2002. For additional redundancy and assistance in a larger scale outage, PG&E is kept on retainer to provide a two hour response time to repair any fiber outage of the public safety loop.

3.3 Planned Capital Improvement Projects

The Department of Public Works Street (DPW) Construction Coordination Center coordinates construction activities in the right-of-way. Public and private entities are required to provide their plans for underground construction for the next five years to DPW every April and October. The goal of the bureau is to coordinate construction activities to minimize disruption to the streets by coordinating efforts to minimize street cuts.

Many organizations are updating their construction plans monthly with the DPW. Although five year plans are submitted, DPW stressed that the plans can be rather dynamic depending on funding and changes in plans.

DPW also works with DTIS to negotiate with telecommunications carriers to share trenching when underground projects are needed. The City's excavation code requires trenching coordination.

3.3.1 Sewer and Water

The PUC is the entity responsible for installing operating and maintaining the sewer and water systems within the City. The PUC is open to installing fiber optic conduit in trenches during sewer replacement or even within existing main line sewer pipes, as long as the conduit does not interfere with the sewer functions. However, the PUC does not believe that conduit can be effectively installed inside building laterals, only in "backbone" routes where conduit can be more cost-effectively installed and accessed.

The PUC has recently received a $300 million bond for water and sewer renovation, which is still in the engineering and design phase, and therefore has not been added to the DPW five-year plan. DTIS is working with the PUC to incorporate conduit construction into water and sewer capital improvement projects. The PUC is not aware of any joint use of sewer replacement trenches currently.

Typical sewer replacement projects are small in scale and only cover a few blocks at a time. Conduit has not been installed during these replacement projects in the past due to the small area that is being repaired.

In early 2004, heavy storms caused flooding in some of the low-lying regions of the City. To address the flooding problems the PUC initiated a five-year CIP to address the flooding problems and other wastewater repairs. The $150 million dollar project began in 2005 and currently five projects have been completed with 12 more in the design and construction phases.

In addition to the five-year CIP, the PUC will continue its annual repair and replacement program of aging wastewater infrastructure as well as spot repair of the wastewater system, as necessary.

The PUC initiated a Wastewater Master Plan Project in the beginning of 2006 to develop long term goals for the maintenance, operations, and repair of the City's wastewater system. The goal of the master plan is to provide a strategic roadmap over the next 30 years.

A draft of the plan is expected in the summer of 2007. The plan for sewer replacement will be to double the replacement schedule of the sewer system from every 200 years to 100 years, which roughly equates to twice the sewer replacement that the City currently performs annually.

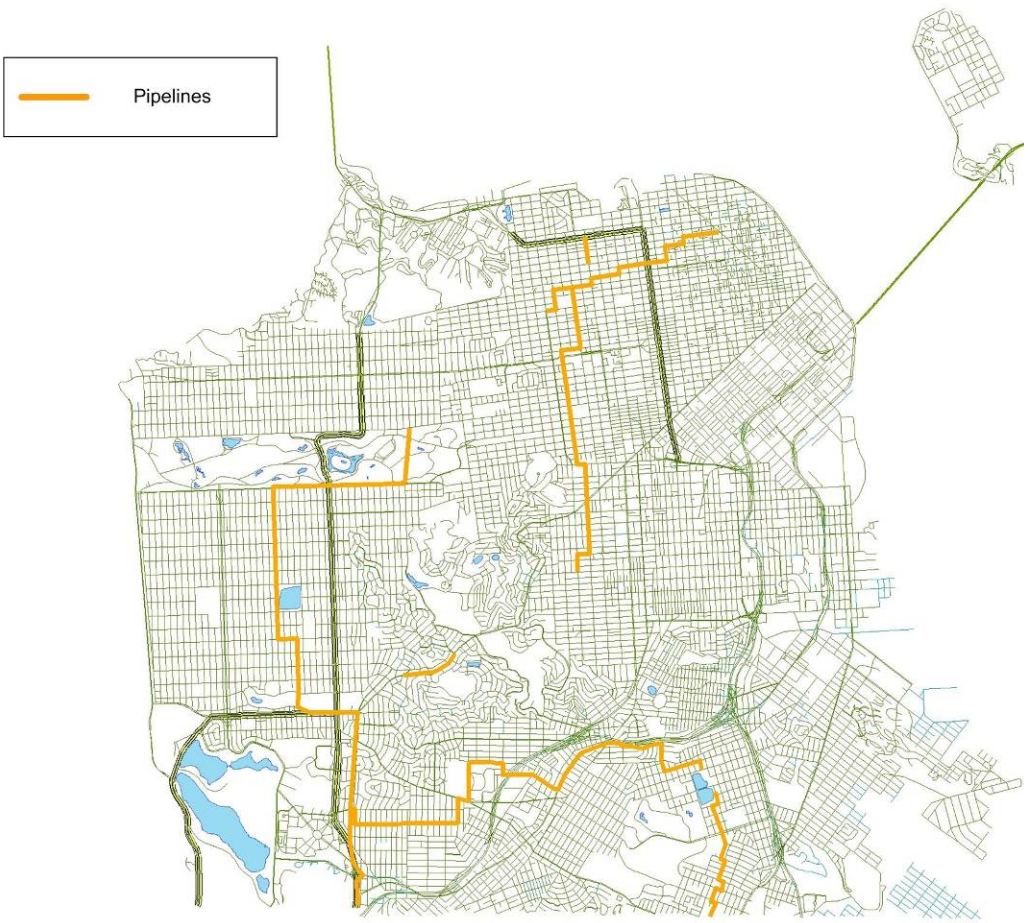
Replacement is planned on a location-by-location basis depending on the condition of the sewer system. As a result, it is unlikely to provide long open trenches best suited for large-scale communications conduit projects—rather it will create areas where conduit can be installed at the time of the open trench for later incorporation into a larger project.

Once the sewer system master plan is approved there is the possibility that that the replacement schedule can be expedited, potentially better-suiting communications conduit installation. PUC wants to develop fiber optic installation specifications for fiber to accompany sewer and water replacement.

Steve Medbery, the PUC Director of Environmental Regulation and Management, reports that the PUC is very open to any proposals for collaboration with a fiber construction project, so long as the proposal does not affect the PUC's ability to maintain and operate the sewer system. The PUC also agrees that any coordination of street cutting would be beneficial to the City as it would minimize cost and the impact on residents. The PUC recommended that any contractor who installs conduit for the City be able to respond quickly to install conduit as soon as the PUC performs a street cut.

The PUC is continually working on improving and maintaining the City's Water supply system. Currently there are 36 capital improvement projects underway in the City of San Francisco aimed at improving the City's reservoirs, pump stations, and transmission lines. The PUC is in various stages of construction for several large scale water transmission line replacements. These transmission line replacements may provide opportunities for joint trenching during construction.

Figure 12: Planned Water System Replacement Projects



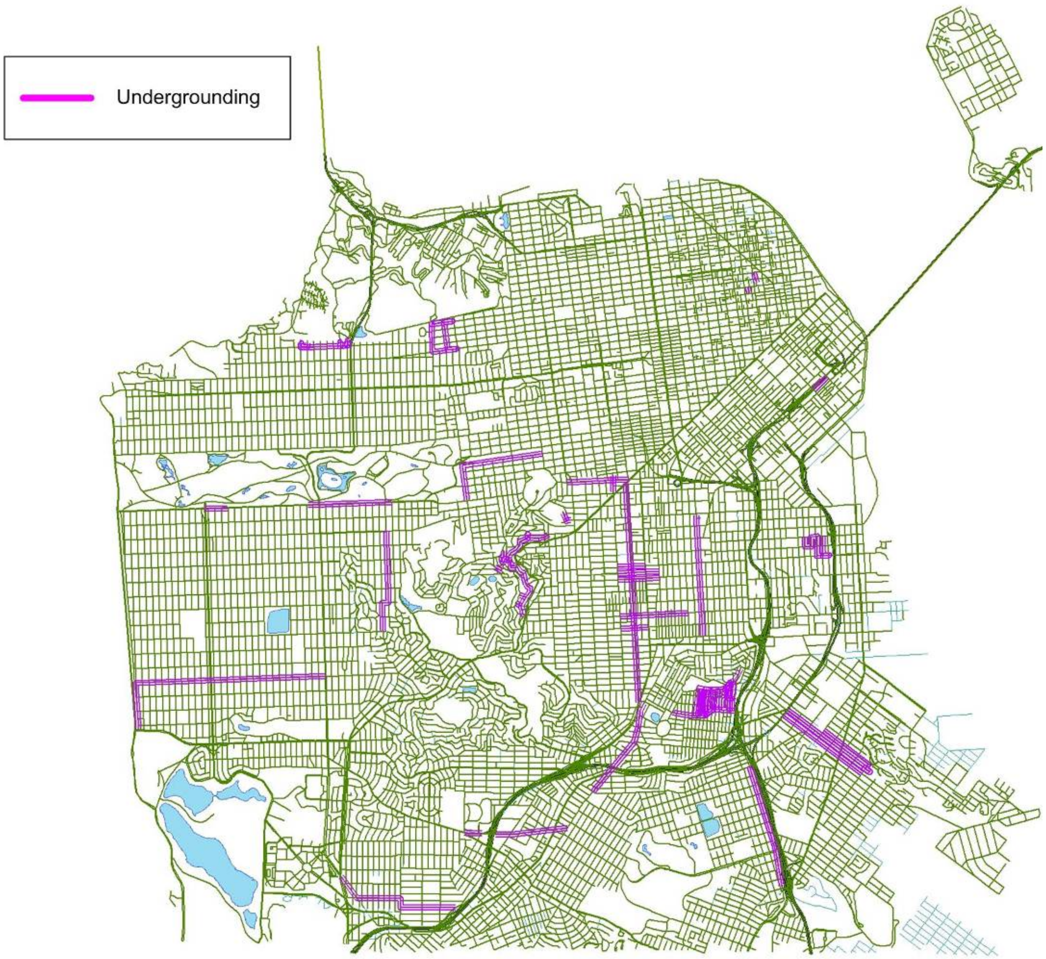
3.3.2 Utilities

DPW estimates that approximately 50 percent of the City's utilities are located underground. Funds for undergrounding are currently exhausted and the charge is being used to pay for past projects, there are no undergrounding projects currently planned.

The City has initiated a utility charge of 2.5 to four percent to move utilities underground. The utility charge covers approximately 11 miles of undergrounding a year. Ninety percent of undergrounding is done in the sidewalks.

Figure 13 shows the areas designated for undergrounding on the five-year plan.

Figure 13: Planned Undergrounding Areas



3.3.3 Road Construction and Repair

According to DPW, there are approximately 1,600 curb miles (both sides of the street) and 900 street miles within the City. There is a five year moratorium on underground construction after a street is repaved, other than for emergency repair of utilities.

The Mayor's office has initiated a broad program to repair the sidewalks in the City. The project was approved by the Board of Supervisors in January 2007. The project involves inspecting every sidewalk and where necessary repairing them over 25 years. There are approximately 122 million square feet of sidewalk in the City, of which an estimated 30 percent is damaged. The plan will call for repairing 140,000 square feet of damaged pavement on 106 square blocks by June 2007. The repaired areas will be selected based on repair need and will likely not be contiguous.

3.3.4 Public Transportation Construction and Repair

MUNI is involved in a major light rail project to expand service between the Bayshore and Mission Bay CalTrain stations and to add a new maintenance facility.

The second phase of the project will be an underground subway line that runs from the Mission Bay CalTrain station north through Market Street and Union Square to Chinatown. MUNI is working on funding for the second phase of the project.

DTIS evaluated constructing conduit during the initial light rail phase of the project, but the cost of conduit construction was then prohibitive in light of DTIS' budgetary constraints. MUNI is installing conduit along the light rail project so DTIS can coordinate with MUNI for the construction of fiber.

DTIS is pursuing gathering funds for the second phase of the project in order to install conduit during construction.

The MTA is also installing conduit and fiber in support of the SFgo project. The goal of the project is to replace all existing copper infrastructure with fiber optics. Some copper is leased, some is owned by MTA. The installation of fiber may provide opportunity for cost sharing and incremental fiber optic builds.

4. FTTP Case Studies

This Section of the Report presents a number of case studies of existing municipal FTTP initiatives and operational FTTP networks. As part of these case studies, CTC offers "lessons learned" where such analysis was offered by the relevant network operator, but CTC cautions against understanding these experiences as "best practices." The municipal FTTP movement is still in its infancy and there is limited empirical data on which to rely for purposes of understanding how processes and business plans have worked. In addition, there are dramatic differences in circumstances between San Francisco and each of the existing municipal FTTP networks in the United States and elsewhere. We caution against simple comparisons and note instead that these municipalities face major differences in financing, topography, technology evolution, market, customer base, competitive situation, and other factors.

4.1 Seattle

Seattle is evaluating the feasibility of a Public/Private Partnership to build and own an FTTP network as a means to reducing the City's risk.[49] The city has engaged in a feasibility and exploratory process that is the first in the United States for a city of Seattle's size.

Population:	563,374
Households:	270,524
Median Household Income:	$45,736
Per Capita Income:	$30,306
Area:	83.87 square miles[50]

Initiation Dates: In 2004, the city's Mayor and Council convened a Task Force to evaluate the city's "technology future." In 2005, the Task Force adopted a goal that would bring true broadband to the entire city by the year 2015.

On the basis of these findings, in the spring of 2006, Seattle issued a Request for Interest (RFI) to attempt to ascertain the interests and ideas of private sector entities interested in partnering with the city on an FTTP network.[51]

The city received more than 30 responses to the RFI, of which at least 10 were sufficiently interesting and responsive that city stakeholders interviewed the respondents during the fall of 2006.[52]

---

[49] Bill Schrier, "Bustin' the Myths," presentation delivered at NATOA national conference, August 25, 2006; CTC interview of Tony Perez, Director, Office of Broadband, City of Seattle, October 5, 2006.
[50] 2000 Census, http://factfinder.census.gov/home/saff/main.html?_lang=en, accessed December 22, 2006.
[51] The City of Seattle Fiber to the Premises Broadband Network Request for Interest, issued May 2006, www.seattle.gov/cable, accessed November 2, 2006.
[52] Seattle has not yet released copies of the responses. The respondents who were interviewed by the city include: ACI Communications; Bechtel Telecommunications; Ericsson; iTown Communications; Lucent

As of this writing, Seattle has not announced next steps on this project.

Business Model: On the basis of the conclusions of the Task Force, the RFI notes that the city will "be an infrastructure partner," not a service provider or network operator. [53]

Perceived Benefits: The Taskforce articulated its vision in this way:

> *Within a decade all of Seattle will have affordable access to an interactive, open, broadband network capable of supporting applications and services using integrated layers of voice, video and data, with sufficient capacity to meet the ongoing information, communications and entertainment needs of the city's citizens, businesses, institutions and municipal government.*[54]

The Taskforce Report concluded that Seattle would require speeds of 20 to 25 mbps in the short run and 100 mbps and more in the longer run—speeds that are not now offered by incumbent providers and are not likely to be offered by those companies in the foreseeable future. Despite the mobility benefits of wireless technologies, the Task Force found that only FTTP could deliver the bandwidth and security necessary "to ensure Seattle's broadband future," though it recognized an important complementary role for wireless.[55]

Significantly, Seattle noted the dramatic impact technology has had on that city's development and nature. It further noted that a lack of true broadband competition could relegate the city "to second tier status in terms of its technological sophistication and [the city could] lose its edge to cities that are better positioned to compete in the emerging global economy."[56] As one Seattle stakeholder put it, "If we don't have true broadband, where will the research and development money go? Where will the software developers move?"[57]

Service Offerings: The city's RFI requires that the network be "capable of providing any combination of voice, video and data services to residents, businesses, institutions and city government."

Technologies; Nextnet Investments; PacketFront Inc.; Qwest; US MetroNets; Verizon; and Vulcan. The broad and unexpected range of respondents suggests that there is some interest in such projects among financiers, manufacturers, non-incumbent carriers, and other parties.

[53] The City of Seattle Fiber to the Premises Broadband Network Request for Interest, issued May 2006, www.seattle.gov/cable, accessed November 2, 2006.

[54] CTC interview of Tony Perez, Director, Office of Broadband, City of Seattle, October 5, 2006; Report of the Task Force on Telecommunications Innovation, May 2005, www.seattle.gov/cable, accessed November 28, 2006.

[55] Ibid.

[56] Ibid.

[57] Tony Perez, Director, Office of Broadband, City of Seattle, speech presented to the Metropolitan Washington Council of Governments Broadband Regional Forum, Washington, DC, October 30, 2006.

On the basis of the conclusions of the Task Force, the RFI notes that the city requires that the network have "very high bandwidth with maximum scalability." The city also requires that the network be non-discriminatory in its treatment of providers of similar services as well as in its treatment of customers.[58] Such an approach is directly contrary to the tiering and pricing options the incumbent providers have explicitly reserved for themselves[59] despite the efforts of "network neutrality" advocates.[60] The city also requires that privacy rights be respected.[61]

Residences and Businesses Passed: The city's intention is that the network serve all homes and businesses throughout Seattle. The RFI requires Citywide coverage, even if that is achieved in a phased manner.[62]

Competitive Providers on the Network: The city's RFI establishes some key technical requirements relative to competition, most significantly that the bidders endeavor to build an open platform. Specifically, the city asks that the private partner endeavor to offer an open access platform for multiple service competitors, which, in the words of the city, "will fuel experimentation and innovation, lead to new applications and services, lower prices and create more choices for consumers." [63]

The RFI also requires that customers have the option of attaching any non-impairing device to the network (not only those sold or rented by the operator). [64]

Financing: Given the preliminary nature of this project, the source of financing has not been determined. According to the Director of Seattle's Broadband Office, however, there has been significant interest on the part of the capital markets and it is the city's preception that in the current environment, financing is available for such projects.[65]

---

[58] Specifically, the city notes that is "vital to the future of the Internet that network owners not discriminate in terms of bit transport or unnecessarily mediate between users and content or application providers….We believe that preferential treatment by network owners or operators of data streams will distort the evolutionary path of the Internet, stifle creativity and innovation and ultimately abridge the ability of the Internet to be a medium for the free dissemination of diverse thought and opinion." The City of Seattle Fiber to the Premises Broadband Network Request for Interest, issued May 2006, www.seattle.gov/cable, accessed November 2, 2006.

[59] AT&T CEO Ed Whitacre, for example, has publicly stated that "what they would like to do is use my pipes free, but I ain't going to let them do that because we have spent this capital and we have to have a return on it. So there's going to have to be some mechanism for these people who use these pipes to pay for the portion they're using. Why should they be allowed to use my pipes?," Business Week, November 7, 2005, http://www.businessweek.com/@@n34h*IUQu7KtOwgA/magazine/content/05_45/ b3958092.htm, accessed December 22, 2006.

[60] See, for example, Lawrence Lessig and Robert W. McChesney, "No Tolls on the Internet," Washington Post, page A23, June 8, 2006.

[61] The City of Seattle Fiber to the Premises Broadband Network Request for Interest, issued May 2006, www.seattle.gov/cable, accessed November 2, 2006.

[62] Ibid.

[63] Ibid.

[64] Ibid.

[65] "What Seattle Learned in Europe," eNATOA Community Broadband Seminar presentation, Tony Perez, Director, Office of Broadband, City of Seattle, November 20, 2006.

In addition, the city has signaled some willingness to participate financially in the project. The RFI provided a brief inventory of city assets that could be offered to a private sector partner as an incentive and to maximize efficiency in construction. Such assets include city-owned utility poles, fiber conduit and cable, real estate, and the support of city staff. The city also held out the potential for "additional investments to aid the partnership" as well as the prospect of significant fees for service in the form of an anchor tenancy.[66]

Governance: As it evaluates the responses to the RFI, the city is evaluating possibilities for ownership by an independent non-profit. Under such an arrangement, the city would sit on the Board of the non-profit and would represent a major network stakeholder.[67]

4.2 Portland, OR

Population:	529,121
Households:	237,307
Median Household Income:	$40,146
Per Capita Income:	$22,643
Area:	134.3 square miles[68]

Initiation Dates: The city conducted an initial feasibility study in 2005[69] and developed extensive data to map and quantify potential fiber routing throughout the city. Toward the end of 2006, the City Council authorized a further study that would develop extensive market and business plan analysis of an open platform network—and attempt to quantify the economic development potential of the proposed network. The city anticipates conducting that analysis in 2007.

Portland's city-wide wireless network became operational in December 2006. The city views the two projects as complementary, not competitive.

Business Model: The city's initial feasibility study (and generally, city data and internal information) confirms a high rate of computer and Internet penetration and, presumably, a significant potential market for the services made possible by FTTP. The city is confident that its residential demographics point to an extensive residential market for such services.

Based on the results of the initial feasibility study, the city believes it has established an initial business case for 100 percent municipal ownership of a fiber optic network under a wholesale model.

---

[66] The City of Seattle Fiber to the Premises Broadband Network Request for Interest, issued May 2006, www.seattle.gov/cable, accessed November 2, 2006.
[67] CTC interview of Tony Perez, Director, Office of Broadband, City of Seattle, October 5, 2006.
[68] 2000 Census, http://factfinder.census.gov/home/saff/main.html?_lang=en, accessed December 22, 2006.
[69] Unless otherwise noted, all data in this case study are based on CTC's interview with David Olson, Director, and Mary Beth Henry, Deputy Director, City of Portland Office of Cable Communications and Franchise Management, December 2006.

Financing: City stakeholders are frank that they believe that (at least partial) municipal financing will be essential to the viability of the project. They are also concerned that partnerships with the private sector, particularly in the early phases of the project, potentially distract from the open access/open platform goals that underlie the entire project. Given that the private sector's financial models tend to be based on closed systems, the city's requirement for open access might be incompatible with those models.

Additional Benefits: The core benefit, according to city stakeholders, will be the long-term economic development, education, and quality of life factors made possible by a next-generation network. The city is concerned that the incumbents are focused exclusively on short-term gain and not on any of the key long-term factors that point to development of 21st Century networks. According to the city, the incumbents' aging infrastructure – and retrofitting of old systems rather than deployment of new -- cannot enable Portland to compete and develop as it needs.

Service Offerings: The City's current, preliminary plan is for a wholesale network, in which case the service offerings would be determined by private sector service providers who lease capacity on the network.

Homes and Businesses Passed: As conceived in the current planning phase of the network, the intention is to pass all homes and businesses in Portland.

4.3 Amsterdam

Population:	743,027[70]
Households:	406,720[71]
Average Household Income:	26,300 Euros[72]
Area:	64 square miles[73]

Project Origin and Initiation Dates: According to city stakeholders, the city learned even before the advent of the Internet--during a phone crisis in 1987--that existing networks could not scale to meet growing future telecommunications needs. In 2000, a few low-income housing developments in the city received fiber-to-the-home connections from a private, Swedish company. The city then noted that these buildings, which had previously housed almost exclusively Moroccan immigrants, were attracting young, professional, white residents of the city—a racial and economic integration success that the city had aspired to but had not achieved at such a level through other projects.[74]

---

[70] City Research and Statistics Department, http://www.os.amsterdam.nl/tabel/5000/, accessed December 22, 2006.
[71] Ibid.
[72] City Research and Statistics Department, http://www.os.amsterdam.nl/tabel/5012/, accessed December 22, 2006.
[73] Beijing-International Website, Sister Cities information, http://www.ebeijing.gov.cn/ying/t95204.htm, accessed December 22, 2006.
[74] CTC interview with Dirk van der Woude, GNA, Amsterdam, December 29, 2006.

This demonstration of the potential power of fiber led to negotiations with existing providers, which were not successful, and then to formation of a blue-ribbon commission to advise the city about next generation networking. The commission concluded that the city could attract investment if it were willing to take a minority stake in the passive layer of the project (the fiber). The city in turn was willing to invest the money if there were already in place a contract with a network operator. Through a tendering process, BBNet was identified as the operator and the project was eventually approved by the Amsterdam city council in 2006.[75]

Construction began in October 2006.[76]

Business Model: Glasvezelnetamsterdam (GNA) represents a public/private partnership between the City of Amsterdam, a number of real estate and pension fund investors, and ING Bank. Under this partnership, the city will build and own a portion of the passive elements of the network only: the fiber optics, but not the active elements, the electronics.[77] The city never even considered providing services on the network.[78] A service provider partner (Telecom Italia unit BBNet—identified through a competitive tendering process that resulted in 10 bids) will serve as operator, provide electronics, and will provide 10 years of (non-exclusive) services in an arrangement under which other service providers can lease access to the network at competitive prices. All participants in GNA support this open access architecture.[79]

According to city representatives, the city's private partners have significant stakes in the project because they are invested in the city: for example, the five local housing cooperatives that are partners in GNA own approximately 70 percent of the housing in Amsterdam. They have a long-term interest in the value of those properties that is enhanced by fiber connectivity. They, like ING Bank, also have a long-term interest in the economic vitality and competitiveness of the entire City of Amsterdam, which they reportedly believe is facilitated by the fiber.[80]

The city's limited ownership percentage is designed, in part, to insulate the project from political fluctuations and to facilitate private-sector investment.[81]

Technical Model and Architecture: GNA represents 100 percent underground construction. Given the complexity of underground construction, the network contains large amounts of fiber and is designed to be future-proof, such that there will be no need to lay fiber again.[82]

---

[75] Ibid.
[76] "Old Networks Not Enough," Dugie Standeford, Communications Daily, November 6, 2006, pages 5-7.
[77] Gordon Cook, "Financing Amsterdam's Huge FTTH Build," Broadband Properties Magazine, page 69, September 2006.
[78] CTC interview with Dirk van der Woude, GNA, Amsterdam, December 29, 2006.
[79] Gordon Cook, "Financing Amsterdam's Huge FTTH Build," Broadband Properties Magazine, page 69, September 2006.
[80] Ibid.
[81] Ibid.
[82] Ibid.

According to GNA staff, the passive fiber-owner has only a few obligations under the model developed in Amsterdam: first, to roll out fiber universally; second, to make sure the contract with the operator precludes discrimination against any service provider (in other words, open access); and third, to provide for conflict resolution between the operator and the service providers.[83]

Financing: The city provided 20 percent of the capital for the first phase of fiber construction in the amount of E6 million (the city's ownership percentage of GNA is 33 percent). The balance of the fiber funding came from the city's partners: ING Bank, five local housing cooperatives, and a fiber company. As of the current date, the project is financed and approved for only the first 10 percent of the city, with the intent to expand the project in the future.[84]

Financing for operations and service-provision is the responsibility of the vendors and the city is not involved other than in the selection of those vendors through the tendering process.[85]

The city hopes that, ideally, the market will respond to the project with additional investment money for later stages of construction. According to city staff, the city would be willing to dilute its ownership percentage in the passive layer so long as there is universal build-out of the fiber.[86]

Service Offerings: GNA will not set retail prices because it controls the passive layer of the network only. Each retail provider will determine the pricing and characteristics of their respective voice, video, and data services.[87]

Residences and Businesses Passed: GNA is intended to reach all 420,000 residences in the city[88] as well as all businesses—the network is designed to connect to each of approximately 450,000 meter box in the city.[89] The fiber will be built not only to individual residences, but to all apartment units within multi-dwelling units as well.[90]

Competitive Providers on the Network: The GNA project is designed for open access—a key goal of the City of Amsterdam. BBNet's contract for service-provision is non-exclusive and all service providers may use the fiber under network terms and conditions.

---

[83] Ibid.
[84] Ibid.
[85] Ibid.
[86] Ibid.
[87] Ibid.
[88] "Old Networks Not Enough," Dugie Standeford, Communications Daily, November 6, 2006, pages 5-7.
[89] CTC interview with Dirk van der Woude, GNA, Amsterdam, December 29, 2006.
[90] Gordon Cook, "Financing Amsterdam's Huge FTTH Build," Broadband Properties Magazine, p. 68, September 2006; CTC interview with Dirk van der Woude, GNA, Amsterdam, December 29, 2006.

4.4 Suburban Utah ("UTOPIA")

The Utah Telecommunication Open Infrastructure Agency (UTOPIA) is a consortium of Utah cities that are deploying and operating a FTTP network which connects every business and household in its member communities. The FTTP network is known as the UTOPIA Community MetroNet.[91]

Communities: Fourteen Utah communities are participating in three successive phases of UTOPIA.

Brigham City (Group II)
Cedar City (Group III)
Cedar Hills (Group III)
Centerville (Group II)
Layton (Group II)
Lindon(Group I)
Midvale (Group I)
Murray (Group I)
Orem (Group I)
Payson (Group I)
Perry City (Group II)
Riverton Cedar City (Group III)
Tremonton (Group II)
West Valley City (Group I)

Population: Approximately 17 percent of Utah's population can potentially be served directly by UTOPIA's planned network

Group I (275,300)
Group II (96,800)
Group III (48,600)
Total (420,700)

Brigham City (17,400)
Cedar City (20,500)
Cedar Hills (3,100)
Centerville (12,900)
Layton (58,500)
Lindon(8,400)
Midvale (27,000)
Murray (34,000)
Orem (84,300)
Payson (12,700)
Perry City (2.400)

[91] Unless otherwise noted, all data in this case study are based on CTC's interview with Paul Morris, Executive Director, UTOPIA, December 1, 2006.

	Riverton (25,000) Tremonton (5,600) West Valley City (108,900)
Households:	Group I (84.050) Group II (30,350) Group III (13,550) Total (127,950) Brigham City (5,500) Cedar City (6,500) Cedar Hills (700) Centerville (4,100) Layton (18,300) Lindon(1,900) Midvale (10,100) Murray (12,700) Orem (23,400) Payson (3,700) Perry City (750) Riverton (6,350) Tremonton (1,700) West Valley City (32,250)
Median Household Income:	Brigham City ($42,300) Cedar City ($32,400) Cedar Hills ($62,700) Centerville ($64,800) Layton ($52,100) Lindon($61,700) Midvale ($40,100) Murray ($45,600) Orem ($47,500) Payson ($43,500) Perry City ($52,500) Riverton ($64,000) Tremonton ($4,800) West Valley City ($45,800)

Per Capita Income:

Group I ($16,600)
Group II ($18,700)
Group III ($16,100)
Total ($17,000)

Brigham City ($15,500)
Cedar City ($14,100)
Cedar Hills ($16,300)
Centerville ($19,700)
Layton ($19,600)
Lindon ($18,100)
Midvale ($17,600)
Murray ($21,100)
Orem ($16,600)
Payson ($14,600)
Perry City ($19,100)
Riverton ($17,600)
Tremonton ($15,700)
West Valley City ($15,000)

Area:

Group I (84.7 square miles)
Group II (54.0 square miles)
Group III (34.7 square miles)
Total (173.4 square miles)

Brigham City (14.3 square miles)
Cedar City (20.1 square miles)
Cedar Hills (2.0 square miles)
Centerville (6.0 square miles)
Layton (20.8 square miles)
Lindon (8.6 square miles)
Midvale (5.8 square miles)
Murray (9.6 square miles)
Orem (18.4 square miles)
Payson (6.8 square miles)
Perry City (7.7 square miles)
Riverton Cedar City (12.6 square miles)
Tremonton (5.2 square miles)
West Valley City (35.5 square miles)[92]

Governance: UTOPIA operates as a political subdivision of the State of Utah and is governed by an Interlocal Agreement.

[92] 2000 Census, US Census Bureau American Fact Finder, http://factfinder.census.gov/home/saff/main.html?_lang=en, accessed December 22, 2006.

Initiation Dates: The planning cycle lasted approximately two and a half years and included a city-by-city evaluation of the demand, service gaps, market potential, FTTP technology, anticipated implementation and operating costs, and the projected revenues.

Construction for Group I cities is underway with an anticipated completion date in the summer of 2007. Construction has started for Group II with completion estimated within three years. Group III construction will follow.

Service Offerings: Internet, high-speed data transport, cable, and telephone. All services are IP based.

Technology: The hardware vendor is Allied Telesyn for the residential gateway. The platform is based on a Layer 2, Multi-Protocol Label Switching (MPLS) active electronics architecture.

Business Model: The business model is an open access/wholesale model. UTOPIA-approved service providers include AT&T (Internet), MSTAR (Internet, cable and telephone), Veracity (Internet and telephone), and Xmission (Internet). UTOPIA is actively seeking other providers to use the network to deliver retail services.

Economics: The network's anticipated life is 20 years. UTOPIA financed the Community MetroNet through a construction loan secured with a pledge of revenue from municipally-backed general obligation (GO) bonds in case that revenues are insufficient (as construction for a phase is completed, the construction loan is converted into a 20 year municipal bond). Eleven of the 14 participating communities opted to back the bond. The communities guaranteeing bond repayment will be built in the first two phases. The total construction loan required to build FTTP in the 11 communities is $340 million.

Additional Benefits: Economic development and long-term economic viability of the region. UTOPIA notes the following:

> The "long haul" infrastructure to support advanced telecommunications needs is largely already in place. What remains is the problem of making that capacity available to the end user by providing the "last mile" (also known as the "first mile") connection. The last mile problem has never been a technical issue. Multiple technologies have existed for years that support the ubiquitous delivery of true broadband. The problem is a business (expenses vs. revenues) problem.
>
> Expenses are an issue only to the degree that there are revenues to offset them at some acceptable level. Return on investment (ROI), then, has been the limiting factor in the deployment of broadband. Incumbent providers operating in a near or totally monopolistic business environment determine, exclusively on the ROI they realize, which communities get service and which don't.

> Because any last-mile solution will admittedly be expensive, it would make sense to leverage the costs of the required infrastructure across as many revenue streams as possible: the greater the traffic across the "electronic toll roads" of the system, the quicker and the greater the returns. However, current monopolistic business models do not favor competitive revenue streams over their existing privately-owned infrastructure. **The current system is anti-competitive.** Thus, not only is ROI consistently insufficient to justify expansion and upgrades for expensive infrastructure, but the lack of competition in the market results in stagnated innovation, poor customer service, and less-than-competitive prices for services.

UTOPIA's open access model directly addresses this issue.[93]

Service Offerings: UTOPIA does not set retail prices, it is a wholesale provider. Each retail provider determines the pricing and characteristics of their respective voice, video, and data services. As a minimum, UTOPIA Community MetroNet will deliver 100 Mbps of bandwidth to every connected home and 1 Gbps of bandwidth to every business. If desired, all of the bandwidth can be allocated to Internet connectivity.

Homes Passed: With construction still is in process, the following passings are planned:

Group I (84,050)
Group II (30,350)
Group III (13,550)
Total (127,950)

Lessons Learned: In UTOPIA's experience, the financial community is not prepared to support broadband projects based upon projected revenue streams. The financing needs to be secured with general obligation pledges or with existing utility revenues such as gas, electric, or water.

4.5 Palo Alto

The City of Palo Alto Utilities (CPAU) has provided dark fiber connectivity to businesses in Palo Alto since 2000.[94] In addition, CPAU conducted a technical FTTP pilot for over 48 months. The pilot was terminated in December of 2005. Rather than the city pursuing

[93] UTOPIA's stakeholders are not concerned about long-haul infrastructure as a key issue. It is however important to note that access to the "long-haul" infrastructure is an issue for many smaller or rural communities, and was likely an issue for many of the smaller communities being served by UTOPIA. In addition, as more local FTTH initiatives are implemented and demand continues to increase, the "long-haul" infrastructure will need upgrades and possibly regulatory and legislative changes.

[94] Unless otherwise noted, all data in this case study are based on CTC's interview with Josh Wallace, Key Account Manager for Commercial Fiber, City of Palo Alto Utilities, November 30, 2006.

an investment in FTTP and becoming a service-provider itself, the city has initiated efforts to encourage a private provider to build the FTTP facilities. The RFP for the private FTTP build out is issued and responses were due on January 9, 2007. Palo Alto received one responsive bid from a consortium led by 180 Connect and PacketFront. Staff is currently negotiating with the group and has sought guidance from the City Counsel as to how to proceed.

Population:	58,600
Households:	25,200
Median Household Income:	$90,400
Per Capita Income:	$56,260
Area:	25.6 square miles[95]

Governance: CPAU provides electric, fiber optic, natural gas, water, and wastewater services. The Utilities Advisory Commission oversees and manages the CPAU, and makes recommendations to the City Council regarding policies, legislative activities, budgets, and rates upon such other matters as the City Council may from time to time assign.

The Utilities Advisory Commission is composed of five members who are not Council Members, officers or employees of the city. Each of the Commission members is a utility customer or the authorized representative of a utility customer. At least four members of the Commission must be residents of Palo Alto.

Initiation Dates: Fiber planning started in 1996, and resulted in a Backbone ring implementation to support dark fiber services. The backbone consists of 33 route miles (over 4,750 fiber-miles), with 144 or more strands of single mode fiber along most routes.

In 2000, the City Council approved a FTTP trial to determine the feasibility of providing citywide FTTP in Palo Alto. The trial consisted of offering video and data services to 66 homes. The trial proved successful from the technical perspective.

The City Council approved the engagement of a consultant in 2002 to complete a FTTP business case. As part of the business case development, Palo Alto residents were surveyed to determine potential market interest in the project. In September, 2002, the business case was completed, and Council agreed both to extend the timeframe for trial participants and to fund the development of a business plan.

In the business plan, the consultant assumed the Electric Fund would issue (tax-exempt) revenue bonds to fund the FTTP build-out. However, in 2004, it was determined that in fact, the Electric Utility could not fund the FTTP project with revenue bonds; as a result, financing costs would be greater than previously assumed.

---

[95] 2000 Census, US Census Bureau American Fact Finder, http://factfinder.census.gov/home/saff/main.html?_lang=en, accessed December 22, 2006.

In January 2006, City Council recommended that CPAU staff develop a Request for Proposal to assess whether any private entities would be interested in pursuing or partnering in, citywide deployment of FTTP. The RFP for the FTTP build out was issued in September of 2006.

Business Model: CPAU provides dark fiber connectivity. Customers are responsible to provide and maintain equipment to light-up or provision the leased fiber strands. Fiber connections are owned, operated, and maintained by CPAU.

The FTTP trial was for a technical evaluation, not market acceptance. During the trial, data and video services were supported. The FTTP business plan for retail voice, video, and data services was not pursued because of legal and economic questions.

The primary goals for the system requested in the RFP are:

- Capability of providing to each customer a minimum bandwidth of 100 megabits per second symmetrical service
- Provision of at least data, video, and telephony services
- Eventual city ownership of the physical system

A secondary goal for the system is to promote competition between multiple service providers. In addition, the following features are preferred:

- An open system
- Network neutrality
- Minimal financial risk to the city [96]

Financing: The fiber ring was financed with an internal loan of $2,000,000 from the Electric Utility for a period of 20 years at zero percent interest rate. The financing included the initial build out and working capital for the first four years of operation.

The FTTP pilot was operated for over 48 months served a total of 70 residents. The cost of the FTTP pilot was $600,000 which was funded via electric utility reserves.

Additional Benefits: Economic development for retention and attraction of residents and businesses. By leveraging the dark fiber, businesses have access to connectivity services within Palo Alto that far out-perform cable modem and DSL services and are considerably more affordable than T3 or other high end connectivity services.

Service Offerings: Dark fiber backbone lease fees are based on the number of fiber miles per month. The base lease price is $272.25 per fiber mile per month. Quantity, route length, topology, and other discounts are available. The minimum backbone lease fee is $425 per month. Lateral connection (premises to backbone) fees are based on the length

[96] City of Palo Alto RFP FTTH01.

and type of the lateral, with a minimum fee of $210 per month. Available configurations include point-to-point, ring, and diverse ring.

Businesses Passed: The majority of business parks and commercial properties are served by the fiber optic backbone.

Competitive Providers on the Network: In addition to supporting city and utility needs, the fiber ring serves four wholesale customers (who lease dark fiber, add electronics and then provide a retail service) and 24 business customers. This customer base is projected to provide $1.9 million in net revenues in 2007.

Lessons Learned: CPAU notes the need to keep pricing structures simple. Some potential network participants did not originally consider lease of dark fiber because of the complexity of the rate structure at the time.

4.6 Jackson, Tennessee

Jackson Energy Authority has implemented a hybrid of retail and open access business model with their FTTP network.[97] Cable television services are provided directly by Jackson Energy while telephone and Internet services are directly available from other providers. Jackson Energy has also added other vertical serves such as remote data backup and other Information Technology (IT) services.

Population:	59,700
Households:	27,000 residential and 4,300 business premises
Median Household Income:	$33,194
Per Capita Income:	$18,495
Area:	49.5 square miles[98]

Governance: The Board of Directors of Jackson Energy Authority oversees and manages the water, wastewater, natural gas, propane gas, electrical, and broadband services. The five-person board is appointed by the mayor of Jackson and approved by the City Council, and each board member serves a five-year term. The Jackson Energy Authority operates as a stand-alone enterprise. Unlike many municipal utilities, Jackson Energy Authority operates under authorization of the State of Tennessee, rather than the city. This allows Jackson Energy Authority more flexibility in delivering services beyond the city limits.

Initiation Dates: Planning began in early 2002, included business plan development, design, legislative approvals, and obtaining financing. Construction started in January, 2004. Services include voice, video, and data.

---

[97] Unless otherwise noted, all data in this case study is based on CTC's interviews with Kim Kersey, Senior Vice President for Telecommunications, Jackson Energy Authority, November 21, 2006.
[98] 2000 Census, US Census Bureau American Fact Finder, http://factfinder.census.gov/home/saff/main.html?_lang=en, accessed December 22, 2006.

Technology Deployed: The hardware vendor is Wave7 and the platform is active.

Business Model: The business plan is to offer retail services and to wholesale the network over an open platform. Video services are offered directly by Jackson Energy Authority and telephone and Internet services are wholesaled to qualified third party providers. The FTTP network is owned, operated, and maintained by Jackson Energy Authority. Back office support and service hosting are done by the retail provider.

Two providers offer retail telephone and Internet services. Aeneas Communications keeps a degree of separation while Cinergy Communications jointly markets the services with Jackson Energy. With Cinergy, Jackson Energy receives a commission for sales and marketing efforts. Back office support and service hosting are contracted with Cinergy Communications.

Economics: The anticipated life is 25 years for fiber, 20 years for field electronics, and 10 years for the cable television headend.

The breakeven point for cash flow is projected at year six or seven.

Financing: The system was financed through bonds primarily secured by Telecommunications Division revenues. The Telecommunications Division may borrow up to $34 Million from the Electric Division for debt service repayment. Any requirements beyond that are backed by city obligation.

Additional Benefits: The FTTP network provides a foundation to support a variety of automation and customer contact needs for the range of utility service provided by the energy authority. In addition, Jackson Energy Authority is a leader in economic development efforts in the region. The broadband services enabled with the FTTP network are a key foundation for economic development efforts.

Service Offerings: Internet: Cinergy Communications offers asymmetrical 512 Kbps/256 Kbps, four Mbps/384 Kbps, six Mbps/512 Kbps, and 10 Mbps/1 Mbps ranging from $25 per month to $55 per month. Discounts are offered when video and telephone services are bundled.

Cable: Jackson Energy Authority offers a full range of analog, digital, premium, pay-for-view, and music channels. Jackson Energy offers all of its 290 channels in a digital simulcast format. Packages range for $16 per month for 24 channels to $52 per month for 128 channels. Eleven HDTV channels are available for an additional $6 per month, and all four premium channels are also available in high definition with subscription and HD converter.

Telephone: Cinergy Communications offers a range of packages from basic local service for $16 per month to full-feature service with unlimited long distance for $39.90 a month.

Vertical services such as voicemail, email notification, and call forwarding are available for additional fees.

Homes Passed: 27,000 residential passings.

Residential Penetration: 12,800 cable customers today, of which 6,571 have Internet service and 5,192 have telephone service.

Businesses Passed: 4,300 business passings.

Business Penetration: 900 total business accounts, of which 650 have cable service; 419 have Internet service, and 303 have telephone service, all in various combinations.

Lessons Learned: Jackson Energy points to a number of lessons learned through its experience to date. First, it notes the advantages a municipal utility has in deploying and offering broadband, in part because customers generally have a high level of confidence and support for municipal utility providers. Second, Jackson Energy notes that working with service providers in an open access environment proved more difficult than anticipated, in part because administration and coordination became very complex where the outside providers are competitors. Jackson also notes that outside providers may have growth goals that do not align with the needs of the network

Another difficulty that Jackson notes about working with service providers is that those providers may not offer the same quality of customer service and technical support as the host network. The lower standards of these service providers can adversely impact customer confidence in the network.

Contribution margins would be greater if Jackson Energy was the retail provider for telephone and data service.

With respect to cable television, Jackson notes that programming costs are one of the highest expenses.

4.7 Reedsburg, Wisconsin

Reedsburg Utility Commission is a leader in municipal broadband offerings. Reedsburg was one of the first FTTP deployments in the country and has successfully defended municipal rights against legal attacks from AT&T and other providers.[99] Reedsburg was an earlier adopter of FTTP. The total implementation costs today would be lower, and vendor products are more mature and leverage more industry standards.

Population: 7,800

[99] Unless otherwise noted, all data in this case study is based on CTC's interviews with Dave Mikonowicz, General Manager, Reedsburg Utility Commission, November 14, 2006.

Households: 4,400
Median Household Income: $39,152
Per Capita Income: $18,828
Area: 5.2 square miles[100]

Governance: The Utility Commission oversees and manages the water, electrical and telecommunication utility. The five-person commission is appointed by the City Council, and each committee member serves a three-year term. The Utility Commission operates as a stand-alone enterprise. The city has also created a seven-person Broadband Communications Advisory Committee to provide guidance on business development and advancement of the communications utility.

Initiation Dates: Planning began in 1999 and implementation was phased. Reedsburg Utilities' first step towards a FTTP deployment was implementation of a fiber internal network that connected key Utility Commission assets and area schools. The second phase of the deployment was expansion of the fiber infrastructure to selected businesses and industrial parks. The third phase was the implementation of a FTTP network that supports voice, video, and data services.

Technology Deployed: The hardware vendor is Calix (formally OSI) and the platform is PON, with two fiber strands to each household, the first for voice and data, the second for video.

Business Model: The business model is retail. The network is owned, operated, and maintained by Reedsburg Utilities. Sales, marketing, back office support, and service hosting are done by Reedsburg Utilities.

Economics: The anticipated life is 20 plus years. The breakeven point for cash flow was successfully reached in less than four years.

Financing: To finance the network, two bonds were issued: one was unsecured, the other was a revenue bond secured by electric and water utility revenues. To date, approximately $13 million in network and customer installation costs have been expended.

Additional Benefits: A key benefit of the network is economic development for retention and attraction of residents and businesses. At the time Reedsburg Utilities decided to pursue the FTTP network, no other high-speed alternatives existed in the community. Today, Reedsburg citizens and businesses have available and affordable connectivity services that far out-perform cable modem and DSL services.

Service Offerings: Internet: the system offers symmetrical services of 1 Mbps, five Mbps, and 10 Mbps ranging from $30 per month to $50 per month. A $5 per month

---

[100] 2000 Census, US Census Bureau American Fact Finder, http://factfinder.census.gov/home/saff/main.html?_lang=en, accessed December 22, 2006.

discount is offered if subscriber also receives cable and telephone service. In addition, business customers have a variety of point-to-point connectivity options.

Cable: Reedsburg Utilities offers a full range of analog, digital, premium, pay-for-view, and music channels. Packages range from $14 per month for 18 channels to $51 per month for 100 channels.

Telephone: the network offers a range of packages including unlimited local service for $21.95 per month and unlimited and long-distance local calling for $39 per month.

Homes Passed: 4,400

Residential Penetration: Approximately 50 percent of homes passed subscribe to at least one voice, video, or data service.

Lessons Learned: Planning and detailed engineering is critical to avoid acquisition of material and equipment that is either not required or has early obsolescence.

Marketing plans are important; however need adjustment on the fly to meet changing market conditions and customer expectations.

Market entry timing is critical. If Reedsburg Utilities was to enter the marketplace today, cable television services might not be pursued due to the required payback time on the headend and the evolution of IP based video services.

Cable television is a difficult market for a small market because of the headend investments. Add-on services are also a challenge; Reedsburg Utilities have looked at Video-on-Demand, but feel they would need 5,000 subscribers to break-even (600 more than total homes passed).

Have back-up plans. Initially, Reedsburg Utilities partnered with a regional telephone company to deliver voice products. The partnership did not work out for a variety of business philosophical reasons. As an alternative, Reedsburg Utilities acquired a soft-switch and is offering phone services without the partnership. Having a CLEC certification in-hand allowed Reedsburg Utilities to pursue the stand-alone option.

4.8 Brief Descriptions of Selected International FTTP Initiatives

The following are brief summaries of a few of the many municipal FTTP initiatives underway throughout the world. The activity in this area has been concentrated primarily in Europe and Asia.

4.2.1 Stockholm

Stockholm's municipal utility, StokAB, has operated a backbone fiber network for over a decade, as do more than 200 of Sweden's municipalities. In 2005, StokAB began extending its fiber-to-the-premises of approximately 100,000 social housing apartments, in a model that is expected to be followed throughout Sweden.

4.2.2 Denmark

The national electric utility in Denmark plans an FTTP buildout to nearly a million homes representing fully one-third of all Danish homes. The construction portion of the project is budgeted at 1.3 billion Euros.

4.2.3 Vienna

The City of Vienna's project, constructed and operated through its municipal utility, will bring open architecture FTTP to nearly a million households. The network will offer symmetrical connection speeds of up to 1 Gbps.

4.2.4 Paris

The French government has undertaken an ambitious national strategy to spur FTTP deployment throughout the country, providing financial incentives and affordable financing.

The City of Paris has embraced these FTTP goals and has announced a goal of fiber connectivity to 80 percent of buildings within the city by 2010. The city has also offered tax incentives to companies that install fiber in sewers and other city assets.[101]

The city is working with a local private entity to facilitate buildout of FTTP in Paris and surrounding areas. Provider Free plans to invest in excess of a billion Euros over the next six years, with the intention of passing four million homes with fiber in that time-period. Parts of the network are planned to be operational by second quarter 2007.[102]

Free's corporate parent, Iliad SA, announced the following products:

- Data: symmetrical upload/download speeds of 50 mbps, with unlimited use
- Voice: unlimited voice calls to fixed lines in France and 28 countries
- Video: 40 channels including some high definition channels[103]

This package will be offered at a monthly fee of around 30 Euros. [104]

---

[101] "Old Networks Not Enough," Dugie Standeford, Communications Daily, November 6, 2006, pages 5-7.
[102] CTC interview of Tony Perez, Director, Office of Broadband, City of Seattle, October 5, 2006; "What Seattle Learned in Europe," eNATOA Community Broadband Seminar presentation, Tony Perez, Director, Office of Broadband, City of Seattle, November 20, 2006.
[103] Ibid.

Iliad also plans to lease capacity to competitors in an open manner. The company has represented that it believes it can recoup its construction costs in approximately four years, assuming market share of 25 percent and approximate revenue per user of 33.50 Euros per month.[105]

The City of Paris has also released an RFP for city-wide wireless service. Responses to the RFP are pending as of the date of this Report.

4.2.5 Cologne

NetCologne is a competitive FTTP network developed as an alternative to incumbent Deutsche Telekom by the subsidiary of a local gas and electric utility partially owned by the City of Cologne. While the city does not own the network, it does own a portion of the parent utility. The network began construction in July 2006 and anticipates providing service to its first customers shortly.[106]

4.2.6 Brisbane

The Australian state of Queensland recently announced an FTTP plan to spend A$550 million to deploy FTTP to the state's largest city, Brisbane. The state plans for government ownership of the network, which will be put out to tender. Minimum speeds are envisioned at 100 mbps.[107]

---

[104] Ibid.
[105] Ibid.
[106] "Old Networks Not Enough," Dugie Standeford, Communications Daily, November 6, 2006, pages 5-7.
[107] Emma Alberici, "Qld plans for super fast broadband," Australian Broadcast Corporation transcript, October 24, 2006, http://www.abc.net.au/pm/content/2006/s1772689.htm, accessed December 4, 2006.

5. Overview of FTTP Technologies

This section provides a brief overview of the current Fiber-to-the-Premises (FTTP) technologies and architectures. Specifically, we present Passive Optical Networks (PON), which is a broadly defined architecture describing almost all current deployments of FTTP. Also, we examine Active Ethernet, which leverages the mature, standards-based Ethernet technologies to create a distributed data network for converged voice, video, and data services.

For an FTTP access network constructed by the City and County of San Francisco, we urge the following technical and engineering considerations.

1. Avoid using active components between the provider premises and customer, primarily due to the size and quantity of outdoor enclosures that would be required (transmission distances are not an issue within the City);
2. Provide a flexible mechanism of interconnection to the multiple ISPs and other service providers, possibly at multiple network layers;
3. Ensure the solution can support different quality of service (QoS) classes so that voice and video can be delivered with acceptable performance, while allowing best effort data services;
4. Ensure that physical hub facilities are designed to house and support equipment for multiple providers, allowing collocation for open access competition; and
5. Provide an operations support system that permits easy transfer of subscribers between multiple ISPs, supports fault management, and supports billing.

Guided by these considerations, we recommend the use of a Home Run fiber optic architecture.

5.1 Background

Until recently, subscriber network wireline access technologies consisted primarily of twisted-pair copper connections designed for voice communications, and coaxial cable connections designed for the delivery of one-way cable television content. Both these technologies were enhanced over the last decade to support the use of the Internet and its packet-based exchange of voice, data, and video. DSL (Digital Subscriber Line) technology was developed to provide high-speed data transmission over twisted-pair copper access infrastructure owned by telephone operators, while the DOCSIS (Data Over Cable System Interface Specifications) standard for cable modem technology leverages the coaxial cable access infrastructure used by cable TV operators to provide data services.

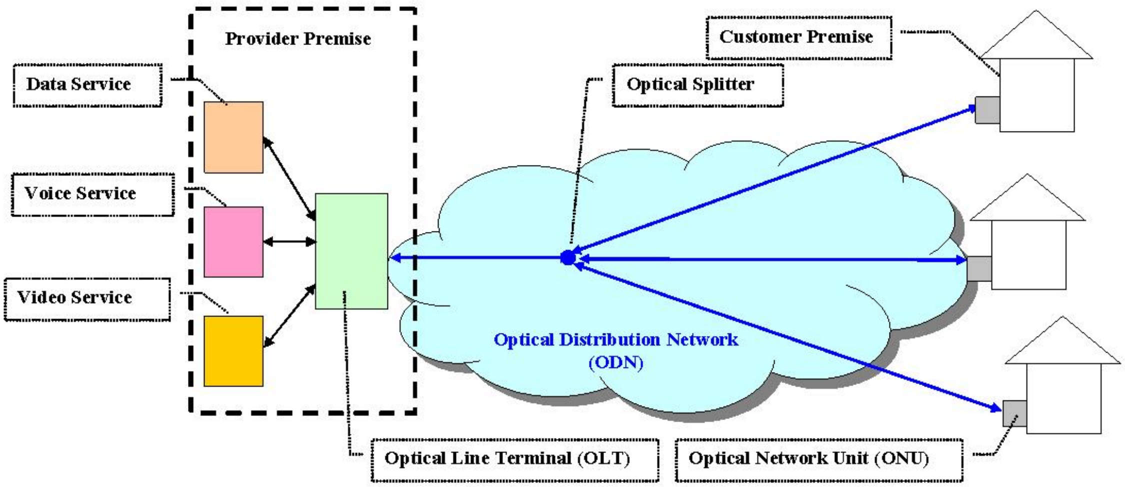
Optical fiber provides orders of magnitude more communications bandwidth than either twisted-pair or coaxial cable. However, until recently, optical fiber was not deployed widely in the access network due to its high cost and because high bandwidth applications that required such infrastructure did not exist. Currently, major network operators are investing heavily in optical fiber access technologies to enable high-bandwidth connectivity to support multiple voice, data, and video services for their subscribers. FTTP (Fiber-to-the-premises) generically refers to any technology that provides an optical fiber connection directly to the customer premises – residential or business. Various FTTP technologies have emerged, including Passive Optical Networks (PON), with its many variants, and Active Ethernet access.

5.2 Summary Comparison of FTTP Architectures

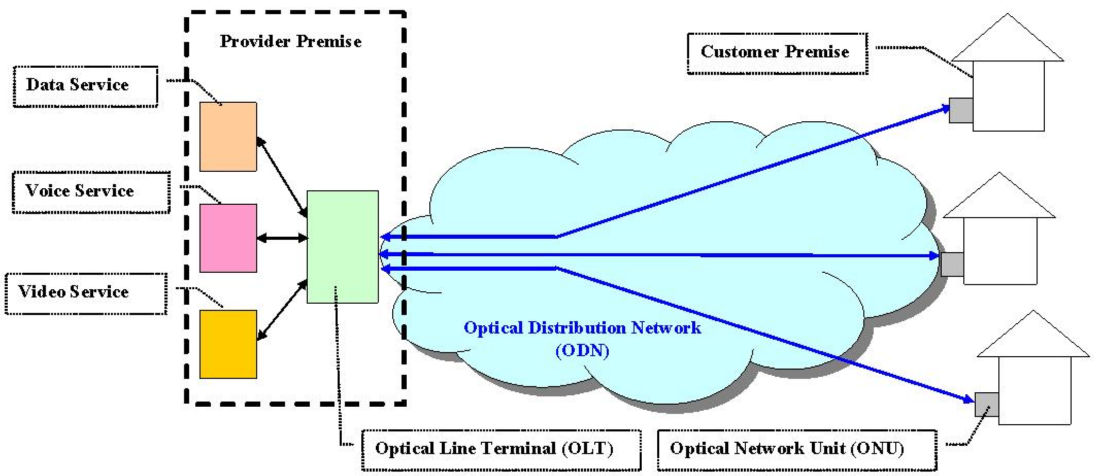
The applicability of each type of distribution network depends on the distances that need to be covered, anticipated user bandwidth requirements, and user density. Most FTTP architectures rely on an optical distribution network (ODN) infrastructure to connect the provider point-of-presence to the customer premises. This ODN infrastructure provides aggregation of the user traffic onto fewer strands of fiber at some intermediate point between the provider "hub" or headend location and the subscribers. Aggregation of connections reduces network deployment costs, and is possible because individual user bandwidth requirements are extremely small relative to the total bandwidth of any single strand of optical fiber. Thus, parts of the distribution network are shared among multiple customers by using either an optical splitter or an active network switch located between the provider point-of-presence and the customer premises, as described in Section 5.3.2.1 and Section 5.4.1, respectively. Alternatively, dedicated fiber connectivity with no aggregation between the provider and subscriber is another plausible architecture. Figure 14 provides an overview of the various access network architectures.

Figure 14: Access Network Overview

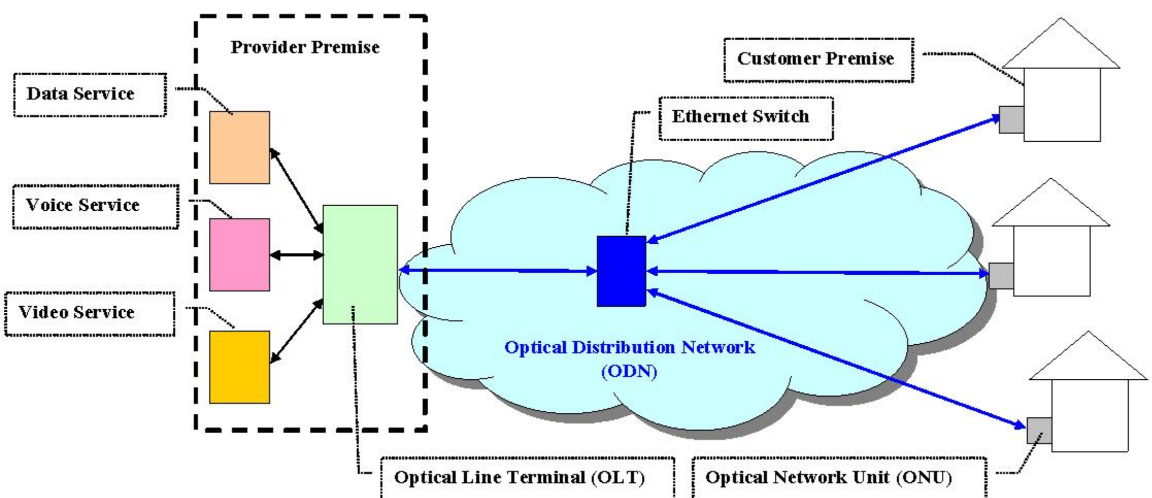
PON Access Network



Home Run Access Network



Active Ethernet Access Network



Typically, dedicated fiber is deemed only cost effective for high capacity subscribers requiring very high bandwidth connectivity, or if users do not want a shared medium. Residential and small business customers can be well served with a shared optical infrastructure when per user demand is lower and user densities are also lower. There are other factors that influence the selection of architecture however, including the size and quantity of outdoor cabinets and their corresponding impact in the communities they are located.

There are two major categories of next generation, fiber-based broadband access technologies currently being developed and deployed: Passive Optical Network (PON) technology and Active Ethernet technology.

Passive Optical Network (PON) in Brief

PON utilizes a completely passive (without powered electronics) optical fiber distribution network to connect the provider premises to the customer premises. In a PON FTTP deployment, devices requiring electrical power only exist at the customer premises and the hub or headend location. PON is using a shared optical fiber path consisting of optical splitters.

Active Ethernet in Brief

Active Ethernet access is based on widely deployed and standardized Ethernet technologies, and requires powered Ethernet switching equipment at one or more intermediate points within the fiber distribution network. This intermediate switching equipment aggregates traffic from individual subscribers, and require large cabinets and electric power. The intermediate switch will have to be upgraded as subscriber bandwidth requirements increase (in addition to the end equipment). In addition, Ethernet does not have well defined mechanisms that can be used to support hard service layer agreements, but is used in conjunction with other standards-based technologies, including Multi-Protocol Label Switching (MPLS) to provide these performance guarantees.

Architectures Currently Deployed

Point-to-multipoint PON has been adopted by major carriers such as Verizon for their latest access network deployments primarily for residential subscribers. Home Run has primarily been used to support high capacity users such as businesses. Ethernet-based Home Run is being deployed extensively internationally, including by Citynet Amsterdam and other European public and private-sector FTTP deployments. Active Ethernet has been deployed by the UTOPIA network in suburban Salt Lake City.

5.3 PON – Passive Optical Network

PON relies on a fiber-optic transmission network that does not use any electronic hardware between the network operator point-of-presence and the customer premises equipment (CPE). A major portion of this passive fiber-optic transmission medium is shared by multiple users through the use of optical splitters that split the downstream optical signal into 32 or more outgoing optical paths for individual subscribers. Using a shared and passive distribution network has advantages that help reduce the initial and operating costs for the network operator. The passive nature of the fiber plant makes it more reliable, future-tolerant, and helps reduce operations costs. The bandwidth that can be supported is only limited by the capability of the electronics deployed at the provider point-of-presence and the customer premises.

5.3.1 Architecture

Figure 15 shows the generic architecture of a PON. The optical distribution network (ODN) consists of a tree network (blue lines) consisting of fiber-optic cable and optical splitters. Thirty two or more users are supported on one such tree. Multiple trees are used to support a larger number of users. Each subscriber is connected via a single strand of optical fiber from a passive splitter. Each fiber has at least two different optical wavelengths (colors), with one for downstream (towards the customer) and another for upstream (towards the network operator) optical transmission. In addition, a third wavelength can be used to support downstream RF video transmission (such as a cable TV lineup), often referred to as an "RF overlay". This fiber optic path constitutes the passive and shared communications path between the electronic hardware at the provider premises and the electronic hardware at the customer premises.

The Optical Line Terminal (OLT) is deployed at the provider premises, and consists of the electronics that establish communications between the Optical Network Units (ONUs) that are deployed at the customer premises. The ONUs demultiplex and decode the communications signals arriving from the OLT into the voice, data, and video signals, which in turn connect to the telephone, computer (or router), and TV (or set top cable box). They also generate the communications signal returning to the OLT from the customer. At the provider premises, the OLT also connects to other network equipment, which support and manage the voice, data, and video services that are offered.

The International Telecommunications Union (ITU) develops globally applicable communications standards and recommendations. Equipment based on ITU recommendations has a basic set of functions that the ITU participants (equipment vendors and service providers) have deemed necessary to support communications in an interoperable manner. Interoperability aims to enable network operators to be able to use equipment of similar functionality from multiple suppliers in the same network without having to rely on any one supplier. However, in practice, deployed PON networks generally use the same supplier of fiber optic transmission electronics and are not able to have PON user premises equipment, for example, be interoperable with PON network operator equipment from another manufacturer.

The ITU develop recommendations for access networks in general, and also has a set of recommendations specifically for FTTP networks. Specifically, the ITU has standardized PON technologies, including Broadband PON (B-PON) and Gigabit Capable PON (G-PON). Both B-PON and G-PON use the basic ODN architecture described above (and depicted in Figure 15) to provide connectivity between the network provider point-of-presence and the customer premises. B-PON and G-PON differ in the encapsulation mechanisms (manner in which data is packaged) and the data rate supported. The key technical characteristics of B-PON and G-PON are summarized in Table 2 (in Section 5.5 below).

5.3.2 PON Transport Equipment

5.3.2.1 Generic PON Architecture

Each PON terminates on an Optical Line Termination (OLT) in the head-end, or hub facility. The OLT connects through a Wave Division Multiplexing (WDM) coupler with a single fiber strand to the ODN, and broadcasts an optical signal at 1490 nm that reaches each subscriber connected to that fiber through passive optical splitters. The OLT also receives signals at 1310 nm from each customer ONU. OLTs are housed in a shelf that typically supports multiple OLTs, common control cards, and interfaces to voice and data services equipment. In one actual equipment implementation, the OLT shelf supports 18 PON cards, each capable of supporting two ODNs. As each ODN supports 32 subscribers, one OLT shelf from this particular vendor is capable of supporting a total of 1,152 subscribers. Multiple such OLTs will be needed to support more subscribers.

Figure 15 depicts three different pieces of electronic hardware connected to the OLT at the provider premises to support voice, data, and video services. This functionality could be contained in a single network element that supports all there types of services. Service support is discussed in the next section.

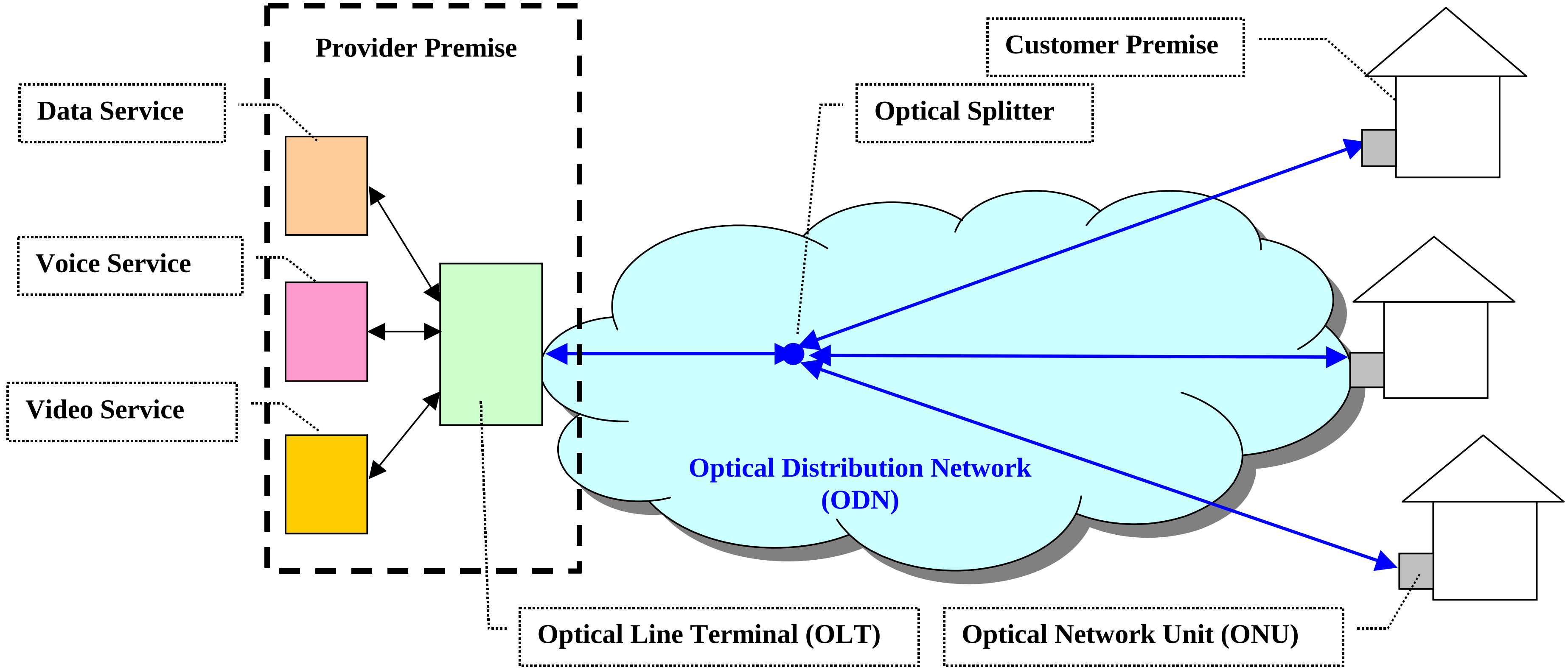


Figure 15: Generic PON Architecture

The Institute of Electrical and Electronics Engineers (IEEE) is another standards forming organization that develops communications standards. The IEEE developed and maintains the series of standards that define Ethernet technologies. Ethernet based access network technologies, Ethernet PON (EPON), have been standardized in the IEEE and in some sense have become competing technologies to B-PON and G-PON standardized by the ITU. Although E-PON also permits the generic PON architecture depicted in Figure 15, passive point-to-point (Home Run) and active Ethernet architectures are also supported.

5.3.3 Service Support

This section provides an overview of how voice, data, and video services can be supported in a PON. The PON transport equipment connects to the equipment on which services are supported via standards based interfaces. Service-specific functionality can be supported on one hybrid network element, or separate network elements dedicated to each service.

5.3.3.1 Voice Service

The PON architecture can support voice services in two ways – circuit switched, Plain-Old Telephone Service (POTS) and/or voice over Internet Protocol (VoIP).

5.3.3.1.1 Circuit Switched Voice

The fiber network can support standard telephone service by connecting the equipment at the operator's facility with a telephone switch, which in turn connects to the public switched telephone network. Support of circuit switched voice is provided through a voice gateway that connects through standard interfaces to a Class 5 circuit switch. The access network provider will need a voice switch, will have to establish interconnection agreements with an ILEC, and must obtain trunks to the Incumbent Local Exchange Carrier (ILEC) switch to support circuit switched voice services. Voice gateway functionality could be provided in a separate network element, or it could be integrated into the OLT shelf.

5.3.3.1.2 Voice over Internet Protocol (VoIP)

VoIP can be supported in two ways over the PON network - it can either be supported natively through the data (Ethernet) interface on the ONU at the customer location, or it can be provided via standard analog phone interfaces.

When VoIP is supported via an Ethernet port, either VoIP telephones must be used at the customer premises, or an interface device must be provided so that a conventional phone can be used. This adapter can be integrated into the ONU, or other CPE device, such that the ONU provides a standard phone interface for the customer. In the scenario with VoIP telephones, typically these devices would be connected behind a customer router that is in-turn connected to the Ethernet port on the ONU. VoIP phones that work wirelessly with the home router are also available.

Regardless of the physical CPE device configuration, provider premises voice infrastructure for a VoIP network is provided through a Soft Switch architecture consisting of a media gateway and call controller that manages calls and provide access to the PSTN.

The Soft Switch performs call processing and manages connections between IP phones and other devices. The Soft Switch is typically licensed for a certain number of client devices and can be upgraded, as more subscribers or phone lines are added to the network. Multiple application servers are used as needed to support services such as voicemail.

The customer also has the option of subscribing to third party VoIP service providers, such as Vonage and Packet8, over the broadband connection using the data port on the ONU. The customer will need to purchase equipment to subscribe to such a service. No additional equipment is needed at the provider premises to enable access to a third party VoIP provider.

5.3.3.2 Data Service

A minimum data services usually include access to the Internet, email accounts, storage space, and web hosting. Routers and switches, connection(s) to the Internet, and multiple servers are required to support basic data services.

A router provides access to the Internet through a high-speed link to the nearest tier 2 or Tier 3 ISP point of presence (POP). Diversely routed redundant connections (possibly to different service providers at different POPs could be used to enhance reliability, however operational costs will be correspondingly higher for this architecture.

On the downstream side (toward the subscribers), the router connects directly (or alternatively through switches) to the OLTs with Asynchronous Transfer Mode (ATM) OC-3 (155 Mbps) or Ethernet connections. This router directs all customer data traffic to and from the Internet and applications servers. Multiple servers are typically required to host customer websites, provide email, authenticate users, and provide domain name resolution. In addition, a local cache could be used to temporarily store repeatedly accessed websites so that access times are lowered.

5.3.3.3 Video Service

The PON network architecture supports two types of video delivery:

- Broadcast video through an overlay wavelength carrying a composite RF signal that supports analog and digital channels; and

- Packetized video that has been digitally encoded, compressed for transmission over an Internet Protocol network (IPTV) using the primary downstream wavelength (competes for bandwidth with data applications).

5.3.3.3.1 Broadcast Video on an Overlay Wavelength

In this method, Broadcast video is supported over an additional optical wavelength at 1550 nm, and hence does not consume bandwidth on the primary downstream channel operating at 1490 nm. However, the use of an overlay wavelength for analog transmission requiring high carrier to noise ratios (CNR) has an adverse impact on the optical power budget, and consequently the transmission distance between the OLT and the subscriber.

A video OLT is used to launch the video signal onto the shared ODN and an identical set of channels reaches each subscriber. A fiber-optic transmitter within the video OLT and an external erbium doped fiber amplifier (EDFA) are typically used to generate the optical power required to feed multiple ODNs. The video OLT receives video content consisting of analog and digital video channels from the video content provider (for example, from a video head-end).

5.3.3.3.2 IPTV and Video

Broadcast television and other video services can also be delivered over IP utilizing the primary downstream transmission wavelength. The RF overlay wavelength with its supporting equipment and constraining transmission characteristics can be eliminated if IP video is used. Both live TV and Video on Demand (VoD) can be provided using IP video. In addition, advanced interactive services, such as Digital Video Recording (DVR), can also be supported. As the total data bandwidth available to a subscriber is finite and is shared among multiple applications, care must be taken in provisioning adequate Quality of Service (QoS) for different types of applications.

At the subscriber location, a set-top box and remote control/keyboard are used to select and decode the packetized video stream. The set-top box decodes the incoming video information and converts it to a format suitable for a digital or analog television. Such a set-top box minimally has a 10/100 Base-T Ethernet port for the data connection and multiple video/audio ports. The consumer interacts with such a system using either a remote control or remote keyboard and on-screen menus.

Video content is received from either a video head-end and/or the Internet, and it is injected in the PON through the router and OLT. Encoded real-time broadcast television is directly multicast to all subscribers while archived video is unicast to customers that have requested such content. Streaming and storage servers, content encoders, authentication and Digital Rights Management (DRM) servers, and a video OSS are needed at the provider premises to enable IP Video service.

5.4 Active Ethernet

Ethernet is a technology with old roots, first developed in the early 1970s, though Ethernet continues to be the basis for a wide range of communications networks. While initial versions were relatively slow (by today's standards), the 10 Mbps and 100 Mbps versions of the technology became the de facto standard for LANs by the mid to late 1990's. Every version of Ethernet, and a range of supplementary technologies, is standardized by the IEEE (primarily in the IEEE 802.3 suite of standards), with support for a range of fiber and copper physical media.

Today, 1000 Mbps (Gigabit Ethernet) and 10 Gbps (10 Gigabit Ethernet) are becoming commonplace as LAN and MAN technologies for critical business and consumer use alike, in part due to its wide adoption and resulting low-cost relative to other technologies. Tremendous development of Ethernet and Ethernet-related technologies is still continuing today, with 100 Gbps versions in the works.

As a candidate FTTP technology, Ethernet provides significant promise with low-cost electronics, readily available and mature standards, flexibility for supporting a wide range of physical architectures, and scalability of capacity. One such Ethernet-based FTTP architecture is referred to as "Active Ethernet".

5.4.1 Architecture

Figure 16 schematically depicts an Active Ethernet access network architecture. Topologically, this architecture is similar to the PON architecture. *The major difference is that Ethernet switches must be placed in sufficiently large enclosures or buildings in the outside plant, to enable sharing of the fiber infrastructure between the active node and the operator premises.*

The presence of the active, intermediate node allows the reach of this system (the distance from the operator premises to the customer) to be greater than for passive technologies because the communications signal is regenerated (detected and recreated) by the switch. However, the use of active electronics in the distribution network necessitates sufficiently large climate-controlled housing cabinets/huts, a power feed, and also typically more maintenance effort, thereby tending to increase operating costs. Further, because the electronics are designed for a specific transmission speed, the intermediate Ethernet equipment will have to be replaced as technology develops and users require higher bandwidth. (A passive optical splitter would not have to be replaced for this reason.)

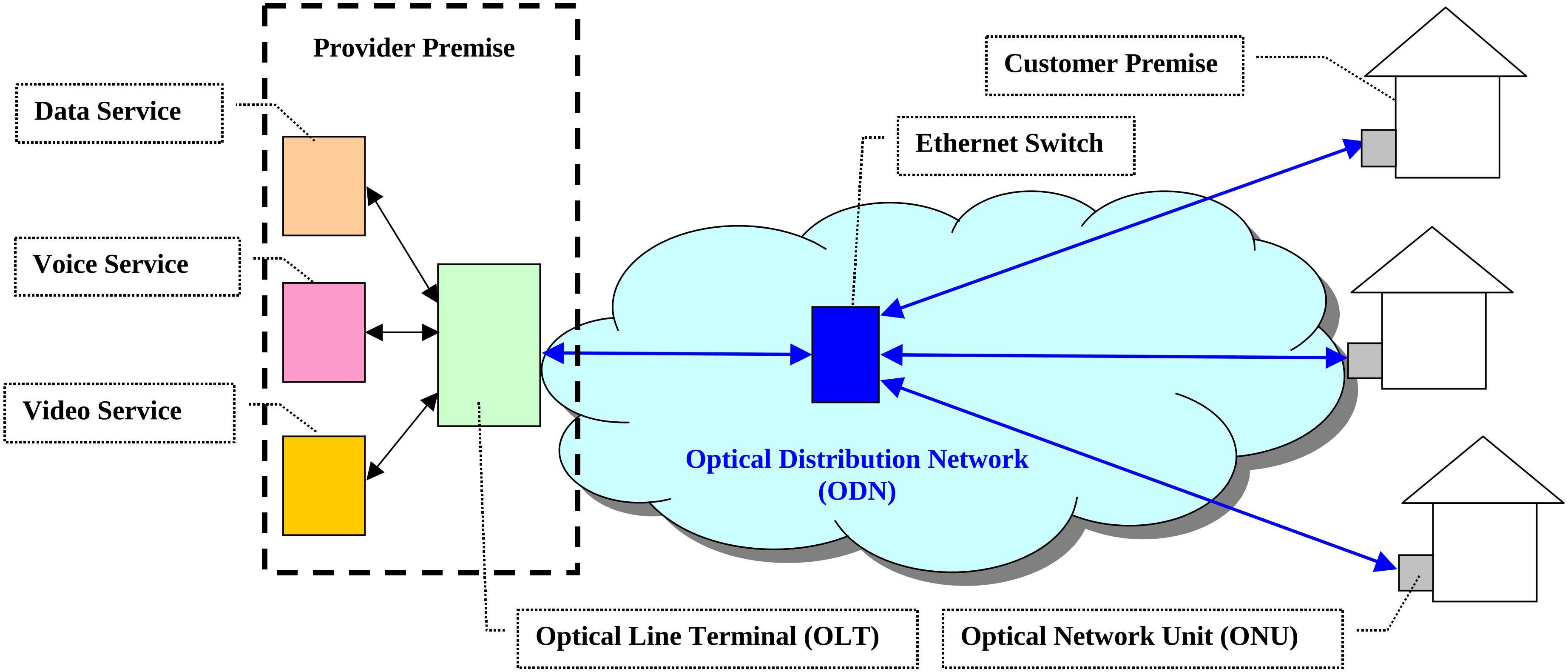


Figure 16: Active Ethernet Access Network Architecture

5.4.2 Service Support

Voice, data and video services can all be supported in an active Ethernet access network. Active Ethernet networks rely on Ethernet for converged transport of voice, data, and video services over the same communications "lines" using Internet Protocol (IP). IP routers and switches are used to deliver and manage these services. The provider router (or multiple routers) used to deliver and manage these services connects to the OLT using multiple Gigabit Ethernet interfaces. Multiple routers and multiple diverse connections are used to enhance service reliability (see Figure 17). As Ethernet is also used to connect to the end customer, both users and services can be managed using virtual private networks (VPNs) and priority queues to deliver the required QoS, and also to limit the bandwidth available to each subscriber. Thus, each user could be managed as a single VPN and each of the services used by the user can also be managed as separate VPNs. MPLS could be used to provide QoS between the service providers and the access network provider.

5.4.2.1 Voice Service

Active Ethernet is ideally suited to support VoIP, because Ethernet is the underlying link layer technology used by IP. A VoIP Soft Switch and call manager connects to the routers at the provider premises to provide voice service. The Soft Switch and Call manager may be situated at a remote location. Third-party VoIP providers can also connect to the provider routers over the Internet to offer their own VoIP services.

5.4.2.2 Data Service

Data services, such as Internet access, email, and web hosting are readily supported in Active Ethernet. The provider routers connect to multiple Tier 2 or Tier 3 ISPs to provide Internet access. Multiple redundant connections are typically used for reliability. Email and web hosting can be supported using local or remote server farms. Servers will also be used to provide authentication, security, and access control.

5.4.2.3 Video Service

Active Ethernet can use either an overlay wavelength for video services or video over IP. In a video over IP system, video is packetized and sent to the customers using broadcast, or multicast using IP.

IP can be used to support voice, data, and video services in Active Ethernet. Thus, both the service support and delivery technologies rely on IP and Ethernet.

Figure 17 depicts at a high level the equipment needed to support voice, data, and video services in IP based service delivery on an Active Ethernet access network.

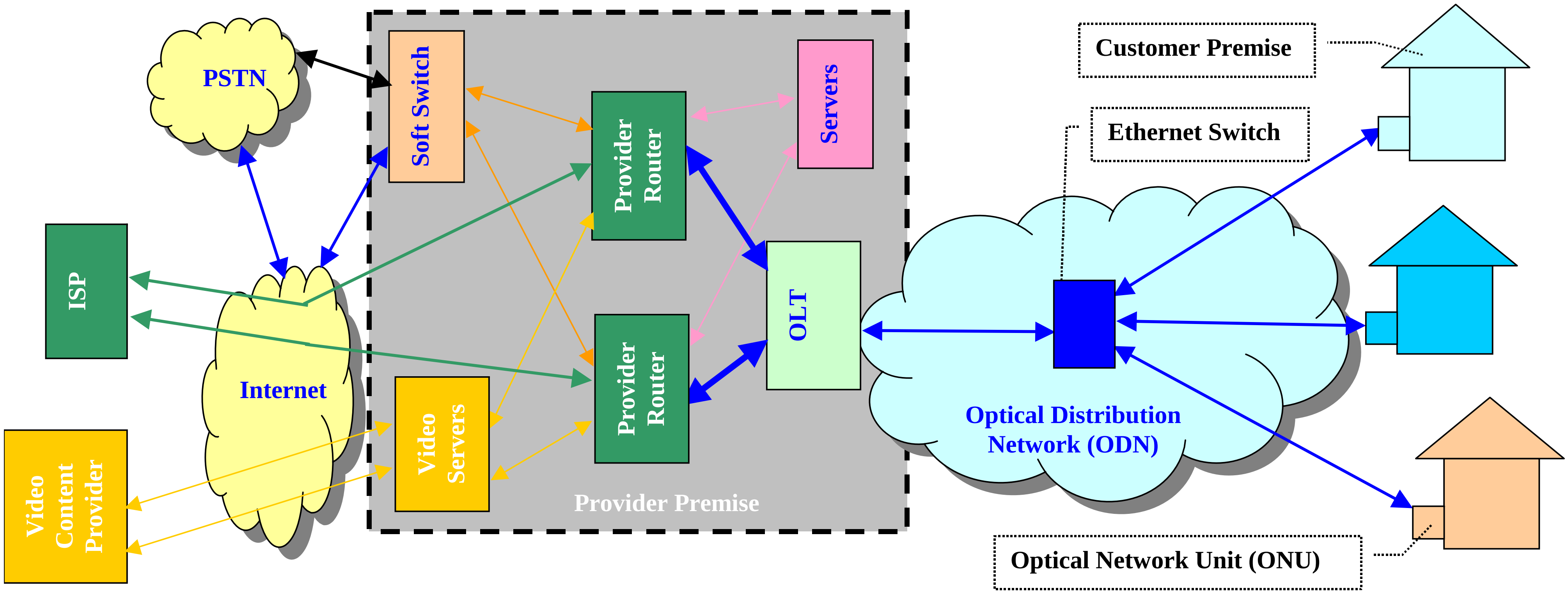


Figure 17: Voice, Data, and Video in an Active Ethernet Access Network Architecture

The equipment shown in Figure 17 to support the voice, data, and video services does not have to be deployed at the provider premises closest to the OLT. It can be deployed at a remote location and connected with high speed optics to the provider routers. The provider routers can themselves be situated at a remote or centralized location with high speed connection to the OLTs or switches at the provider office closest to the customers. Thus, there is a lot of flexibility in deployment options.

5.4 Point-to-Point Home Run Architecture

Figure 17**Error! Reference source not found.** schematically depicts the passive point-to-point Home Run architecture. *In the passive point-to-point Home Run architecture, each user gets a dedicated fiber from the operator point-of-presence to the user premises.* Optical fiber bandwidth is not shared between multiple users, thus the highest possible bandwidth (and future scalability) can be provided to the customer with this architecture. Ultimately, the supported bandwidth depends on the electronics deployed at the customer and operator point-of-presence. The data rate and communications signals used in Ethernet are different from those used in B-PON and G-PON. The key technical characteristics of E-PON are compared to those of B-PON and G-PON below.

The presence of a dedicated fiber between the operator point-of-presence and the user also makes it flexible for a user to obtain services from a particular provider—the service provider would be present at the operator point-of-presence, either by placing its own equipment at that location or by connecting through the operator’s backbone network, and could connect its services directly and physically with the fiber to that user, with a clear point of demarcation between the service provider and the operator of the physical plant.

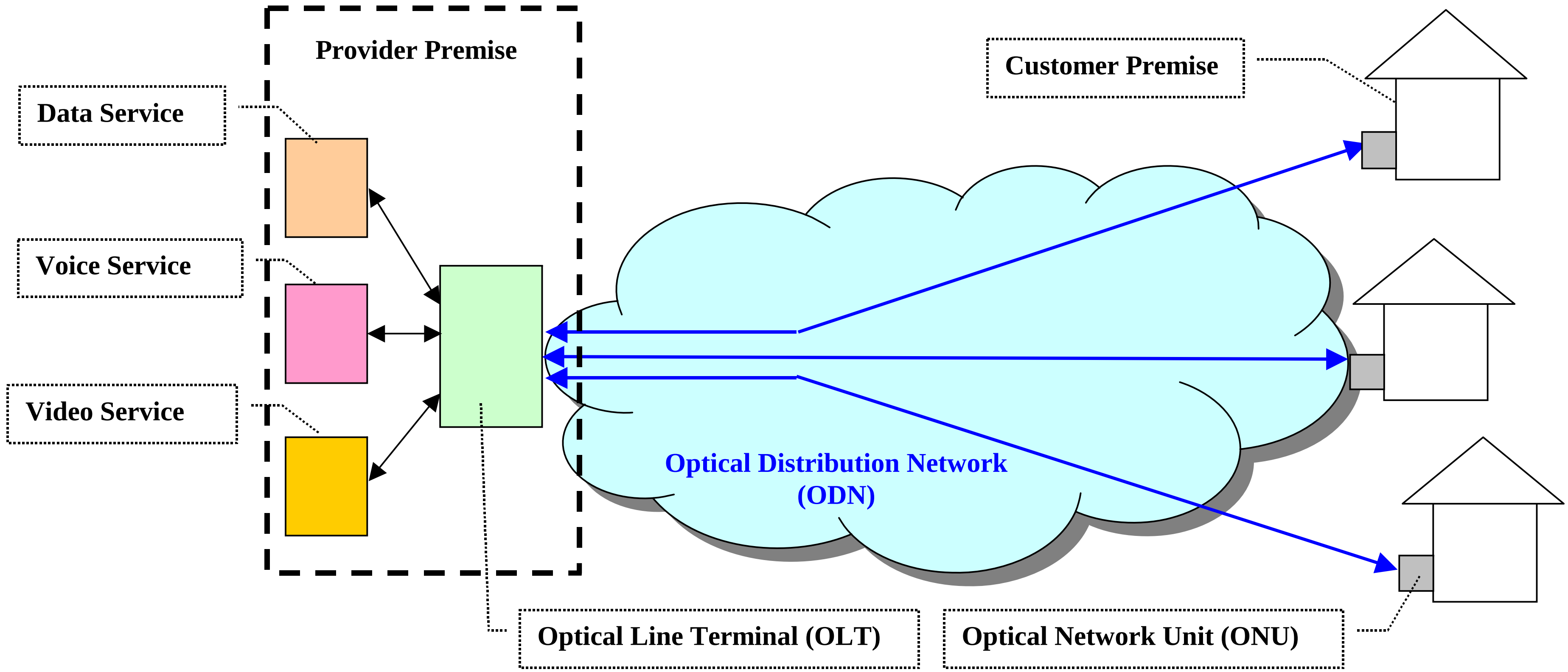


Figure 18: Point-to-point Home Run Architecture

5.5 Comparison of Architectures and Recommendation

Point-to-point Home Run fiber optic architecture differs from PON in the following ways:

1. A dedicated fiber path is provided to each subscriber in a Home Run architecture, while parts of each fiber path and capacity are shared between multiple subscribers in the PON.
2. Optical splitters are used in PON, while these are not required in Home Run.
3. Each dedicated fiber connection requires a pair of dedicated transceivers (one at the customer premises and one at the provider premises), while a single transceiver at the provider premises can support multiple users in PON.

Because of these differences, point-to-point Home Run architectures provides the following technical and engineering advantages, relative to PON

1. Each subscriber can be allocated the full bandwidth supported by the end electronics, thus providing much higher speed connections;
2. Optical splitters do not have to be used in the outside plant, thus eliminating cabinets to house splitters;
3. Can flexibly support open access at the infrastructure layer (in other words, ISPs can collocate equipment at the provider premises to gain access to the dedicated optical fiber to the customer premises);
4. Nearly any technology can be used in a point-to-point physical topology, without limiting the equipment selection to a specific type of technology (for example, G-PON versus E-PON);
5. As any technology can be used, it is possible to use a wider range of electronics, including less-costly, mass-produced, off-the-shelf fiber optic Ethernet equipment not necessarily designed for PON. As any standards-compliant Ethernet equipment can be used, the equipment can be purchased from a wide range of vendors--the user equipment does not need to be from the same manufacturer as the service provider equipment, and replacement equipment does not need to be from the same manufacturer as the original equipment; and
6. Greater transmission distances can be achieved from the provider premises without the use of splitters that cause signal attenuation.

However, a Home Run architecture has the following technical and engineering disadvantages:

1. More optical fiber is required – one strand per subscriber;
2. Requires more electronic components than a PON (for example, 64 transceivers are required to support 32 customer in Home Run architecture, while only 33 are

required in PON), and thus more hardware space is required to house the larger number of transceivers at the provider premises.

3. More fiber terminations are required – one termination per subscriber – requiring more space in the provider premises; and
4. A flexible fiber interconnection mechanism is required. Either manual patch panels or an electronically reconfigurable optical cross-connect could be used. The former raises operations costs, while the later has a higher initial cost.

With respect to network security, a Home Run architecture is potentially less prone to security breaches, both from the perspective of protecting multiple service providers in an open access environment from unauthorized access to their services, and protecting subscribers' data from unauthorized interception over shared portions of the access network. Rather than a shared connection through which data from multiple subscribers passes, each subscriber's data travels over a dedicated fiber optic strand from the customer's premise to their provider's hub router or switch. Although this can clearly be an advantage of a Home Run architecture, suitable access and data security can be achieved in other ways that do not require dedicated fiber.

The following table qualitatively compares PON, Active Ethernet, and Home Run technologies across a number of attributes such as capacity, reach, scalability, QoS support, and open access capability.

Table 2: FTTP Access Technology Comparison

Attribute	PON		Active	
	B(G)-PON	E(GE)PON	Active Ethernet	Home Run
Type of ODN	Passive	Passive	Active	No ODN
Standardized	ITU-T G.983 (G.984)	IEEE 802.3ah	IEEE 802.3ah	None
Capacity	32(64) users per passive tree	16 users per passive tree		
Reach	20km (28dB) from OLT	20km	10km (6dB) from Active Node	Equipment dependent
Rates	Up to 2.4Gbps per PON	Up to 1.2Gbps per PON	Up to 1.2Gbps per user	Equipment dependent
Bandwidth Efficiency	High	Low	Low	Low
Services	TDM Voice, Data, RF Video IPTV and VoIP also possible over data connection	Voice over IP, Data, IP Video	Voice over IP, Data, IP Video	Any
QoS Support	Standardized with Class of Service	Partially Standardized	Partially Standardized	Equipment dependent
Security	AES encryption	AES encryption	AES encryption	Equipment dependent
Network Management	OAM functions are standardized	Being developed	Being developed	Equipment dependent
Scalability	Up to 32(64) users at 1.2(2.4) Gbps on one PON tree, more users can be supported with more fiber and equipment	16 users per passive tree, more users can be supported with more fiber and equipment	Higher capacities and more users can be supported with more equipment	Provides theoretically unlimited capacity depending on the electronics chosen
Maturity	Products available from multiple vendors	Products available from multiple vendors	Products available from multiple vendors	Products available from multiple vendors
Current adoption	Major Network Operators Like Verizon & ATT	Foreign carriers	Municipalities and Utilities	Greenfield developments
Open-access Capability	Not for RF video	All three services	All three services	All three services
Service Provider can access customer over direct fiber	No	Yes	No	Yes
Service Provider can access customer via Layer 2 tunnel (such as VLAN or VPN)	Yes	Yes	Yes	Yes
Service Provider can access customer via Layer 3 (such as VPN or routing policies)	Yes	Yes	Yes	Yes
Reference Figure	Figure 15	Figure 15	Figure 16	Figure 18

As discussed earlier, for an FTTP access network constructed by the City and County of San Francisco, we urge the following technical and engineering considerations.

1. Avoid using active components between the provider premises and customer, primarily due to the size and quantity of outdoor enclosures that would be required (transmission distances are not an issue within the City);
2. Provide a flexible mechanism of interconnection to the multiple ISPs and other service providers, possibly at multiple network layers;
3. Ensure the solution can support different quality of service (QoS) classes so that voice and video can be delivered with acceptable performance, while allowing best effort data services;
4. Ensure that physical hub facilities are designed to house and support equipment for multiple providers, allowing collocation for open access competition; and
5. An operations support system that permits easy transfer of subscribers between multiple ISPs, supports fault management, and also supports billing will be required.

Guided by these considerations, we recommend the use of a Home Run architecture.

6. FTTP Design and Deployment Cost Models

This section examines the engineering considerations and the implementation costs that must be considered with respect to the general feasibility of constructing a Citywide fiber optic network, whether a City-owned, internal network (I-Net) for non-commercial, municipal entities or a commercial FTTP network capable of offering voice, video, and data services to residents and businesses.

Specifically, we examine the major design considerations that affect cost, performance, and scalability, organized into the following major system components:

- Physical fiber optic plant construction;
- Network transport electronics, providing basic backbone communications to the end-user premises;
- Network management and monitoring systems; and
- Application and service infrastructure, including telephone, video, and data systems.

Where appropriate, varying design models are presented and compared.

Generally, our design models and cost estimates show that the outside plant cost of a Home Run fiber topology is approximately 30 percent more than a typical PON architecture using splitters, but that the selection of network transport technology (Ethernet versus G-PON) does not greatly affect cost either way.

6.1 Fiber Optic Plant Construction

6.1.1 Design Model Considerations

Fiber optic construction is quite often the most costly single category of capital expenses for any metropolitan area network (MAN) or commercial subscriber network. Consequently, proper planning and engineering are necessary to minimize the risk of wasted expenditures while ensuring the end product will support both current requirements and any likely future technology or application. The factors that affect the cost of fiber construction will be explored relative to a suitable design model for an FTTP deployment in San Francisco. This design model will serve as the basis for extrapolation of implementation costs based on incremental cost components derived from specific physical attributes affecting construction costs in San Francisco.

Although variations are very likely in any actual implementation, a design model considering the following variables will provide the basis for suitable estimates:

- ***Passings:*** Number of potential customer locations, or "passings" the system will encompass, including residential, business, and municipal entities;

- ***Service area:*** The physical size of the area to be served and total corresponding street miles; and

- ***Topology:*** A physical backbone topology, including number of hub facility locations, the manner in which fiber interconnects hubs logically, and to some extent, the manner in which fiber connections are aggregated between the end customer and the hub locations.

In San Francisco, there are approximately 365,000 passings (homes and businesses), which we will approximate as 400,000 for purposes of this analysis to account for growth. The design model will assume the need to support connectivity for every passing without requiring modification to the backbone physical fiber "plant" with each new subscription request. It should be noted that the subscriber "drop," or cable connection from the nearest backbone tap to the user, would be installed upon subscription, and thus relate to the number of actual customers, not the number of passings.

According to City statistics, San Francisco covers approximately 47 square miles, and has approximately 900 miles of streets. The design model assumes a reasonably even distribution of passings throughout the City. While variations in density might affect the implementation costs for specific areas in a staged deployment, the large scale of a Citywide network deployment makes it valid to use an average to estimate Citywide costs.

An important aspect of physical topology is the manner in which connectivity is aggregated throughout the system. Very seldom does a large network, particularly a commercial carrier network, connect from a single central hub location to every individual customer over dedicated physical lines (fiber, or otherwise). The sheer amount of cables entering a single location would be unmanageable in most situations, particularly in metropolitan environments. Consequently, the physical topology of an FTTP network in San Francisco must involve some degree of intermediate link aggregation, in which one or more layers of network facilities sit between the customer and the central carrier systems. These intermediate aggregation points allow lower capacity connections to be combined into fewer, larger capacity connections.

Depending upon the type of FTTP technology (PON, Active Ethernet, etc.), the physical hardware components can vary (as discussed in Section 5 above). One main difference between FTTP technology types is the type and quantity of network electronics located in outdoor cabinets and enclosures. Whether for cable television, telephone, or FTTP systems, these cabinets are almost always located in public rights of way. Consequently, the size and quantity is a critical factor in evaluating an FTTP technology.

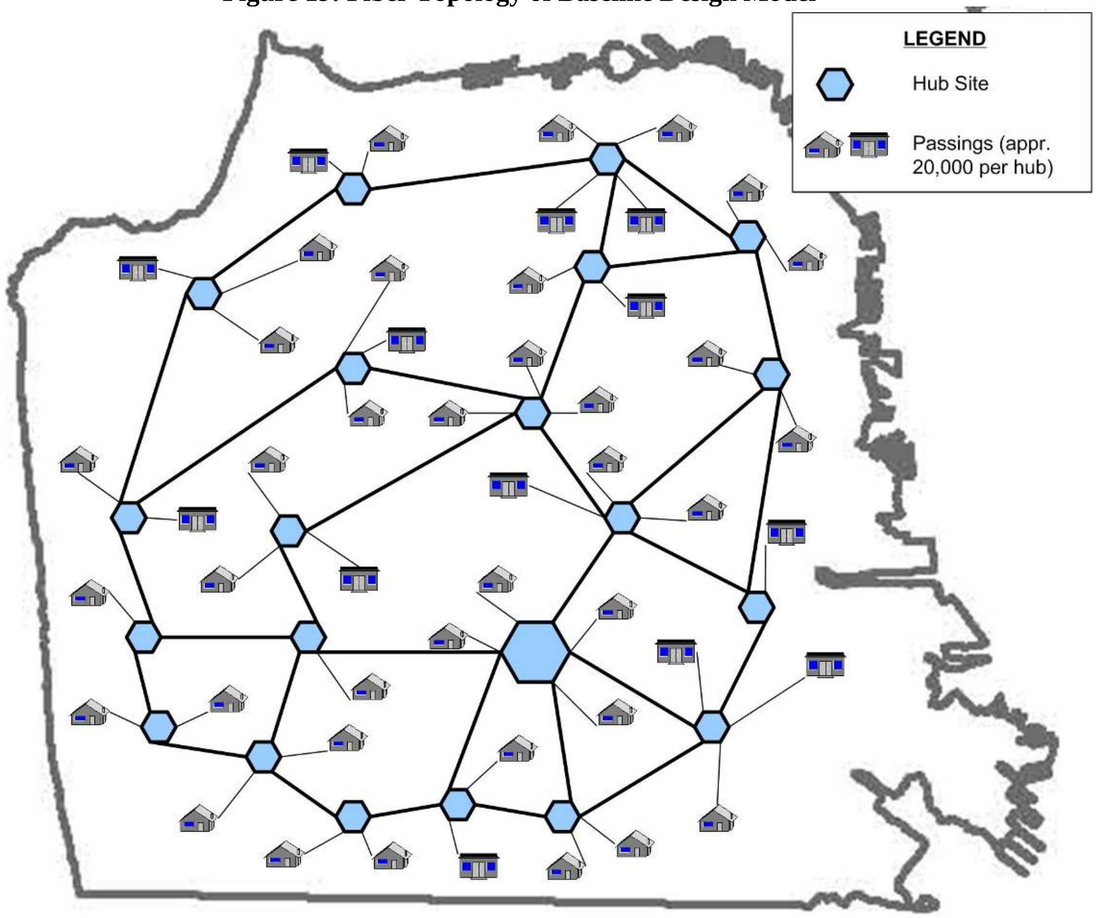
With FTTP technologies, only the typical Active Ethernet network architectures require any "active" electronics in outdoor enclosures. Conversely, PON technologies require only passive, small hardware related to physical support, splicing, and splitting of fiber cables in outdoor locations. The outdoor enclosures for network electronics in an Active Ethernet network can be very large, containing a large amount of network electronics, batteries for backup electrical power, fiber termination hardware, and climate control systems. For example, some of the outdoor enclosures supporting the UTOPIA Active Ethernet network in Utah measure more than 12 feet long, six feet tall, and several feet deep, serving approximately 224 subscribers.

Because the density of subscriber passings in San Francisco would require 700 or more large enclosures throughout the City for an Active Ethernet network, the enclosure size would present a considerable obstacle for such a deployment in an urban environment like San Francisco. For this reason, ***only FTTP architectures that require no outdoor electronics will be considered feasible with respect the analysis in this document***. Consequently, the fiber topology for the design model will assume only fiber optics and passive components between the subscriber and hub locations. However, this does not exclude the use of Ethernet hardware configured for a fiber topology with direct Home Run connections between subscribers and hubs (such as an E-PON network).

Specifically, we will assume an architecture with approximately 20 hubs to serve up to 400,000 subscribers. The hubs would each have diverse underground fiber optic entrances into the hubs to connect subscribers to the FTTP backbone network and to minimize the points of failure on the network. Due to the number and size of fiber optic cabling entering each hub, underground entrances will be needed to accommodate the cabling.

Each of these hubs will be interconnected in one or more fiber optic backbone rings, providing physically diverse paths between hub sites to increase survivability of the network through the use of redundant backbone links and redundant network electronics. One or more of these hubs will serve as a larger "headend" location to house central systems for network management and services.

Figure 19: Fiber Topology of Baseline Design Model



This model has the benefit of distributing the risk of service outages caused by any one physical catastrophe at a hub site to less than 20,000 subscribers, which is a typical target for the cable industry. Although 20 hubs has been chosen as the basis for a reasonable design and cost model, the actual implementation could vary without substantially impacting the overall cost.

As a reference, increasing the number of hubs:

- Further distributes this risk of catastrophic hub failure to smaller groups of subscribers;
- Reduces the average fiber distance from the hub to each subscriber, further increasing the average availability and reliability of the fiber as it relates to fiber damage;
- Increases the aggregate cost of real-estate and support systems (backup power, climate control, etc) for hubs; and
- Allows service infrastructure (servers, etc.) to be deployed on a more distributed basis to increase scalability for demand, though likely at a higher cost.

Conversely, decreasing the number of hubs:

- Can increase the number of subscribers affected by a catastrophic hub failure;
- Increases the average fiber distance from the hub to each subscriber, thereby decreasing the overall network availability as it relates to fiber damage (unless redundant paths are provided to a deeper intermediate aggregation point in the network);
- Reduces aggregate cost of hub location real-estate and support systems through certain economies of scale; and
- Increases the cost for fiber construction near hub sites where the quantities of fiber strands is exceedingly high, necessitating more expensive underground construction.

6.1.2 *Incremental Fiber Construction Cost Components*

The physical fiber plant construction costs are broken into two basic types of construction: aerial and underground. The subdivisions of cost within these categories are labor and material. The basic cost components for fiber construction are briefly outlined in the following sections.

6.1.2.1 Aerial Construction

Aerial construction varies in cost primarily as a result of different equipment, contractor selection, and design specifications. The labor costs typically exceed the material costs substantially. Whereas the total per mile aerial construction cost can range from $25,000 to $50,000 (and sometimes more), the material costs usually represent only $5,000 to $10,000 per mile of this cost.

Aerial construction labor consists of installing the supporting strand, lashing fiber optic cable to the strand, splicing the fiber optic cable, distribution center placement, and activation testing of the plant. Often times, costs are driven up by make-ready work, performed to relocate existing aerial attachments (other fiber, telephone, and cable), and sometimes extend or replace utility poles to ensure minimum clearances required by code are achieved. Incremental aerial construction material costs include the fiber cable, splice enclosures, fiber taps for individual subscriber drop connections, strand, and attachment hardware.

6.1.2.2 Underground Construction

Underground construction costs vary significantly depending upon the construction methodology and ground surface. While material costs for underground construction are comparable or slightly more than with aerial construction, the labor costs are significantly more. Consequently, per mile costs for underground construction can range from approximately $75,000 to more than $300,000, with costs averaging nearer the high end of this range for urban areas. Because the city is an urban environment, the cost will be at the higher end of the range, assuming restoration of concrete sidewalks or asphalt streets.

Underground construction can be accomplished in many ways. The labor to place cable or conduit will usually dominate the underground construction cost. The following methods of constructing underground plant are listed in order of increasing construction cost.

- ***Plowing***: If a cable path is unpaved, the least expensive method of construction is plowing cable into the ground. A cable plow has a blade that feeds cable into the ground. No material is removed from the earth. The plow opens a narrow trench, places the cable, and closes the trench in a single step. Plowing is not typically suitable for large banks of conduit, but can be performed with direct burial cable and some types of flexible conduit;

- ***Trenching:*** The second method is to trench, and then backfill after cable or conduit placement. When paved areas are encountered, it may be possible to cut, trench, place conduit, backfill, and patch the street. This is a flexible method for installing large amounts of cable or conduit, but can leave permanent cosmetic and/or structural damage to rights of way and roadways.

- ***Directional Boring:*** Often street cuts are not allowed, and it is necessary to bore under a street. Boring can be performed with a variety of techniques including the use of an auger, water pressure, and pneumatic devices. Each method requires a pit to be dug on each side of the street, or length to be bored. The boring device is placed into one pit and will pierce a hole under the street to the second pit. When placing underground cable plant in the street, it is possible to use the pot and bore construction technique. Using this method, a small portion of the street is opened at periodic intervals. The distance between each of these intervals is then bored.

Traffic control and time of construction can also increase costs. Underground construction costs are very dependent upon the specific area where construction occurs.

6.1.2.3 Subscriber Installation

The subscriber installation includes all materials required to connect the subscriber device to the fiber optic cable plant tap. There are several different installation categories, including residential aerial, residential underground, multiple dwelling units, and commercial. For single-family homes, the first fiber optic cable installed into the home is the primary outlet installation. This installation includes the fiber optic cable that connects the ONT home terminal to the cable plant tap. Material used for aerial installation typically includes aerial messenger, fiber optic outside cable with connectors, indoor cable, wall plates, hardware, and fittings. The inside wiring in single family units may include twisted pair for telephone, Category 5e (CAT5e) cable for data service, and/or coaxial cable for television service. Typically, when an apartment complex or Multiple Dwelling Unit (MDU) is wired, all apartments are wired with cable to a connection point in the building called a Fiber Distribution Center. This allows the installer to connect or disconnect customers without entering their apartment. When customers desire additional television outlets, the primary outlet is split, and an additional cable is placed to the second television.

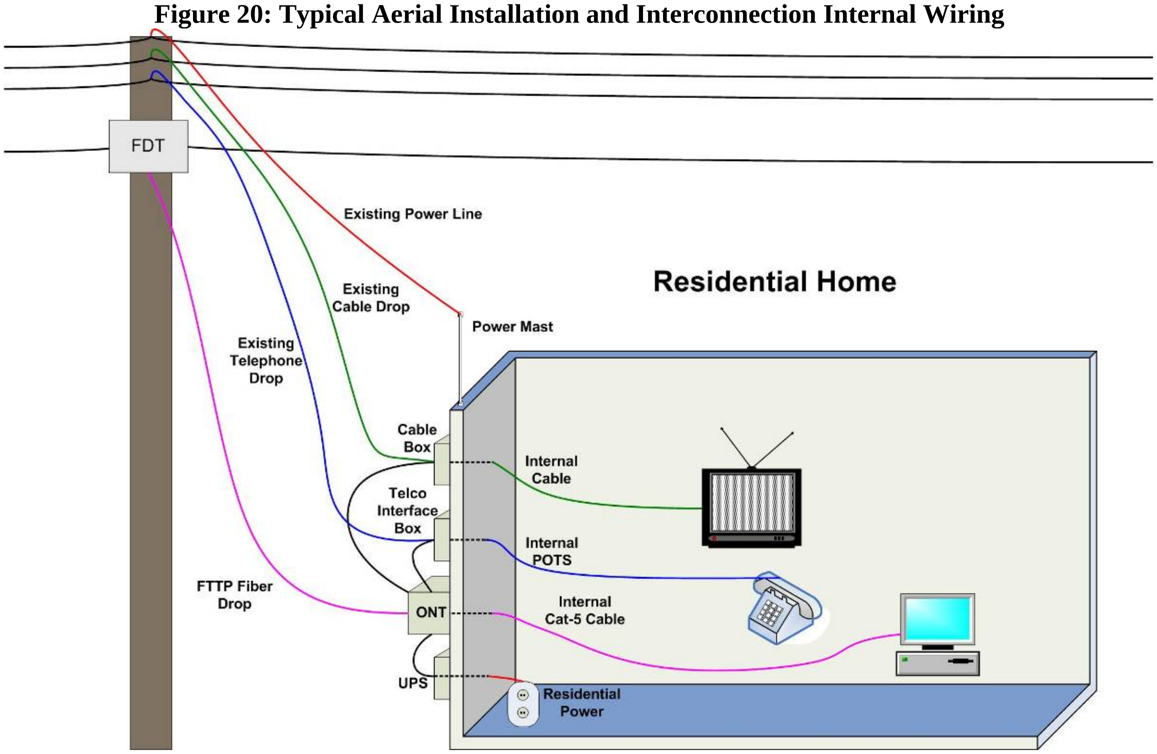
6.1.2.3.1 Single Family Aerial Installations

To minimize installation costs, the San Francisco system design model architecture provides an optical tap within 150 feet of the home. The fiber optic drop cable is pre-terminated with special hardened SC/APC-type connectors; as a result, the installer is not required to splice the fiber optic cable.

To complete an installation, the installer would start at the distribution center for the home and patch the existing fiber from the distribution center to the desired fiber optic tap. Next, the ONT home terminal is attached on the home near the existing telephone drop entrance point, and a power cable is run to the nearest power outlet. The ONT is then connected to the fiber optic tap using the pre-terminated fiber optic drop cable. Finally, the installer would connect the desired services to the ONT. In many cases, the cable television and telephone service may be connected without additional wiring (using existing coaxial cable). Data services will require addition of CAT5e cable to the subscriber's computer, and/or installation of a wireless router for connection to additional computers.

A typical aerial installation is shown in 20.

Figure 20: Typical Aerial Installation and Interconnection Internal Wiring



6.1.2.3.2 Single Family Underground Installations

Underground installations differ from aerial installations from the fiber optic tap to the home. Conduit is run from the pedestal that contains the fiber optic tap to the home. The pre-terminated fiber optic drop cable is then placed in the conduit and connected at each end. Again, no fiber splicing is necessary. Underground costs vary depending on the amount of underground, the ground conditions, and the obstacles in the ground.

6.1.2.3.3 Apartment **(MDU***) Installations*

Apartment installation requirements are usually different at each building. Generally, the entire apartment building is wired for service. A single drop is connected from the fiber optic drop to the fiber distribution center located in the building. When a new apartment is constructed, the building can be pre-wired. During construction, the electric contractor places coaxial, telephone, and CAT5e data cable inside walls. After drywall is completed, fittings and terminations are placed on the cables. Pre-wiring all new buildings reduces labor costs substantially.

When cable is installed in an existing building, there are many different installation methods available. The exact method to be used is usually negotiated with the building owner. In some buildings, the cables can be concealed in common closets connected by vertical cable risers. In other cases, cables must be placed in wire molding in hall areas. It is also possible in smaller apartment buildings with approximately four units to place multiple ONT and drop cables in locations similar to home installations. Therefore, each apartment building may have different installation costs per unit.

6.1.3 Fiber Construction Cost Models

This section provides the basic attributes and estimated costs of fiber construction for both I-Net and FTTP networks.

For the I-Net construction, we examine construction both with and without the use of conditioned conduit provided by PG&E, Comcast, and RCN.

With respect to the FTTP deployment, we examine fiber construction for the two most viable, currently available FTTP technologies that do not require active equipment at intermediate locations in the distribution network, including standard PON (B-PON/G-PON) and Home Run Ethernet (EPON/GE-PON). We will not develop a detailed cost estimate using Active Ethernet due to the need for 700 or more unacceptably large outdoor cabinets; we instead select 1) Home Run Ethernet and 2) standard PON for our detailed cost estimates.

6.1.3.1 Internal Network Fiber

Construction of new I-Net fiber to expand the City's existing FiberWAN can be done either independently or in conjunction with an FTTP network. The network serving internal City needs and serving the public would be independent networks Based on the actual locations of all City facilities, we estimate that approximately 250 additional locations could be connected to a fiber network constructed with a backbone ring architecture similar to the backbone described for our FTTP network design model, such that new FiberWAN sites are located within 0.25 miles of the backbone ring fiber. In the event that both I-Net and FTTP networks are constructed, the hub sites and backbone ring construction would likely be the same for both.

In the case of I-Net fiber built in conjunction with an FTTP network, we estimate a total fiber construction cost of approximately $12.25 million. For this estimate, we assume no use of conditioned conduit, but rather that the I-Net is constructed using existing MTA conduit and other "unconditioned" resources to serve the dual purposes of both connecting additional sites to the City's FiberWAN and providing the first step towards the construction of a Citywide FTTP network for non-internal purposes. Our construction cost estimates and basic construction attributes for this scenario are summarized as follows:

<u>I-Net Fiber Construction Attributes/Costs (No conditioned conduit)</u>

- Approximately 32.5 miles of minimum 288 count backbone ring fiber, including 30.2 miles using existing conduit;
- An average fiber drop distance to each new site of approximately 0.25 miles, for a total drop distance of 62.5 miles, constructed without the use of existing conduit;
- Assume 50 percent aerial and 50 percent underground construction for existing and new construction; and
- Total material cost of $1.9 million
- Total labor cost of $10.3 million

In the case of an independent I-Net build, the lowest cost construction opportunity likely requires maximum use of existing conduit resources, including conditioned conduit. We estimate the total cost to connect the same 250 sites to be approximately $5.42 million, assuming availability of conditioned conduits for all underground construction. While this provides a lower cost for I-Net fiber, this fiber could not be used for non-internal purposes disallowed by the conditions placed on the conduit. Our construction cost estimates and basic construction attributes for this scenario are summarized as follows:

<u>I-Net Fiber Construction Attributes/Costs (Maximum use of conditioned conduit)</u>

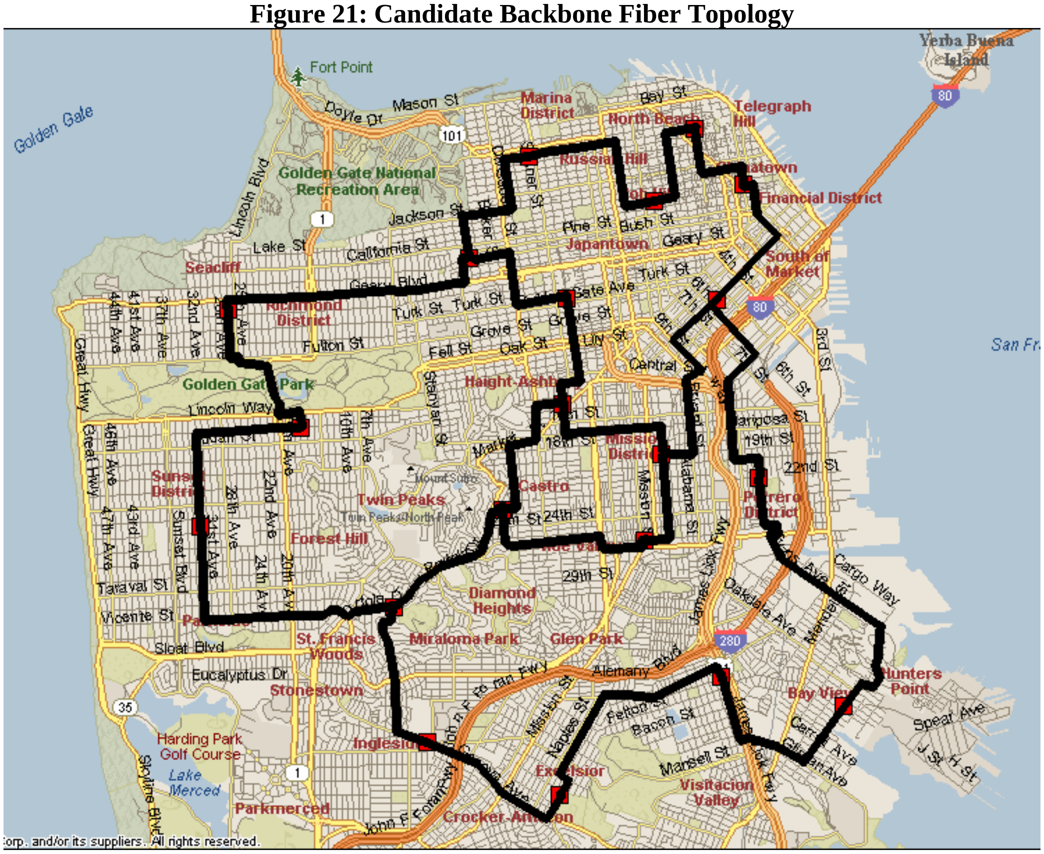
- Approximately 32.5 miles of minimum 288 count backbone ring fiber, including 31.0 miles using existing conduit;
- Expand FiberWAN coverage to Castro, East Bay, Embarcadero, Mission, Noe, North Beach, Pacific Heights, Presidio, Richmond, Sunset, and Visitacion Valley:
- An average fiber drop distance to each new site of approximately 0.25 miles, for a total drop distance of 62.5 miles, with all underground construction using existing conditioned conduit (assuming availability of conditioned conduit in all underground areas);
- Assume 50 percent aerial and 50 percent underground construction for existing and new construction; and

- Total material cost of $1.3 million
- Total labor cost of $4.1 million

6.1.3.2 FTTP Backbone Hub Infrastructure

Our FTTP design model calls for a backbone consisting of 20 hub locations interconnected by diversely routed backbone fiber rings. This backbone fiber is necessary regardless of the FTTP technology, and is an incremental cost to other FTTP construction costs. For the purposes of cost estimation, a candidate backbone fiber topology was developed using actual street routing (21). The FTTP backbone may in some cases be able to share conduit with the City network backbone, where routing requirements and conditions on use permit. However, these would be independent networks.

Figure 21: Candidate Backbone Fiber Topology



Backbone fiber construction will cost an estimated $680,000, to include a minimum of 72-count fiber over the backbone routing dedicated for hub-to-hub communications. This assumes construction in conjunction with a full FTTP build out, and is an incremental addition to these costs.

6.1.3.3 Passive Optical Network (B-PON/G-PON)

To determine the approximate fiber construction costs for a PON FTTP network, we must further develop our design model to include attributes specific to a G-PON or B-PON network. Recall that our design model calls for 20 hub locations, each serving 20,000 passings and about 2.5 square miles. From each hub site, fiber extends to Fiber Distribution Cabinets (FDCs) where passive fiber splitters are housed for splitting feeder fibers for distribution to individual taps. Within the FDC, each fiber is typically split to serve 32 individual subscriber drops.

FDCs are typically sized to support in the ballpark of 500 passings, which means that approximately 40 FDCs are required per hub. We estimate that the average fiber distance from a hub to an FDC is approximately 0.5 miles. A 36-count fiber cable is sufficient from each hub to FDC based on this ratio of passings per FDC, with some additional capacity for dedicated fiber to larger customers or for future expansion. Thus, each hub will have approximately 1,584 fibers terminated from the distribution network, which equates to approximately four standard equipment racks (typically two feet wide by four feet deep) for fiber termination panels.

There are hub-related costs proportional to the number of fibers terminating at the hub, including material and labor for fiber termination. Fiber-related hub site costs specific to a G-PON/B-PON network are estimated at approximately $205,000 per hub, or $4.1 million total, and include:

- Fiber entrance cabinets: $24,000 per hub
- Fiber termination panels: $110,000 per hub
- Fiber installation labor: $71,000 per hub

We assume that nearly all 900 miles of streets within San Francisco must be covered to reach all potential subscribers. Thus, we developed detailed designs for sample service areas to determine average Citywide costs per street mile as it relates to varying fiber counts, taps for drops, subscriber drops, splicing, and method of construction (aerial, trenching, boring, etc).

A sample design for aerial construction was detailed for a medium-density neighborhood in San Francisco. This design (Figure 22), spanning 1.1 street miles, provides an average drop length and specific requirements for materials and labor relating to tap placement, splice cases, outdoor cabinets, aerial strand, and attachment hardware. Our estimates indicate an average of 1.04 miles of aerial construction is required per street mile in areas served by aerial plant, which means that approximately 466 aerial plant miles are required to serve 450 street miles (estimated 50 percent of the total 900 street miles) served with aerial construction. An estimated cost of $89,500 per aerial strand mile was generated from this design, which equates to a total aerial construction cost estimate of $41.7 million.

Note: Information used in this design was based on the City's GIS system.

Figure 22: Sample PON Aerial Construction Fiber Design

Similarly, a sample design for underground construction was detailed for a medium-density neighborhood in San Francisco. This design (23), spanning 1.1 street miles, provides an average drop length and specific requirements for materials and labor relating to tap placement, conduit, splice enclosures, splice vaults, tap vaults, and distribution cabinets. Our estimates indicate an average of 1.51 miles of underground construction is required per street mile in areas served by underground plant, which means that approximately 681 underground plant miles are required to serve 450 street miles (estimated 50 percent of the total 900 street miles) served with underground construction. An estimated cost of $340,000 per underground construction mile was generated from this design, which equates to a total underground construction cost estimate of $231 million.

Figure 23: Sample PON Underground Construction Fiber Design

The total fiber construction cost for a G-PON/B-PON network, including aerial distribution network construction, underground distribution network construction, and backbone construction equates to approximately $279 million, or $762 per passing. This cost does not include per subscriber costs for individual drop connections or related electronics, nor does it include other hub-related costs for electronics to provide transport or services. These costs will be detailed in later sections. Also, depending upon the business model for the FTTP network, some or all of these costs might be specific to the particular service provider.

6.1.3.4 Home Run Ethernet

Compared to the G-PON/B-PON fiber architecture, a Home Run network will provide a dedicated fiber per passing from a hub location with no passive splitting in the field. This requires much larger fiber counts, but has the added advantage of being able to support virtually any network technology and provide dedicated fibers for any or all users as needed for scaling capacity.

To determine the approximate fiber construction costs for a Home Run Ethernet, or E-PON FTTP network, we must further develop our design model to include attributes specific to a Home Run fiber network.

Recall that our design model calls for 20 hub locations, each serving 20,000 passings and about 2.5 square miles. From each hub site, fiber extends to splice vaults where fiber splice enclosures are housed for breakout of feeder fiber to smaller cables for distribution to taps. Each hub will have approximately 20,000 fibers terminated from the distribution network with a dedicated fiber per passing, which equates to approximately 32 standard equipment racks (typically two feet wide by four feet deep) for fiber termination panels.

There are hub-related costs proportional to the number of fibers terminating at the hub, including material and labor for fiber termination. Fiber-related hub site costs specific to a Home Run network are estimated at approximately $1.7 million per hub, or $33.9 million total, and include:

- Fiber entrance cabinets: $192,000 per hub
- Fiber termination panels: $910,000 per hub
- Fiber installation labor: $591,000 per hub

We assume that nearly all 900 miles of streets within San Francisco must be covered to reach all potential subscribers. Thus, we developed detailed designs for sample service areas to determine average costs Citywide per street mile as it relates to varying fiber counts, taps for drops, subscriber drops, splicing, and method of construction (aerial, trenching, boring, etc).

The sample aerial construction sample design used for the G-PON/B-PON, based on a medium-density neighborhood in San Francisco, was modified to incorporate the increase in feeder fiber count required to support a Home Run architecture compared to a typical PON network. This design, spanning 1.1 street miles, provides an average drop length and specific requirements for materials and labor relating to tap placement, splice cases, outdoor cabinets, aerial strand, and attachment hardware. Our estimates indicate an average of 0.86 miles of aerial construction is required per street mile in areas served by aerial plant, which equates to approximately 57.7 miles of aerial plant miles are required to serve 67.2 street miles per hub (estimated 50 percent of the total passings per hub) served with aerial construction. An estimated cost of $4.2 million per hub for aerial construction was generated from this design, which equates to a total aerial construction cost estimate of $41.9 million.

Similarly, a sample design for underground construction was detailed for a medium-density neighborhood in San Francisco. This design (Figure 23), spanning 1.1 street miles, provides an average drop length and specific requirements for materials and labor relating to tap placement, conduit, splice enclosures, splice vaults, tap vaults, and distribution cabinets. Our estimates indicate an average of 1.72 miles of underground construction is required per street mile in areas served by underground plant, which equates to approximately 115.3 miles of underground plant miles are required to serve 67.2 street miles (estimated 50 percent of the total passings per hub) served with underground construction. An estimated cost of $32.7 million per hub for underground construction was generated from this design, which equates to a total underground construction cost estimate of $327 million.

The total fiber construction cost for a Home Run FTTP network, including aerial distribution network construction, underground distribution network construction, and backbone construction equates to approximately $403 million, or $1,105 per passing. This cost does not include per subscriber costs for individual drop connections or related electronics, nor does it include other hub-related costs for electronics to provide transport or services or hub real estate costs. These costs will be detailed in later sections. Also, depending upon the business model for the FTTP network, some or all of these costs might be specific to the particular service provider.

6.1.4 Fiber Construction Phasing Approaches

As discussed, the City operates FiberWAN, its own private fiber optic network currently interconnecting 27 City facilities. Because much of the fiber constructed by the City is located in conditioned conduit, it cannot be used to support any commercial or residential users. However, this infrastructure alone represents hundreds of thousands of dollars per year in savings relative to the leased communications services that would otherwise be required. Thus, there may be net savings resulting from continued fiber construction to City facilities and other qualified internal entities.

Construction of an independent, City-owned, internal network (I-Net) would not preclude the construction of an FTTP network for commercial or other non-internal purposes, but, of course, this expanded FiberWAN fiber could not be used as the "launching pad" for this purpose if conditioned conduit is used. In other words, one possible construction strategy is the construction of separate fiber infrastructure for internal purposes (using conditioned conduit) relative to fiber for an FTTP network. The cost-effectiveness of constructing independent networks versus a unified FTTP construction project for both purposes is entirely dependent upon timing, as discussed in the following sections.

6.1.4.1 Approach 1: Internal Users Only

An initial fiber deployment phase to construct fiber for internal, City users not already served by the City's fiber infrastructure is a clearly identified need. Constructing I-Net fiber immediately, utilizing the City's extensive access to conditioned conduit wherever possible to reduce construction costs and time is one possible deployment approach. As demonstrated by the estimates provided in Section 6.1.3.1, an initial savings of up to approximately $6.9 million is possible when conditioned conduit is leveraged relative to construction of I-Net fiber without conditioned conduit. This is because many parts of the City have conditioned conduit available from PG&E, Comcast, and RCN but have no conduit available from MTA and other "unconditioned" conduit sources. These savings must assume no near-term plans for a wider FTTP deployment beyond internal users, as the construction of a Citywide FTTP network would provide an equally effective cost-savings mechanism for the construction of an I-Net.

An I-Net-only approach using conditioned conduit has the benefit of requiring minimal disruption to City ROW (at least in the near term), and can likely be accomplished faster due to the significantly decreased magnitude of the physical construction and planning efforts and lessened capital expenditure. By constructing I-Net fiber quickly and using conditioned conduit, the City could save approximately $575,000 per year in leased services[108], which recoups the I-Net fiber construction costs entirely in just over nine years while potentially providing enhanced communications capabilities to the users. This simple analysis reasonably assumes network electronics and operations expenses are similar with or without the leased communications service costs. The cost savings are reduced somewhat if substantial network electronics upgrades are necessary that can not be accommodated within the same budgets that would otherwise fund replacements and upgrades for network electronics required with the leased services.

In order to serve as an initial step towards an incremental build-out of an FTTP network to serve non-internal users, future I-Net deployments should seek to avoid using conditioned conduit. *Therefore, the decision whether to deploy FTTP and the FTTP deployment timeline are critical in assessing whether to install future fiber deployments in conditioned conduit.*

If the City determines that it is unlikely to ever build an FTTP network to support public or non-Internal needs, then using conditioned conduit for additional I-Net construction is a low-risk, highly beneficial approach. In other words, the lowest cost means to acquire fiber for internal purposes is likely the best option in this scenario, regardless of conditional usage of the fiber. Even if the City decides it may deploy additional fiber for non-internal purposes, but waits nine years or more to begin a substantial public FTTP deployment (due to cost or other reasons), then there is still no lost investment. In this scenario, the I-Net users have the benefit of the fiber much earlier than if the I-Net fiber had been delayed with a broader FTTP deployment.

On the other hand, if the City waits some number of years less than nine to start building a public FTTP network, then the maximum potential wasted investment in fiber construction is equivalent to the value of the leased communications services for the remaining time up to nine years, or rather, the amount of the I-Net construction costs not yet recouped by leased cost savings. For example, if the City waits for seven years to begin a FTTP deployment, the maximum sunk investment in fiber placed in conditioned conduit is equivalent to two years of leased services that would otherwise be required without the additional I-Net fiber, or approximately $1.2 million. This is a value judgment that is not entirely financial. The opportunity cost of not meeting other funding needs with this same amount of money must be weighed against the value of enhancing communications capabilities for City I-Net users for those years, with respect to meeting the goals of the City and serving its citizens.

---

[108] Based on City-provided leased circuit costs, assuming the construction of I-Net fiber to an additional 250 City sites with average leased circuit costs of approximately $2,300 per year for each site

6.1.4.2 Approach 2: Internal Users and FTTP for Target Development

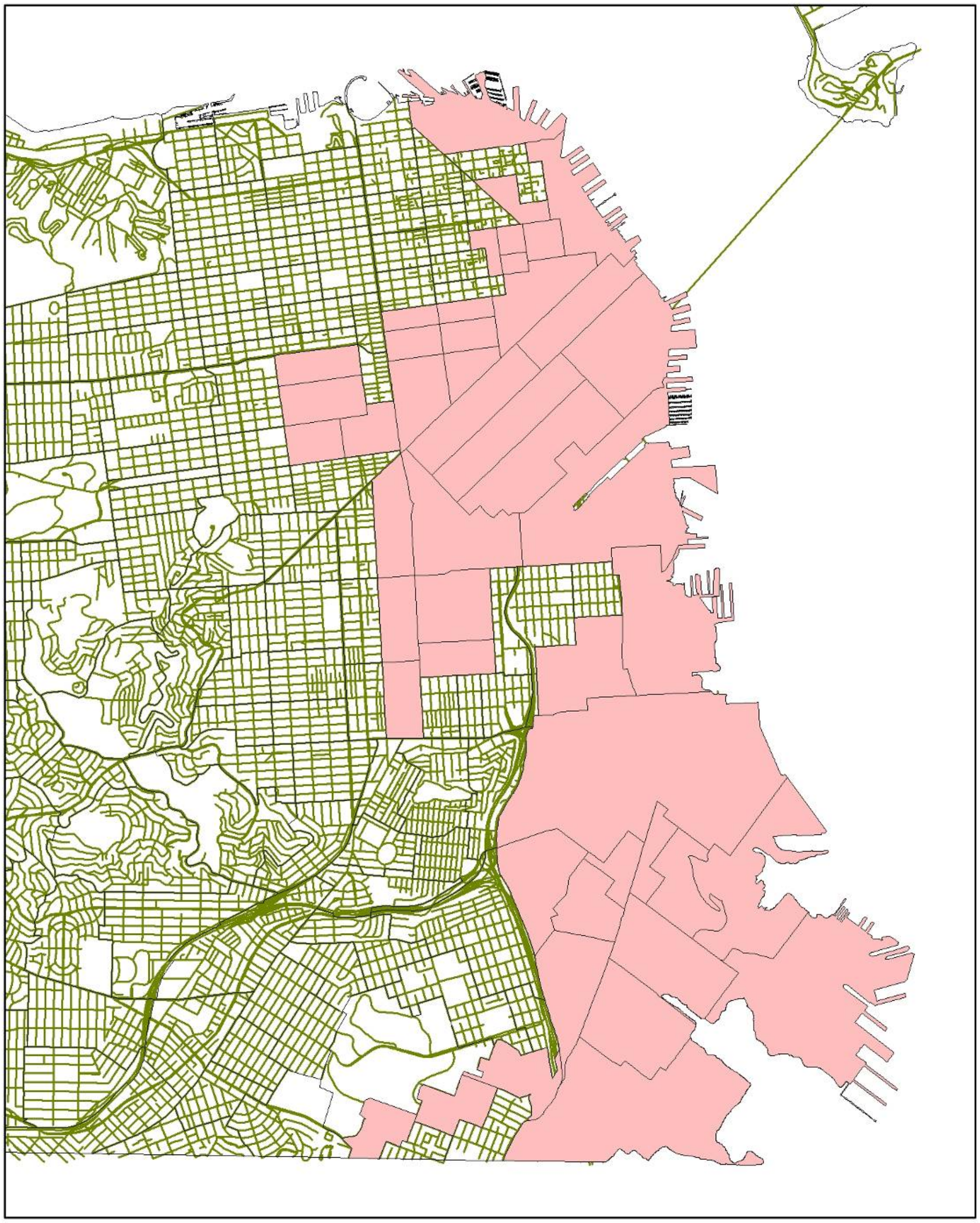
If the City is committed to building an FTTP network to support non-internal users over an extended time period but beginning in the near term (much less than nine years), then it might be that some or all new fiber construction should occur independent of conditioned conduit, whether for I-Net purposes or not. If the City's decision to construct an FTTP network requires fiber construction physically passing within close proximity to the identified I-Net locations, this may allow fiber to be constructed to the City I-Net locations in the near-term on an incremental cost basis that would likely far exceed the cost benefit of even using existing conduit. Further, this approach has the added benefit of providing fiber that can serve as an initial step towards a full Citywide FTTP deployment.

The viability of an approach in which building I-Net fiber becomes an incremental step for some type of FTTP deployment, or vice versa, depends on the degree to which the fiber construction for any near-term FTTP deployments and I-Net sites physically coincide. If the near-term FTTP deployment does not place new fiber at or near I-Net locations in significantly less than nine years on average, then the use of conditioned conduit must be considered at least for those sites not near the initial FTTP phase.

Based on the cost estimates developed for a Citywide FTTP deployment, the estimated cost for construction of an FTTP network for key development areas and fiber for I-Net users is approximately $130 million to $200 million given a 50 percent take rate and depending on the FTTP technology and management model chosen. In addition to I-Net candidate locations, this includes all businesses and residents in the proposed San Francisco Enterprise Zone as defined by the Mayor's Office of Economic and Workforce Development, constituting a total of approximately 12 square miles of economic development area including:

- Hunter's Point;
- Bay View;
- South Bayshore;
- Chinatown;
- Mission District;
- Mission Bay;
- Potrero Hill;
- South of Market;
- Tenderloin; and
- Western Addition (Figure 24).

Figure 24: Proposed Enterprise Zone



Given that the City has clearly identified target development areas, we expect that any near-term FTTP deployment, if not Citywide, would occur to these areas and would require new construction in the same manner as for a Citywide deployment.

It is important to note that the number of I-Net sites connected in this approach does not correlate to the number of sites connected in Approach 1 for constructing Citywide fiber for I-Net users only. An FTTP deployment targeting all passings in a given area has the potential to reach a greater number of candidate I-Net users than with other construction opportunities. Consequently, the City may choose to connect additional lower priority sites with this approach, such as unmanned or leased City facilities, as the incremental cost of building these sites is lower where FTTP is being deployed. Approach 1, on the other hand, would likely only involve higher priority sites citywide, and thus would include overall fewer sites.

For the remaining I-Net sites, we would recommend constructing fiber using conditioned conduit to the extent that later FTTP deployments would not offer coinciding fiber paths for nine years or more.

6.1.4.3 Approach 3: Full Citywide FTTP Deployment

If the City decides to initiate a Citywide FTTP deployment in the near term with a completion timeline occurring in the near term, then there is likely no benefit to using conditioned conduit at all, except as a means to provide redundant connectivity for critical I-Net sites over diverse physical paths.

6.2 Network Transport Infrastructure and Electronics

This section provides an overview of the design considerations and cost estimates for the network hardware required for basic communications transport over the FTTP fiber infrastructure.

6.2.1 Design Considerations and Assumptions

As with fiber construction, a cost estimate for network transport electronics requires further development of a suitable design model. Although design variations and extensive technology enhancements are very likely even over the next couple of years, a design model considering the following variables will provide the basis for suitable cost estimates:

- ***Take-rate:*** Target "take-rate", or percentage of these passings for which the system will be designed to fully support without impacting the physical design.

- ***Customer bandwidth and services:*** The bandwidth available to an individual subscriber is contingent upon the types of services offered, and to some degree, the manner in which services are delivered.

- ***Physical topology:*** The physical topology of the fiber network design model.

As mentioned, we based the fiber infrastructure design model on there being approximately 400,000 passings. A typical cable provider take rate in a successful service area is about 50 percent, and will thus be a reasonable target for this system design with respect to baseline network electronics costs. Therefore, wherever applicable, the system will incorporate sufficient network hardware capacity to support at least 50 percent of all passings, or approximately 200,000 subscribers. While take rate does not greatly affect the cost of fiber, as all passings represent candidate customers that must be serviceable without new backbone fiber construction, many of the network transport electronic components and systems for specific service offerings (servers for email, telephone switches, etc) are modularly scalable to allow for a more gradual deployment as dictated to meet actual demand. While various take rates will be examined with respect to business models and overall financial feasibility, this section will focus on this end target of 50 percent take rate for overall cost estimates, and where appropriate, per customer costs.

The bandwidth requirements and service offerings go hand-in-hand, and have a significant impact on the selection of network electronics. The objective of any FTTP network design model should be to support a full range of video, voice, and data services. Specifically, the network should initially support high-speed Internet access competitive with other FTTP networks in the Country, standard telephone services, and cable television video broadcast services. Moreover, the system should support high-definition video and video-on-demand (VoD) at a level equivalent to modern cable systems, with scalability to migrate towards a more predominantly on-demand environment for video services.

For FTTP networks that use a separate optical wavelength (RF overlay) to carry broadcast video services, as with most current B/G-PON systems, the video bandwidth is not a component of the "data" capacity of the network. However, in the case of Active Ethernet and E-PON networks that carry all video services on the same data channels with other services using high bandwidth Ethernet transport, the bandwidth requirements for the video services must be more closely assessed.

For example, a standard definition video channel requires approximately four Mbps of bandwidth (using MPEG-2 compression), while a high-definition channel requires 19 Mbps of bandwidth. Fortunately, in the case of broadcast video (as opposed to VoD), advanced Ethernet networks can support "multicasting" of video streams that allow the network transport electronics to create copies of any individual video stream, or "channel", at the edge of the network for any subscriber who requests that particular stream by "tuning" to the channel using their set-top box. Multicasting technologies ensure that the network backbone links between hubs and from the hubs to any intermediate active nodes need only carry at most one "copy" of each broadcast video signal. Each subscriber connection must carry up to the total maximum capacity for a particular subscriber, which can simultaneously require support for multiple video streams (for multiple televisions in a single home), Internet access, and telephony.

The following summarize our baseline estimates for initial capacity requirements on an FTTP network. The backbone network design is scalable in a cost-effective manner to rapidly accommodate increased demand; these estimates have been chosen based on industry norms as a starting point:

- Backbone network: 10.5 Gbps (per hub):

  - o 800 Mbps for standard definition video broadcast channels (200 channels at four Mbps each)
  - o 950 Mbps for high-definition video broadcast channels (50 channels at 19 Mbps each)
  - o 8.25 Gbps for VoD
    - Assumes 40 percent of all residents watching TV simultaneously at peak times[109] (total 300,000 residents Citywide, or 15,000 per hub), with approximately 10 percent viewing VoD programming (total 1500 viewers per hub).
    - Of these, 10 percent are watching HD programs (150 streams per hub), and 90 percent are watching SD programming (1350 streams per hub).
  - o 32 Mbps for telephone service per hub (assuming 64 kbps per call, with approximately five percent of all subscribers calling simultaneously at peak times)
  - o 500 Mbps for Internet access (assumes an mean simultaneous use of 50 kbps per subscriber)

- Subscriber connection: 67 Mbps (per subscriber peak):
  - o 57 Mbps for video (3 televisions per home on average[109], with 19 Mbps per HD video stream)
  - o 10 Mbps for Internet access (typical high-end connection speed of current offerings)
  - o 128 kbps per phone line (two lines per subscriber)

As can be seen from our baseline capacity requirement calculations above, video represents the vast majority of the capacity requirements for a system, with voice and other data network applications representing a small percentage of overall demand. There is definite industry trend away from the use of an RF overlay for video services, and thus, data capacity requirements of video will ultimately be a factor for network capacity provisioning regardless of the type of network transport hardware. As video services migrate towards a more on-demand environment, these capacity demands will grow exponentially without the ability for multicasting technologies to mitigate this issue. Ultimately, this means that any current FTTP network in the early planning stage should consider a highly scalable physical architecture to support these future demands, such as that provided by a Home Run fiber topology.

The physical topology of the fiber network, which has already been discussed, defines the physical interface requirements for the electronics, and presents opportunities for enhancing network survivability through the use of redundant paths where available. It is thus important for network electronics within the backbone to have mechanisms to enable automatic use of redundant links in a failover situation.

---

[109] **Nielson Media Research**, *Nielson Reports Americans Watching TV at Record Levels*, press release, September 29, 2005.

6.2.2 PON Architecture and Cost Estimates

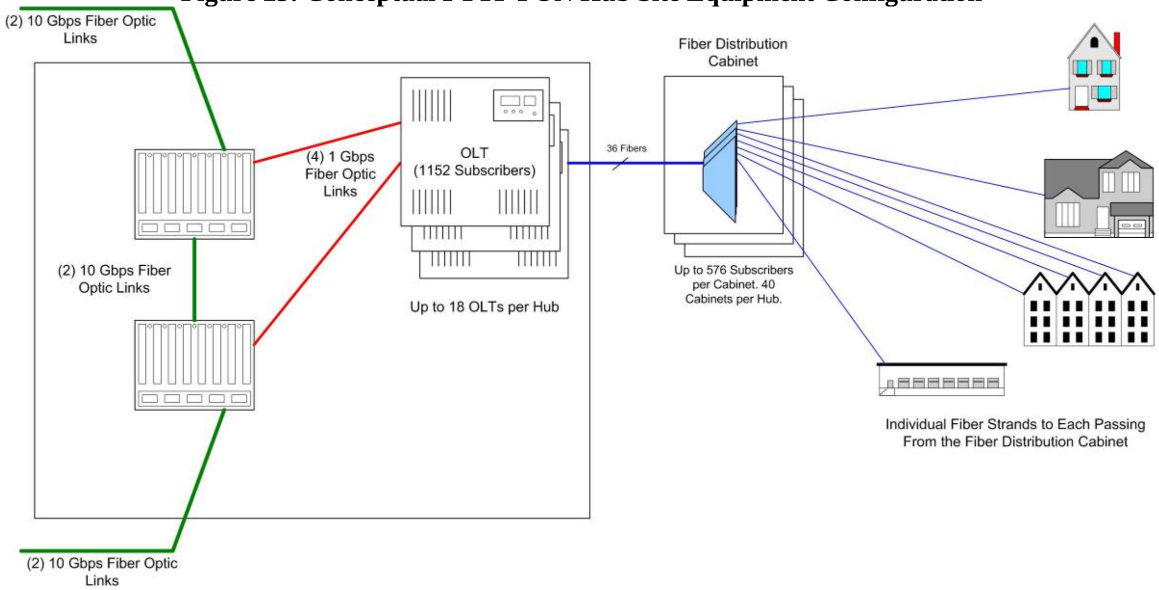
The PON network design model includes 1:32 ratio of fiber strands to passings, which requires a total of 313 activated OLT interfaces per hub site to support 10,000 subscribers. Based on typical OLT hardware port density, this equates to roughly six standard equipment cabinets (typically two feet wide by four feet deep) and an estimated per hub cost of approximately $1.56 million per hub ($156 per subscriber).

Backbone network electronics capable of aggregating the data capacity of the OLT interfaces and providing inter-hub communications for content distribution and management are also required. This would include core IP routers for aggregation of high speed links (1 Gbps, or greater) onto multiple backbone links of even greater capacity (10 Gbps). At least where an RF overlay is used for video distribution, separate backbone fibers could carry central feeds from one or more headend facilities, with the video signal coupled to each OLT port through RF amplifiers at the headend.

A fully redundant backbone router configuration capable of aggregating numerous gigabit per second connections from the OLTs, and providing two or more 10 Gbps backbone ring connections to adjacent hubs, including servers and related costs for critical network support services and management, would require approximately two equipment racks of space and a total of approximately $400,000 per hub ($8 million total).

Figure 25 provides illustrates the basic PON transport equipment configuration at a hub site.

Figure 25: Conceptual FTTP PON Hub Site Equipment Configuration



6.2.3 Home Run Ethernet Architecture and Cost Estimates

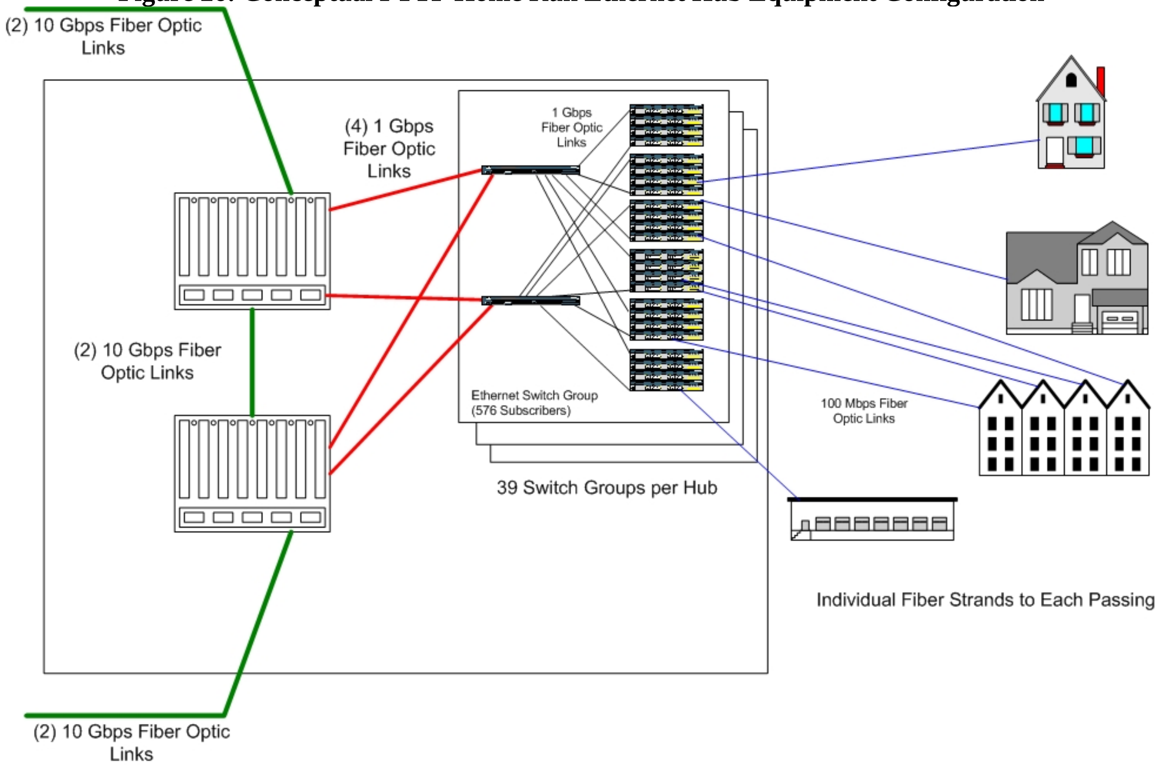
The Home Run Ethernet design model calls for a dedicated fiber strand per subscriber at the hub, which means a dedicated Ethernet fiber port operating at a speed of at least 100 Mbps (based on the above estimated peak requirement of at least 67 Mbps per subscriber) must be supported at the hub. The speed is scalable beyond 100 Mbps simply by upgrading the Ethernet equipment at the hub.

Due to the high port density compared to the typical design of actual Ethernet switches and routers, multiple layers of switching and routing hardware will be necessary to aggregate the connectivity from each subscriber. Note that due to the port capacity requirements, a similar quantity of Ethernet hardware, or more, is necessary for a standard Active Ethernet topology with active devices at intermediate outdoor cabinets employed.

Figure 26 illustrates a candidate equipment configuration developed for the purposes of cost estimation. The access layer of the network consists of approximately 420 24-port Ethernet switches, supporting range of basic Ethernet, IP, and MPLS features. These switches can be stacked via Gigabit Ethernet interfaces in groups of two to four switches, with each stack interfaced to two redundant core routers via multiple Gigabit Ethernet links. The access layer switching equipment at each hub would cost approximately $1.03 million for 10,000 subscribers, or $103 per subscriber.

The core routers each must support 100 to 200 Gigabit Ethernet interfaces, and provide multiple 10 Gigabit Ethernet interfaces for backbone transport between hubs. Including servers and related costs for critical network support services and management, we estimate this configuration would require approximately 50 equipment racks of space and a total of approximately $893,000 per hub ($17.9 million total).

Figure 26: Conceptual FTTP Home Run Ethernet Hub Equipment Configuration



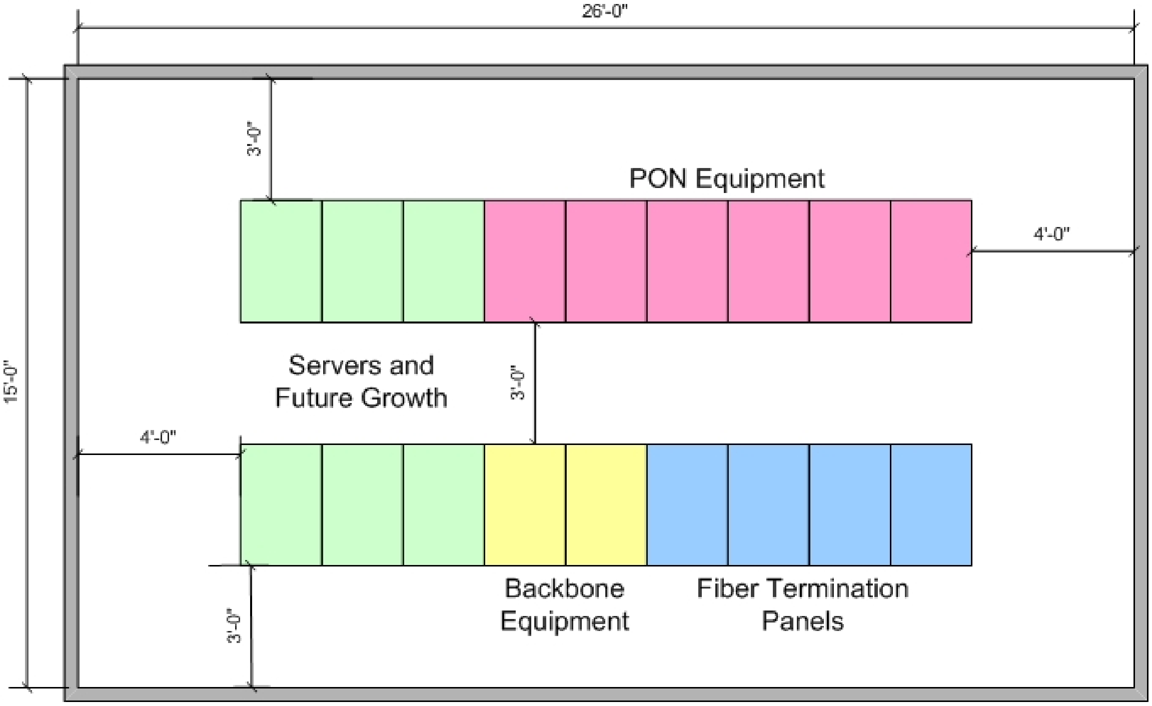
6.3 *Physical Hub Facility Infrastructure*

The 20 hub sites, one of which would serve as a primary hub, or headend location, has physical requirements and associated costs that vary with the topology of the network and technology utilized. As shown, the space requirements of a Home Run network of any type are much greater with respect to fiber termination infrastructure than a traditional PON network that uses splitters in the distribution network. Both types of networks are examined in the following sections with respect to hub site physical attributes and costs.

6.3.1 PON Hub Facilities

From the various infrastructure components examined above, we see that a hub site in a PON network based on our design model requires a total of approximately 12 equipment racks, not including space for specific application and service infrastructure, such as servers for telephone and VoD services. Thus, the facility should support approximately 18 racks of equipment in total, allowing for some expansion and support for a distributed architecture for applications and services, as desired by the City or commercial service providers. Including space for support infrastructure, such as climate control, fire suppression, security, and backup power systems, we estimate the need for approximately 1500 square feet per hub (Figure 27), which equates to approximately $600,000 per hub site for construction (not including real-estate).

Figure 27: Candidate FTTP PON Hub Site Layout



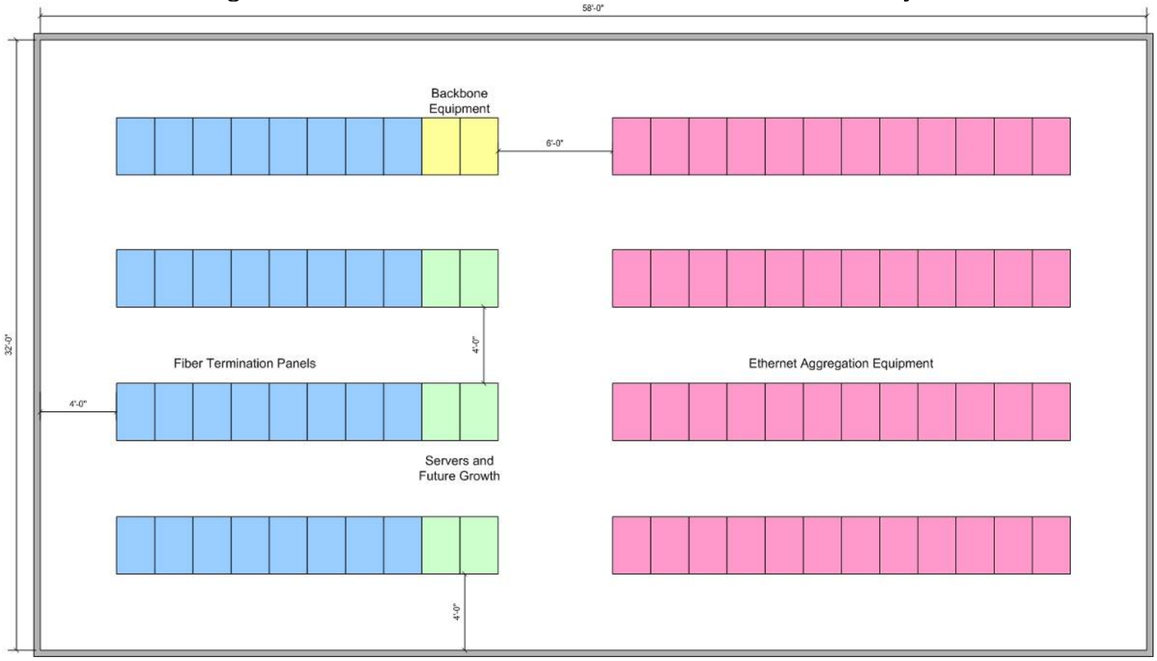
The headend location must support all centralized systems, including most, if not all, of the modulation/encoding and combining systems for video broadcast services. To accommodate some office space for administrative purposes and staffing for network operations personnel, and based on similar sized subscriber networks, we estimate a headend of approximately 25,000 square feet and costing an estimated $10 million (not including real estate) would be required.

Relative to the typical hub location, the headend will require certain core service-related systems in a retail model where the City provides services directly to the customer. While most of these systems are very much incremental on a per subscriber basis, assume a cost of approximately $7.5 million for headend video related systems.

6.3.2 Home Run Ethernet Hub Facilities

From the various infrastructure components examined, we see that a hub site in a Home Run Ethernet network based on our design model requires a total of approximately 42 equipment racks, not including space for specific application and service infrastructure, such as servers for telephone and VoD services. Thus, the facility should support approximately 50 racks of equipment in total, allowing for some expansion and support for a distributed architecture for applications and services, as desired by the City or commercial service providers. Including space for support infrastructure, such as climate control, fire suppression, security, and backup power systems, we estimate the need for approximately 3,000 square feet per hub (Figure 28), which equates to approximately $1.2 million per hub site for construction (not including real-estate).

Figure 28: Candidate FTTP Home Run Ethernet Hub Site Layout



The headend location must support all centralized systems, including most, if not all, of the modulation/encoding and combining systems for video broadcast services. To accommodate some office space for administrative purposes and staffing for network operations personnel, and based on similar sized subscriber networks, we estimate a headend of approximately 30,000 square feet and costing an estimated $12 million (not including real estate) would be required.

Relative to the typical hub location, the headend will require certain core service-related systems in a retail model where the City provides services directly to the customer. While most of these systems are very much incremental on a per subscriber basis, assume a cost of approximately $7.5 million for headend video related systems.

6.4 Incremental Subscriber Costs

There are certain per subscriber costs, not directly related to the initial capital for the basic backbone infrastructure or other core systems, which are incurred strictly on an incremental basis for each subscriber. These costs vary, at least with respect to what the City might incur, depending upon the business model for the network. In other words, if the City is both the infrastructure provider and the service provider (retail model), then the City incurs the entire incremental subscriber cost. On the other hand, if the City is only the backbone infrastructure provider, with third party competitive providers offering services to the customers (wholesale model), then the City would incur a smaller share of the incremental subscriber costs.

For a PON network, per subscriber costs include materials and labor relating to:

- Core OLT equipment at the hub ($156 per subscriber)
- Central or distributed telephone system hardware ($25 per subscriber)
- Optical splitters
- Subscriber drops
- Subscriber inside wiring
- Customer premises equipment (CPE)

The total estimated per subscriber incremental cost for these components in a PON network is approximately $1,550 in a network with voice, video and data services (including $156 per subscriber for incremental network transport electronics identified in Section 6.2.2). Of this cost, the City would only incur approximately $530 in a wholesale model.

For a Home Run Ethernet network, per subscriber costs include materials and labor relating to:

- Core network transport/switching equipment at the hub ($103 per subscriber)
- Central or distributed telephone system hardware ($25 per subscriber)
- Optical splitters
- Subscriber drops
- Subscriber inside wiring
- Customer premises equipment (CPE)

The total estimated per subscriber incremental cost for these components in a home run network is approximately $1,650 in a network with voice, video and data services. Of this cost, the City would only incur approximately $540 in a wholesale model.

In both the PON and Home Run wholesale models, the provider would be responsible for the CPE, which is the majority of the per subscriber costs. CPE equipment costs may vary depending on the equipment chosen and the equipment contracts negotiated between the provider and the manufacturer. Companies with large FTTP deployments, such as Verizon, have been able to reduce their per subscriber costs by negotiating lower equipment pricing with vendors.

6.5 Summary of Cost Estimates

The following summarizes and compares the costs presented for the FTTP design models presented in the previous sections.

Table 3: San Francisco FTTP Design Model Cost Summary

Cost Component	G/B-PON FTTP Network	Home Run Ethernet FTTP Network
Backbone Ring Fiber	$680,000	$680,000
Hub Fiber Infrastructure	$4.1 million	$33.9 million
Aerial Distribution Network Fiber Plant	$41.7 million	$41.9 million
Underground Distribution Network Fiber Plant	$279 million	$327 million
Hub Network Transport Equipment	$8 million	$17.9 million
Headend and Hub Facility Costs (fixed)	$21.4 million	$34.8 million
Total Implementation Fixed Costs Subtotal	**$355 million**	**$455 million**
Wholesale Cost Model		
Per Subscriber Costs/ Total for 200,000 subs (Section 6.4)	$530/ $106 million	$540/ $108 million
Total Implementation Cost for 200,000 subs	**$461 million**	**$563 million**
Retail Cost Model		
Per Subscriber Costs/ Total for 200,000 subs (Section 6.4)	$1,550/ $310 million	$1,650 / $330 million
Additional Headend Video System Costs	$7.5 million	$7.5 million
Total Implementation Cost for 200,000 subs	**$673 million**	**$793 million**

6.5.1 Potential Cost Savings through Collaboration of Coordination

The table below defines potential cost savings using partnership-based approaches and coordination of this project with planned Citywide projects. The figures are ball park estimates only. These estimates look only at potential cost efficiencies and make no assessment regarding the likelihood that the necessary level of cooperation would take place, or whether private entities would find cooperation with City to be in their interests. For example, scenario two assumes an unprecedented level of cooperation between the City and incumbent investor owned utilities, under which the provider would voluntarily give access to their underground conduit for free. The actual cost savings can be determined through further discussions with potential partners and an in-depth analysis of their contribution to the project.

Table 4: Potential Cost Savings Through Collaboration of Coordination

Scenerio	Estimated Cost Savings ($000)			
	B/G-PON FTTP		Ethernet FTTP	
	Low	High	Low	High
1. Use Existing Unconditioned Conduit	2,790	5,580	3,270	6,540
2. Share Conduit with Existing Provider	83,700	125,550	98,100	147,150
3. Coordinate with Sidewalk Rebuild	0	22,800	0	22,800
4. Coordinate with Another Utility Project	13,950	41,850	16,350	49,050

1) Scenario 1 assumes a savings of one to two percent
2) Scenario 2 assumes a savings of 30 to 45 percent
3) Scenario 3 assumes a savings of up to ten percent.
4) Scenario 4 assumes a savings of five to 15 percent.

7. Open Access Overview

This section defines "open access", and provides an overview of the relevant concepts as they pertain to the planning and implementation of an FTTP network. Further, this section describes candidate open access deployment models, and provides an analysis of the various FTTP technologies and fiber topologies relative to their impact to open access.

7.1 What is Open Access and Why is it Important?

In the formative days of the Internet, before the widespread deployment of broadband access networks such as cable modem, DSL and FTTP, dial-up modems were used to access the internet over telephone wires. Subscribers had open access to any ISP by simply using their computer's modem to dial the ISP of their choosing. The telephone companies (who owned the access network--the telephone wires and equipment in their offices) were not legally allowed to control/limit the flow of data communications traffic in any way, nor could they block or limit access to the phone lines of a particular ISP. This, in part allowed the Internet to grow into the indispensable information storehouse it is now, because both content creators and users were allowed unhindered connectivity.

Today, however, the vast arrays of multimedia applications that are accessible via the Internet have bandwidth requirements that far exceed the capabilities of a dial-up modem connection. Thus, individuals must utilize the higher capacity service offerings of the limited number of network operators that own, or have access to (in the case of some DSL providers), advanced communications infrastructure connected to their homes. However, it is impractical, and physically impossible, for numerous providers to build competing networks with separate physical infrastructure, as evidenced by the fact that very few markets can even support two cable television providers due to the cost of construction. Moreover, it is physically impossible for the public rights of way to support dozens of separate competing networks, although many more than two choices are typically necessary for true competition to exist in a marketplace.

However, in the same way that citizens and businesses alike have non-discriminatory access to roadways, communications infrastructure can be built and designed to allow access to multiple providers of services for each subscriber. Government can facilitate this process by laying the foundation for competition in the form of communications infrastructure, and allowing the free market to drive innovative service development and competitive pricing.

In the context of broadband services and in the most abstract sense, there are two distinct but interrelated perspectives on open access – the User Perspective and the Internet Service Provider (ISP) Perspective.

For the user, open access is the ability to access a service provider of choice; in an unconstrained, non-discriminatory manner; for telephony, cable television, and various

Internet services and content (for example, VoIP telephony, IPTV, email) without being restricted to the service provider affiliated with the broadband access network owner whose optical fiber arrives at the premises.

For the voice, data, and video service provider other than the broadband network provider, open access is the ability to obtain nondiscriminatory wholesale access to the broadband network owned by another entity in order to provide communications services to end-users physically connected to that network.

In order to satisfy both perspectives, a broadband access network should not only enable the network owner/operator (such as a municipal utility) to offer non-discriminatory access of its transmission services to ISPs but also enable the end users to freely select between multiple ISPs.

Figure 29 is a conceptual depiction of an open access capable network, and shows three service providers and three subscribers connected over a single open access capable network. The dashed colored lines between the service subscribers and service providers represent flexible logical connections over the physical broadband access network. There are two major segments to these connections – the ISP to network operator segment (**S1** in Figure 29) and the network operator to subscriber segment (**S2** in Figure 29). The provider premises equipment is the point of interconnection between these two segments and the demarcation point between the service provider and access network operator. The flexibility of this equipment determines how simple or complicated it is to implement open access.

The manner in which these two segments are implemented depends on the technology selected and the operational procedures established by the access network operator. The ISP-to-network operator segment could be over the Internet, as shown in Figure 29, or over a high-speed connection on another metro-network operator. Alternatively, the ISP could be required to co-locate some transport equipment in the provider premises. The network operator-to-subscriber segment is the responsibility of the access network operator, and could be provided using G-PON, Active Ethernet, E-PON, or another active access technology.

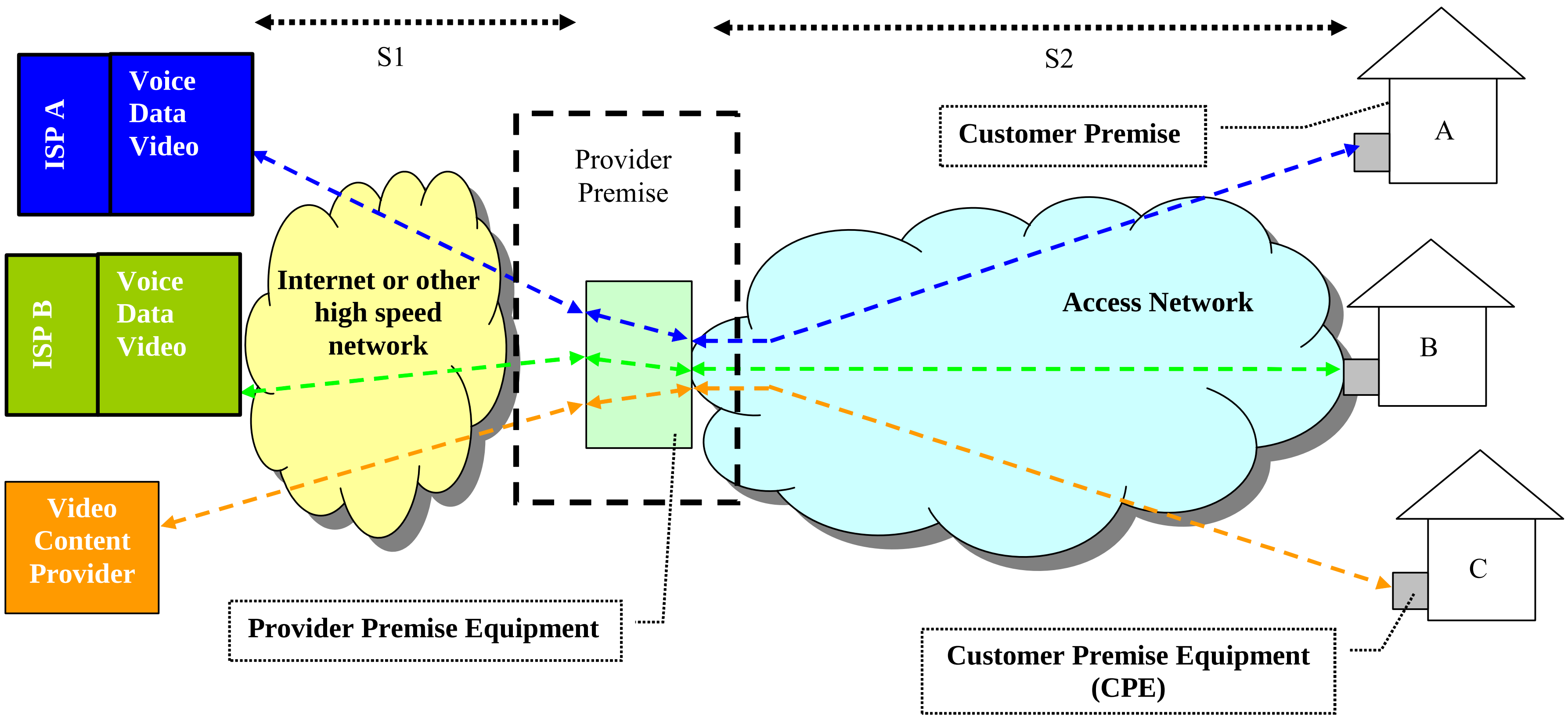


Figure 29: Example of Open Access to a Selection of ISPs

In the example in Figure 29, each user connected to the access network has a choice of three distinct service providers and can freely select which one to use. The access network operator owns the access network consisting of the provider premises equipment, the outside plant network and electronics, and possibly the CPE at the customer premises, and provides transmission services over this infrastructure at wholesale rates to the service providers. The service providers could offer a bundle of services including telephony, TV, and Internet access or may only provide one or two of these. In this example, two of the service providers offer a triple-play bundle of services while the third one is exclusively a video content provider. Similarly, the subscribers could select one service provider to get all three services, or pick services from different service providers. In this example, subscribers A and B obtain services from ISP A and ISP B respectively. Subscriber C, however, only obtains video services from the third provider. Subscriber C could obtain other services elsewhere (such as over wireline phone from the local telephone operator).

The fees for services on an open access network could be structured in different ways but two major components can be identified – the access fees (for the access network connection to the subscribers) and the service fees. These two components could be payable separately to the access network operator and the service provider or it could be collected by one entity and shared between the service provider and access network operator to simplify customer billing.

A very different, but possible alternative to segment **S2** is unlit fiber. In this option, the access network operator deploys the passive point-to-point optical fiber infrastructure between the provider premises and the subscriber home and manages the provider premises buildings. Service providers lease space in the provider premises and passive fiber infrastructure to connect to subscribers that select them. The access network operator could deploy manual optical fiber patch panels or a reconfigurable optical cross-connect to interconnect the service provider equipment to the subscriber fiber. The service providers could deploy the technology of their choice (such as Ethernet switches) at the provider premises, both to connect back to the service provider and to directly connect to customers.

In this mode of operation the access network provider is somewhat similar to a dark fiber provider with the primary difference that the dark fiber lease terms would be very different. The service provider would be required to relinquish connection as soon as the subscriber wants to terminate service or switch to another service provider. Potential complications of this alternative include:

- Potentially very operationally intensive service provider switchover procedure requiring manual reconnection at the fiber patch panel;
- Service provider specific CPE at the customer premises requiring time consuming and expensive manual replacement each time a service provider is switched; and
- Service provider equipment would need to terminate a large number of subscriber optical fiber.

Open access can be achieved by appropriately engineering the access network. There are various technological alternatives for enabling open access.

7.2 Alternatives for Open Access

Open access can be service specific and implemented at various network layers.

7.2.1 Open access at What Network Layer?

One can contemplate providing open access capability at different network "layers". Thus open access could be provided at the supporting infrastructure (Layer 0), physical transmission medium (Layer 1), data-link (Layer 2), or network (Layer 3) layers. Table 5 summarizes these alternatives.

Open access at the supporting infrastructure level entails the Access Network Provider owning the physical infrastructure supporting fiber construction, such as conduit and utility poles, provide access to these resources on a nondiscriminatory basis so that other entities can deploy the transmission media (twisted-pair cable, coaxial cable, or optical fiber) and end electronics required to establish broadband communications. This type of open access is not practical on a large scale, and only mentioned briefly for completeness.

Physical layer open access is achieved by deploying (and owning) the transmission medium (optical fiber) and hub facilities necessary for communications, and making it available on a nondiscriminatory basis to other entities that provide the end electronics (CPE and central office equipment) required to establish broadband communications. All electronic hardware required to enable communications would be the responsibility of the service provider. Although feasible, this type of open access has many operational complexities that would make it less attractive to potential service providers of certain types.

In Layer 2 and Layer 3 open access, both the transmission medium and the end electronics required to establish broadband communications would be owned and operated by the access network operator, and its use would be open to other entities on a nondiscriminatory basis. The service providers would have to deploy equipment locally (or remotely) to offer services at network Layer 2 or Layer 3. Open access is deemed to be at Layer 2 if technologies such as ATM or Ethernet are used to interconnect the access network operator and service provider networks such that Layer 2 addresses (MAC address) are used to identify users and segment the services. If this is done with network layer technology, such as Internet Protocol (IP), we have open access at Layer 3.

Table 5 summarizes these alternatives.

Table 5: Open Access Alternatives

Open Access Layer	**Network Operator** (Open access provider)	**Service Provider** (Open access user)
Infrastructure	Owns conduits, poles, collocation space	Deploys transmission infrastructure including medium and end electronics as well as all other higher layer processes required to provide service
Physical	Owns transmission infrastructure and hub facilities	Deploys end electronics and other higher layer processes required to provide service
Data Link	Owns electronics and offers ATM or Ethernet services	Interconnects with ATM or Ethernet and deploys other higher layer processes required to provide service
Network	Owns electronics and offers IP interconnection	Interconnects with IP and deploys other higher layer processes required to provide service

The depth of ownership (such as, for example, infrastructure only or infrastructure and physical) determines the complexity of the network and operations of the access network operator and the level of investment required to achieve open access.

Ethernet and ATM are the predominant Layer 2 technologies. Although both these technologies operate at the data link layer and provide basically the same fundamental communications functions each has its strengths and weaknesses.

7.2.1.1 Ethernet Layer 2 Open Access

Ethernet started as a LAN technology and gradually became the technology of choice in enterprise networks because of its cost effectiveness and ease of use. As its popularity grew, it became prudent to support Ethernet in its “native” format over the access, metropolitan, and core networks. Ethernet began as a LAN technology designed to support “best-effort” services in a small localized network—as a result, it did not initially have the requisite management and QoS capabilities (which contributed to its ease of use, low cost, and in turn, its popularity). As Ethernet grew into more intensive and long distance applications, these capabilities became important and were added incrementally with various extensions to the relevant standards on an as-needed basis.

Ethernet services are supported on an Ethernet-based network built with operator owned Ethernet switches located at the operator premises and VLAN-aware Ethernet CPEs deployed at the customer location. The Ethernet switches could either be connected with dedicated point-to-point (Home Run) fiber, with shared point-to-multipoint fiber, or over an active Ethernet distribution network. Basic Ethernet was extended in IEEE 802.1Q to allow VLAN tags, which are attached the basic data frame and used by the Ethernet switch to identify VLAN membership. VLANs can be used to support open access.

Customers and service providers can be managed by assigning them to separate virtual LANs (VLANs), either based on the switch port or on the CPE MAC address. Connectivity is established between the subscriber and his selected service provider by correctly mapping the subscriber VLAN to the service provider VLAN at the operator Ethernet switch.

Figure 30 shows a conceptual representation of an Ethernet based Layer 2 open access capable network. In this example, subscribers ***a1*** and ***a2*** are assigned to unique VLANs ***a1*** and VLAN ***a2*** by the access network operator. Both these subscribers happen to select ISP A that is assigned to VLAN A. Subscriber ***a1*** and ***a2*** gain access to their choice of ISP, because the operator's Ethernet switch maps both VLAN ***a1*** and VLAN ***a2*** to VLAN A. ISP A only requires a single physical connection to the provider switch. This connection could be using direct optical Ethernet connection to the ISP switch or over a leased connection on the metropolitan or even long haul network of a third network operator. Multiple subscribers can be segregated on this single connection using VLAN tags. Packets arriving at the provider Ethernet switch are directed to the correct subscriber based on the customer VLAN tags. Subscribers can be moved to another ISP by merely reassigning the VLAN tags at the operator Ethernet Switch.

Various services going to the same users can also be segregated using different VLANs. Services need to be segregated in this manner in Ethernet so that each service can be treated differently to provide QoS adequate for the service. In addition, IEEE 802.1p allows separating Ethernet frames into eight different priority categories. Each category could be processed differently in the Ethernet switches, thereby providing some level of QoS support.

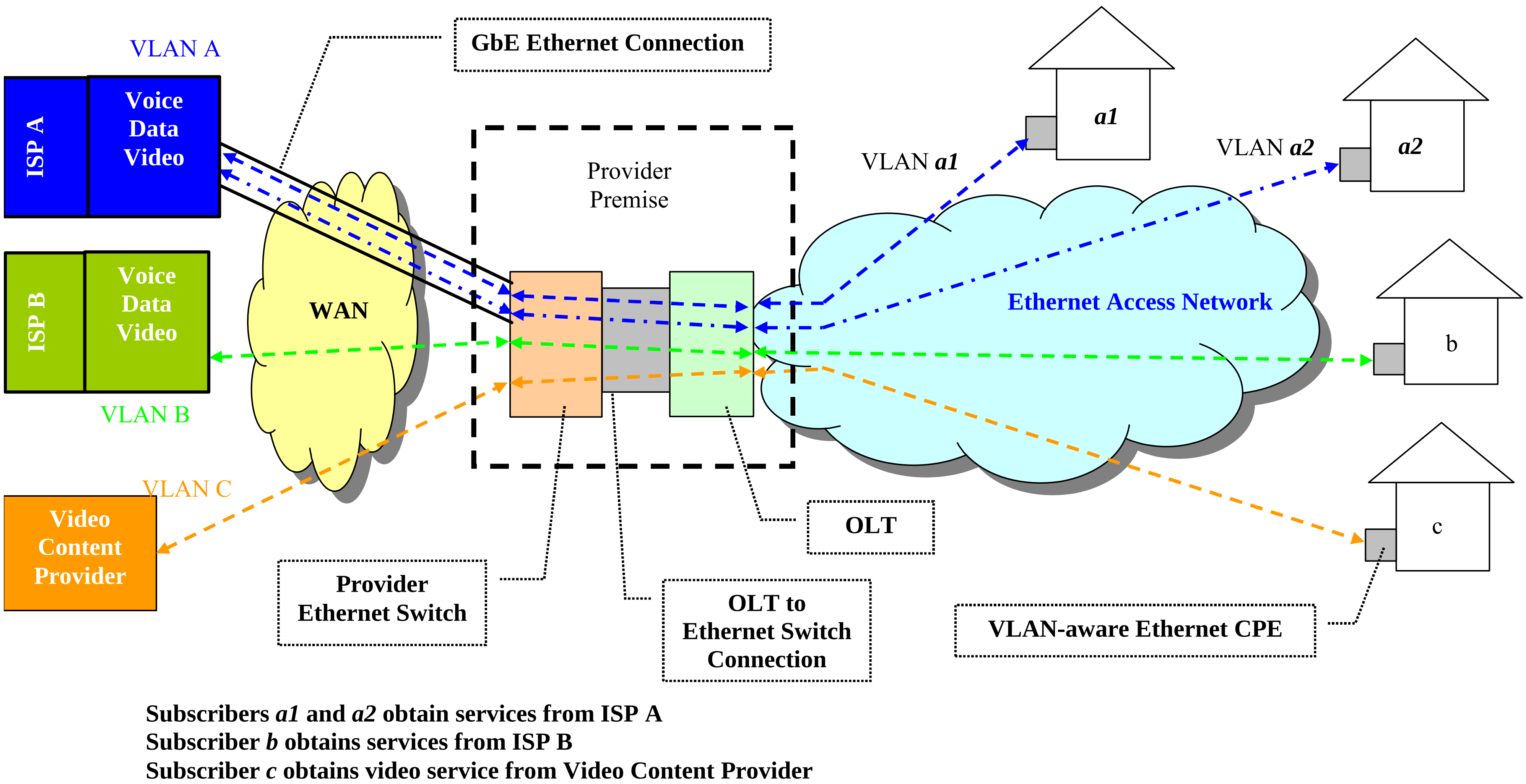


Figure 30: Layer 2 Ethernet Open Access to a Selection of ISPs

7.2.1.2 ATM Layer 2 Open Access

ATM technologies were architected with well defined QoS mechanisms and hence can readily support the bandwidth, latency, and packet loss requirements of voice, data, and video services. ATM breaks down information into fixed size bundles called cells to facilitate processing in hardware. In addition to the data payload, ATM cells include header information to define logical connections, and make it efficient to switch the cells in electronic hardware. ATM cells also contain various other indicators that identify the QoS class so that each service gets the required QoS, thus improving network performance for specific applications or users. Further, ATM has well-defined management processes to manage the network elements, users, and traffic. In spite of its technological features, ATM has not gained momentum in the market place due to its cost and complicated set up. It was originally developed as a core network technology, was expensive, and not able to penetrate into the access network. However, various aspects of ATM are used today in B-PON and G-PON.

In an ATM-based link layer network, subscribers are assigned individual Permanent Virtual Circuits (PVCs), which are logical connections between the provider ATM switch and CPE. Open access is provided by switching the subscriber PVC to the subscriber selected service provider. As ATM is the underlying technology, QoS processes are well defined and services can be supported with quantifiable QoS.

Figure 31 depicts the hardware and logical connections that could be used in an ATM-based open access capable network. The provider ATM switch is the central interconnection point for multiple ISPs. Each subscriber gets a PVC from the provider switch to CPE. Similarly, each ISP is assigned a PVC from the provider switch to the ISP ATM switch or ATM-capable router. The provider ATM switch provides the flexibility required for open access. For open access, the subscriber PVC can be mapped to the user-selected ISP PVC at the provider ATM switch. When all services are contracted from a single ISP, the complete subscriber bandwidth is mapped to the selected ISP, as shown in the example of Figure 31 for subscribers ***a1***, ***a2,*** and ***b***.

PVCs may be further partitioned into more granular ATM virtual channels (VC) that carry different services. Each VC can be individually provisioned with a different ATM class of service to support the QoS required by the service carried on it.

Similar bandwidth partitioning can also be used to support open access at the individual service level. In the example of Figure 31, subscriber ***c*** elects to obtain video content from one provider while she elects to obtain data and voice service from ISP B. ATM VCs are provisioned to segregate traffic based on service and ISP. The VC supporting video service is switched to the selected Video Content Provider at the provider ATM switch while the data and voice VCs are switched to ISP B. ATM allows this type of very flexible open access while also supporting hard SLAs and QoS on a service-by-service basis.

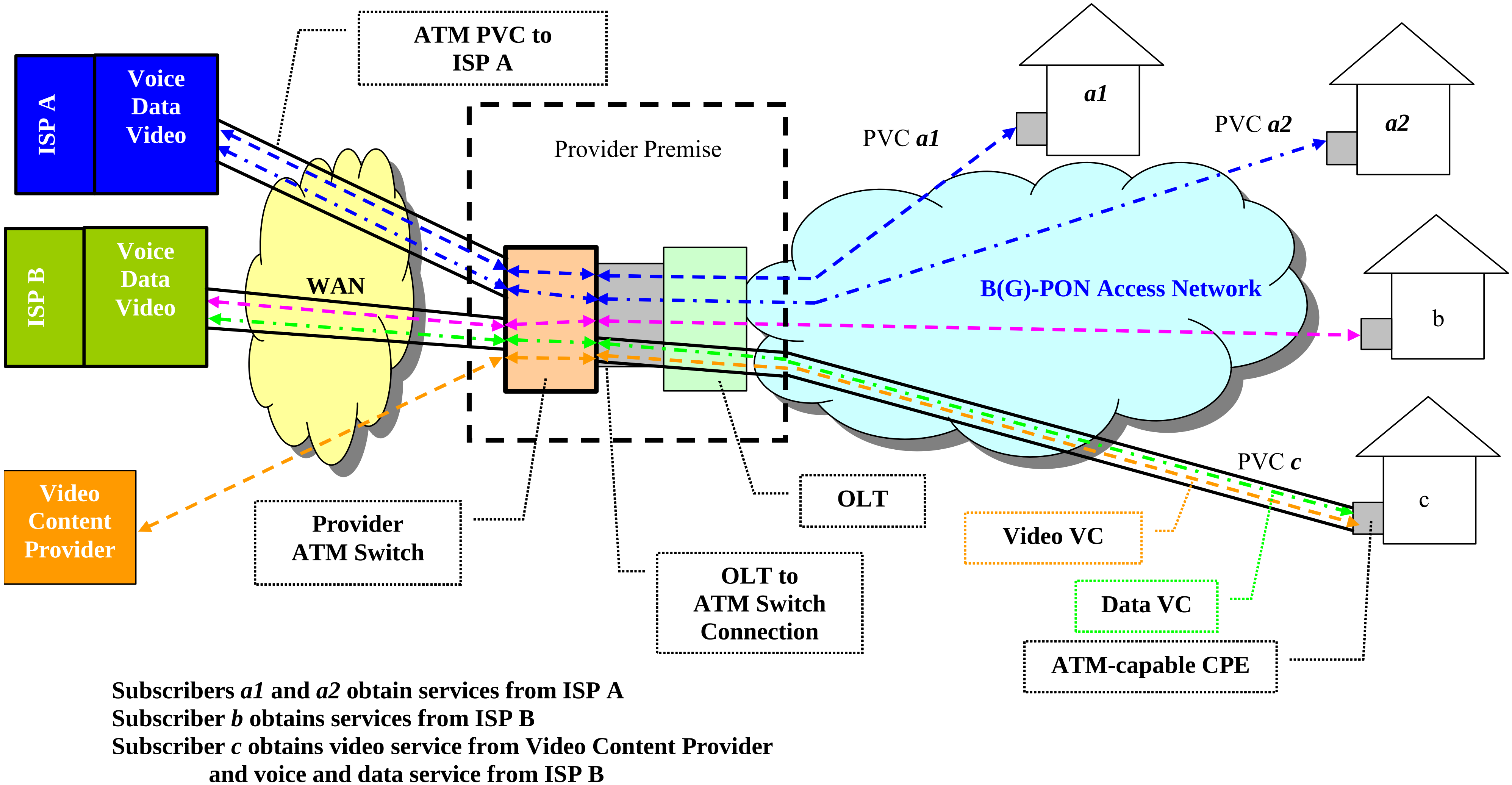


Figure 31: Layer 2 ATM Open Access to a Selection of ISPs

7.2.1.3 Layer 3 Open Access

Layer three open access is typically provided using IP technologies. To support Layer 3 services and open access, the network operator and the service providers need to cooperate on packet routing. The IP router hardware in the network operator and service provider networks usually act as peers for routing purposes. Layer 3 open access is not dependent on the Layer 2 encapsulation or the Layer 1 infrastructure used to support transmission. Using packet over SONET (POS) encapsulation over E1/T1 lines is common, however, IP over ATM, IP over Ethernet, and IP over Frame Relay are also options. IP has become the dominant Layer 3 networking technology and it is continually evolving and its capabilities are being enhanced. However, it has its own strengths and limitations.

IP bandwidth utilization (the fraction of the deployed transmission bandwidth that is actually being used to carry traffic) must be kept low; typically less than thirty percent; for an IP network to achieve adequate QoS. (As a comparison, in ATM up to eighty percent utilization can be reached because it has explicit QoS support.) For the service provider, lack of explicit QoS support in IP makes committing to a strict SLA difficult despite the presence of some IP QoS features. On the network management side, Simple Network Management Protocol (SNMP)-based OAM tools are frequently used to manage IP networks. These tools typically support network monitoring, performance measurement, statistics, and network or route discovery, however, service provisioning is not generally supported.

In IP networks, data security can be provided in a standards-based manner using IPSec for encrypted VPN support. There are two modes of operation supported in IPSec. The tunnel mode uses point-to-point tunnels between customer devices to achieve secure communication over the Internet. The transport mode provides secure communications within IP networks.

IP rerouting mechanisms indirectly provide resilience. However, due to poor convergence times, protocols such as OSPF, Routing Information Protocol (RIP), and Border Gateway Protocol (BGP) cannot be relied upon to deliver strict SLAs on recovery times.

Figure 32 depicts, conceptually, the hardware and logical connections that could be used in an IP-based open access capable network. The provider MPLS-capable router is the central interconnection point for multiple ISPs, and is also the service support point for the individual subscribers. Each subscriber is assigned a VPN from the provider router to CPE. Similarly, each ISP is assigned a MPLS LSP from the provider IP router to the ISP router. The provider IP router provides the flexibility required for open access. To enable open access, the subscriber VPN can be mapped to the user-selected ISP LSP at the provider router. When all services are contracted from a single ISP, the complete subscriber bandwidth is mapped to the selected ISP as shown in the example of Figure 32 for subscribers ***a1***, ***a2,*** and ***b***.

VPNs can also be used to support individual service level open access. In the example of Figure 32, subscriber ***c*** elects to obtain video content from one provider while she elects to obtain data and voice service from ISP B. VPNs are mapped to segregate traffic based on service and ISP. Traffic on the VPN supporting video service is routed to the selected Video Content Provider by the provider IP router, while the data and voice traffic are routed to ISP B. IP with MPLS allows this type of very flexible open access, however, supporting strict SLAs and QoS end-to-end (from the service provider to the end customer) and on a service-by-service basis is challenging. However, proprietary implementations might be able to provide this functionality in a non-standard basis.

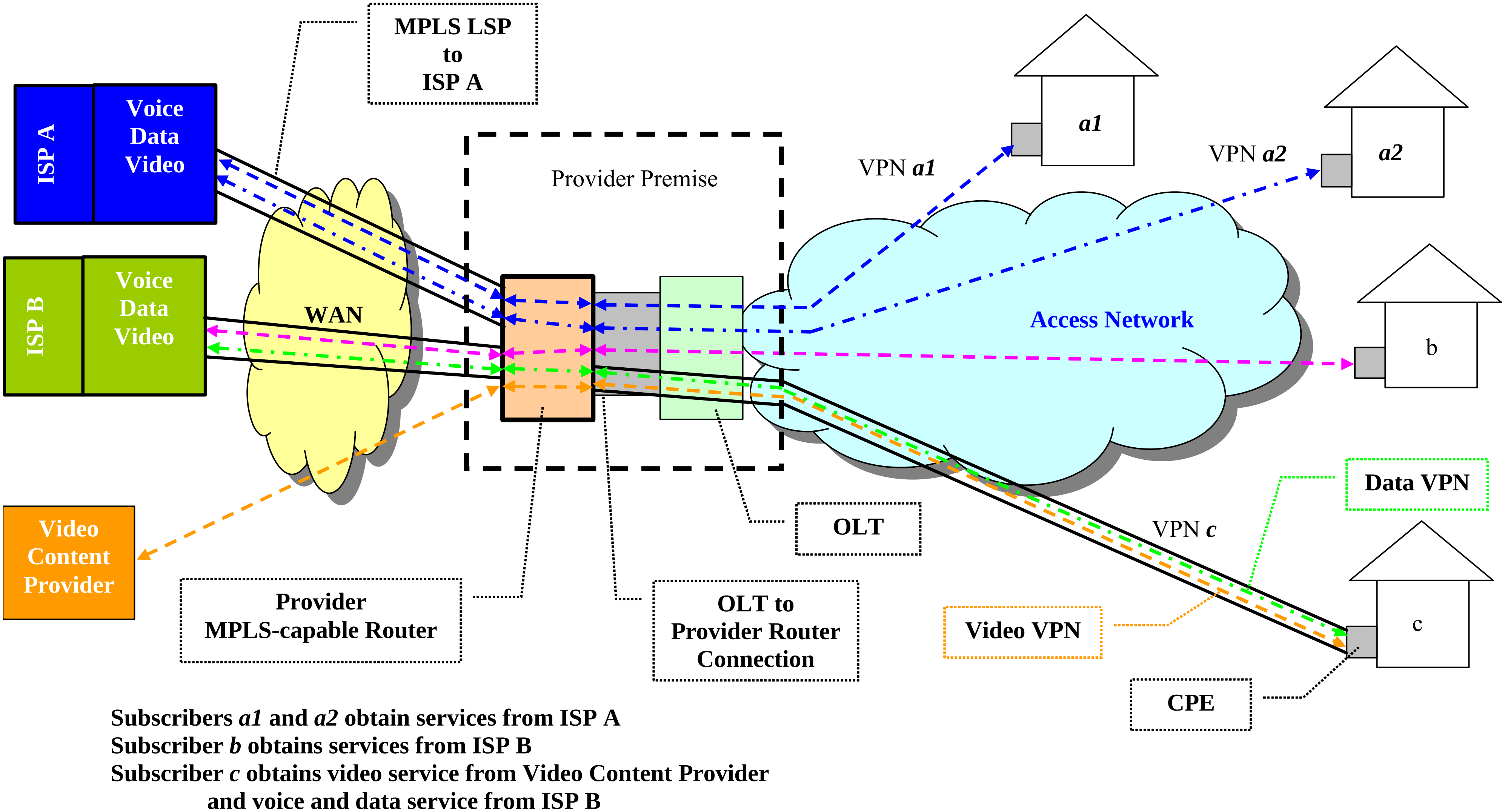


Figure 32: Layer 3 Open Access to a Selection of ISPs

7.2.2 Open Access to Which Services?

A previous section discussed how various services such as telephony, TV, and Internet access are supported over PON and Active Ethernet access networks. Open access could be enabled for all voice, data, and video, or a subset of these.

Data services are supported using IP and are most amenable to open access, because IP technologies operate at the network layer and by design provide the required flexibility. The Access Network Provider needs to provide connectivity from the subscriber CPE to the router of the selected ISP through its own router. The ISP router handles all aspects of Internet access. The Access Network Provider router separates the upstream (service provider side) and downstream (subscriber side) address spaces and also routes IP datagrams between the ISP and subscriber based on the subscriber selections. The Access Network Operator assigns an IP address to each of its subscribers to uniquely identify them in the IP address space so that downstream traffic reaches the correct subscriber. This address can also be used in source-based routing to direct upstream traffic to the correct subscriber-selected ISP. Once correct network layer connectivity is established between the subscriber and ISP in this manner other data applications such as email and web-hosting can be setup.

Voice and video content that are supported using IP (VoIP and IPTV) are carried like any other data stream and are supported in the same manner as data. However, data, voice, and video services have different bandwidth, latency, and packet loss requirements and each must be managed in a slightly different manner to provide adequate QoS. Priority queuing and QoS mechanisms have to be used to ensure that each service gets the requisite bandwidth and meets the service latency and packet loss requirements so that subscribers' expectation are met. This must be possible end-to-end from the service provider to the subscriber (Both segments **S1** and **S2** in Figure 29). The Access Network Provider is responsible for ensuring adequate performance in segment **S2** and the ISP is responsible for providing adequate performance in segment **S1**. It is best if bandwidth and QoS can be provisioned on a user-by-user basis and service-by-service basis. This capability allows each user and service to have its own bandwidth and QoS characteristics, which in turn would enable the service provider to better manage bandwidth and offer tiered services at different price points.

The type of access network deployed could restrict the types of services that may be supported in an open manner. For example, it is difficult to support multiple cable TV providers on a B-PON based video delivery system that relies on a single overlay wavelength to carry RF video to each subscriber. On the other hand, IPTV video delivery is more amenable to open access, because each user can be addressed individually and packetized content directed exclusively to the addressed user.

7.3 Open Access in FTTP Architectures

7.3.1 PON

PON access networks are open access capable and can allow access to multiple ISPs, alternate telephony providers, and multiple video content providers. PON can support open access at Layer 1, Layer 2, and Layer 3. Layer 2 and Layer 3 open access were depicted in Figure 30, Figure 31, and Figure 32. Ethernet-based PON deployments such as E-PON can be made open access capable at Layer 3 using IP as depicted in Figure 32, or at Layer 2 as depicted in Figure 30, independent of the ODN topology.

Non-Ethernet PON can also support open access at Layers 2 as depicted in Figure 31, or at Layer 3 using IP as depicted in Figure 32. B-PON and G-PON fall in this category, and predominantly utilize the shared configuration.

5.2.1 Home Run

A point-to-point Home Run fiber optic architecture is also amenable to Layer 1 open access as depicted in Figure 33. A dedicated fiber is connected to each subscriber who has to deploy a CPE dedicated to the ISP of his choice. The Access Network Provider does not deploy any communications electronics, but has to have a fiber management infrastructure that allows easy and flexible interconnection to alternative service providers. A fiber cross-connect could be used for this. Each service provider must collocate electronics at the provider premises. This equipment connects with multiple fibers and the Network Provider fiber cross-connect to the fibers to the subscribers. Thus, each subscriber can only connect to one service provider and is restricted to getting all services from that service provider. It is not possible to get different services from different service providers as in Layer 2 and Layer 3 open access. The service provider equipment aggregates traffic from each of its subscribers, and can carry them on logical connection to the rest of his network.

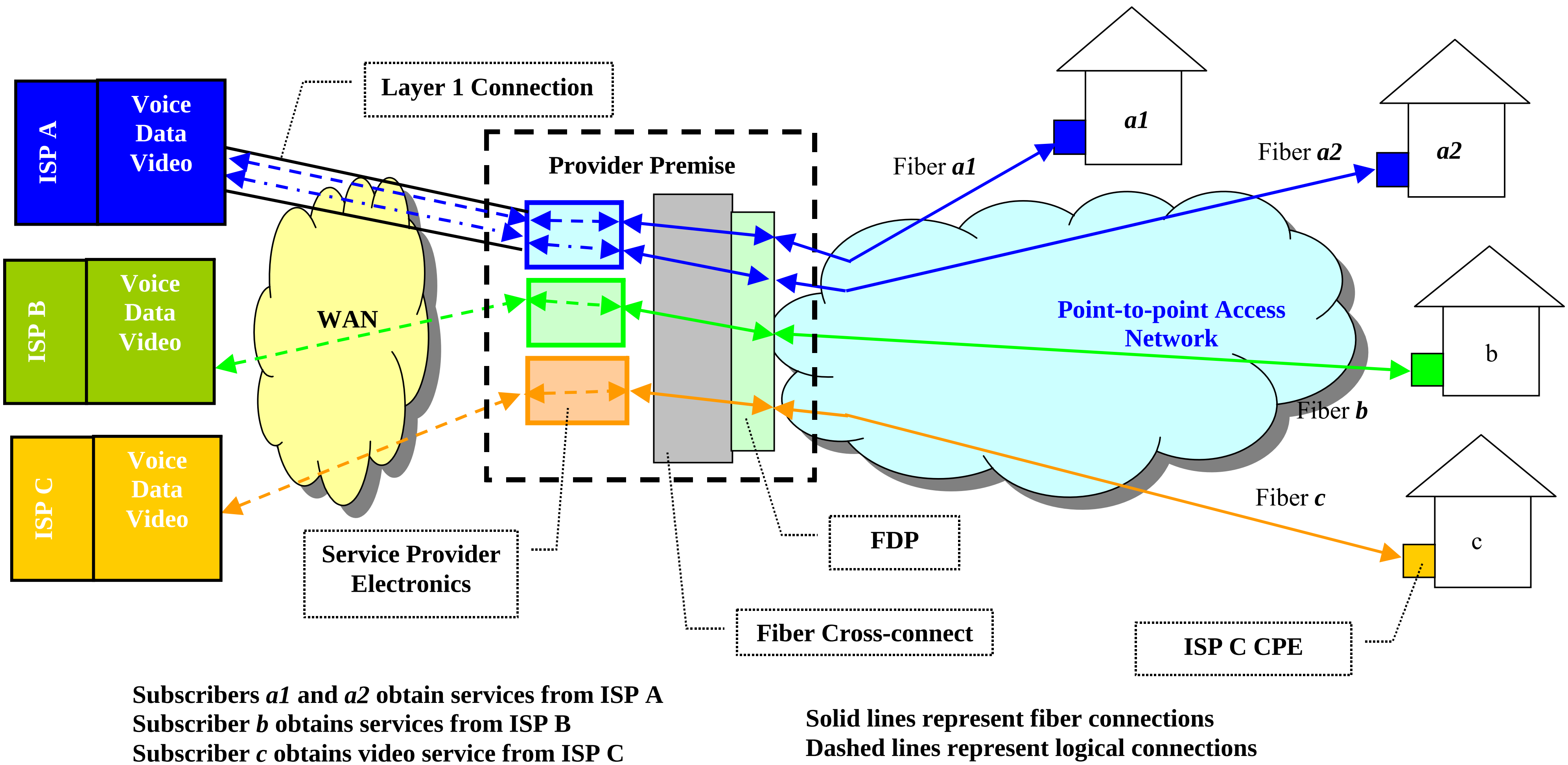


Figure 33: Layer 1 Open Access to a Selection of ISPs

Service providers are switched by reconfiguring the Network Provider optical cross-connect and swapping the CPE at the subscriber location. Although reconfiguring fibers could be simplified with the optical cross-connect, swapping CPE is labor intensive, time consuming, costly, and the responsibility of the service provider. Each service provider is free to use the technology of their choice, as long as transmission is possible over the fiber path deployed by the Network Provider.

7.3.2 Active Ethernet

Open access can be enabled in active Ethernet access networks at Layer 2 or Layer 3 in the same way as in PON. The only difference is that Ethernet switches are used in the distribution network as shown in Figure 16. The requirement for additional equipment in the distribution network makes active Ethernet less suitable for urban environments where cabinet space is typically at a premium.

7.4 Considerations for Open Access FTTP Network Selection

Open access can be provided with all major access network technologies. We recommend that a Home Run fiber topology be strongly considered due to its ability to offer open access at any network layer, and its ability to support nearly any network transport technology.

The selection of suitable topology and technology depends on deployment constraints, ease of use, scope of coverage, per subscriber bandwidth supported, performance considerations, and cost. The following should be considered while assessing technology and topology for an open access capable FTTP network:

- Flexibility and ease of adding new service providers
- Value to subscribers of ability to pick different service providers for different services
- Speed and ease of switching between service providers
- Per user bandwidth supportable
- Support of QoS
- Maturity, level of deployment, and level of standardization of technology
- Level of manual operations in switching service providers
- Minimize number of fibers that need to be terminated
- Presence of electronic hardware in the outside plant
- Network operations cost
- Billing and customer support procedures
- Network maintenance and repair procedures

Table 6 qualitatively compares some of these attributes for two implementation choices – Shared B(G)-PON technology with open access supported at Layer 2 and Home Run Ethernet technology and open access provided at Layer 2.

Table 6: Access Network Solution Comparison

Attribute	Access Network Technology	
	B(G)-PON	**Home Run Ethernet**
Flexibility and ease of adding new service providers	Good	Good
Ability to pick different service providers for different services	Yes	Yes
Speed and ease of switching between service providers	Good	Good
Per user bandwidth supportable	Medium	High
Support of QoS	Good	Not as Good
Maturity and level of standardization	New but more comprehensive standards	Older but some key functions still being standardized
Level of manual operations in switching service providers	Minimal	Minimal
Level of deployment	Being deployed extensively in the US	Being deployed extensively internationally
Number of fibers that need to be terminated	One per 32 or 64 subscribers	One per subscriber
Electronic hardware in the outside plant	None	None

8. Internal Network Business Case

The City-owned internal network proposed here expands the reach of the City's fiber assets and provides an opportunity to upgrade City capacity beyond the T1 circuits currently used to connect many public locations. CTC's needs assessment and analysis demonstrates that many City agencies are concerned by the cost of leasing T1 circuits—but even more so by concerns that the leased circuits are limited in performance and capacity and that these limitations constrain the City's capability to meets its own needs for applications and data exchange in support of day-to-day operations.

City-owned fiber is already proven to offer enormous benefits over leased services. The City College, for example, operates a fiber ring that was constructed by DTIS. According to City College Information Technology Director, Tim Ryan, the College has demonstrated the following benefits from its fiber optic network:

- Reduced cost relative to leased T1 circuits
- Reduced network complexity
- Increased reliability (prior to fiber, City College had two T1 links that were unreliable)
- Scalability of bandwidth for the future
- Carriage of the VoIP phone system

8.1 The Cost Benefits of a City-Owned Network

Comparing the cost between a leased service and a City-owned and operated network is not trivial, as it requires making certain assumptions regarding future requirements and/or future costs of leased services. Fortunately, City-owned infrastructure costs, including both hardware and physical fiber plant, remain relatively constant with respect to initial and ongoing expenses (though their capabilities increase with time).

What is also clear is that the cost of needed leased services will increase dramatically with time—because the City's communications needs will grow dramatically (the institutional needs assessment above demonstrates that the available connectivity options are not meeting even today's needs) and because there is little competition for such services.

The functional demands of public safety applications alone weigh strongly against the use of leased services, regardless of cost. Taking cost into account, however, a City-owned fiber infrastructure is the most cost-effective approach for meeting internal City networking needs in the long-term.

CTC estimates that the approximate cost to construct a backbone City-owned institutional network through "conditioned" conduit would be $8.9 million ($5.4 million for fiber and

$3.5 million for electronics). Assuming savings of the bulk of the City's current annual lease expenditures of $2,524,000 to AT&T, we estimate that the City's fiber investment would be recouped in nine years.

If the fiber is deployed independent of the conditioned conduit, we estimate a cost of $15.8 million ($12.3 million for fiber and $3.5 million for electronics). Based on savings on current expenses, we estimate that the City's fiber investment would be recouped in approximately 22 years.

It is important to note that these payback periods are conservatively based on current lease levels and costs -- which are guaranteed to grow. In contrast to leased circuits, City-owned fiber can be upgraded to higher capacity at no increase in recurring costs. The City's fiber offers capabilities that leased circuits cannot and enhances the City's ability to innovate and grow with new applications. And, significantly, the City's owned fiber does not entail recurring costs for capacity *ad infinitum* as do leased services.

Another way of understanding the value of City-owned fiber is to compare its financed cost to the alternatives. Assuming the City financed the cost of building the network (financing the fiber over 20 years and the electronics over seven years), the annual principal and interest (P&I) payment would be $1.59 million. In addition to the P&I payment, we estimate the annual operations and maintenance costs at $1.05 million per year. This results in an average cost per month of $881 for each of the selected sites. By comparison, comparable functionality from leased services would cost far more than that amount. AT&T's higher-end leased offerings such as OC3 and OptiMAN can address these capacity issues, but the lease costs are prohibitive. For example, OptiMAN monthly lease fees can range above $10,000 per month for each circuit.

8.2 The Functional and Technical Benefits of a City-Owned Network

The majority of the City's communications networking needs are currently met through leases of circuits from AT&T. This approach has some benefits: for example, it does not require internal staff to operate and maintain the network; its upfront costs are lower than constructing City-owned fiber, and the time to deployment can be shorter. Leasing, however, has critical disadvantages that make it much less desirable than City-owned and operated fiber, particularly with respect to public safety and emergency support services. Specifically:

- The City does not have total control and management over the network
- The City may not be able to evaluate the reliability or availability of a leased circuit because it has no knowledge of AT&T's proprietary network and its physical infrastructure
- Leased services are not independent of the networks used by the public and are therefore less secure and reliable
- The City does not have control over network security between end points

Each of these items is addressed in detail below.

8.2.1 City-Owned Fiber Facilitates Control and Management

A network built upon leased network services obtained from a service provider cannot provide the control and management that is available in a City-owned and operated network.

Leased network services are in essence a “black box” in terms of control and management. The City is forced to rely on the provider (usually the phone company) to maintain and operate the core equipment of a leased service (these tasks include configuring the equipment, monitoring the hardware and physical infrastructure, and performing routine maintenance).

San Francisco’s internal capacity requirements include video, voice, and data communications. Both voice and video services usually require dedicated bandwidth. Two-way voice and video services require dedicated bandwidth and very predictable transmission delay properties.

In other words, linking two-way radio communications systems or supporting videoconferencing over IP or using TDM connections requires the ability to manage bandwidth across the entire network. Although this functionality can be provisioned on the edge device when using a managed service provider for connectivity, if the City owns and operates its own fiber network, it will have control and capability to increase bandwidth based on the City’s time frame (which will in turn allow the City to properly plan for integration of new applications without an increase in cost for provisioning of new bandwidth). Further, it offers the ability to implement advanced Quality of Service mechanisms that are enforced on a network-wide, end-to-end basis.

Under the leased model, the City must request (and pay for) AT&T to make changes in the core of the network for a new application, increase bandwidth, or to implement new policies for enhanced Quality of Service.

Under the leased model, the City is also not able to control who manages and maintains the core of the network. The knowledge, skill set, and security background of those operating the network is often beyond the control of the City.

With a private fiber optic network, each piece of the communications network is controlled and managed by the City. The City may choose to operate the network on its own with its own staff, or it may outsource the operations to a contractor of its choosing. Either way, choices regarding the management of the network are in the hands of the City—not the phone company.

8.2.2 City-Owned Fiber Facilitates Availability and Reliability

The availability of a communications link is derived from the probability of a failure within the network between two points. In a leased circuit network, the end user is not aware of all of the potential risks to availability of the network. Several key factors that affect availability and cannot be determined by the City include:

- Physical redundancy in the plant;
- Physical redundancy in the building entrances;
- Physical redundancy in the networking equipment;
- Ensuring network equipment is properly configured and regularly tested to take advantage of hardware and link redundancy;
- Redundancy for power and HVAC;
- How many facilities the circuit crosses between endpoints;
- Whether the plant is located underground or aerial;
- Who has access to the core networking equipment and plant;
- How old or well maintained the core equipment is;
- How the system is monitored and maintained; and
- The single points of failure in the communications link.

Many of the factors can be approximated or relative numbers may be obtained from the leased circuit provider; however for critical government services such as public safety, the approximations and availability estimates from leased network services may not meet the availability requirements of a critical traffic network. In the case of physical architecture issues, such as the physical routes of cabling, approximations are not sufficient, and detailed maps are usually considered proprietary and confidential to a commercial provider such as AT&T.

In addition, lessees such as San Francisco are subject to the lessor's schedule for repair and maintenance of the circuit. Although it may be possible to include provisions in the service level agreement (SLA) for special priority service restoration, it is unlikely that SLAs will be adhered to during major disaster events. Further, there may be no way to ensure that a leased circuit for public safety is the first link to be repaired during a major disaster.

A similar problem can arise in both scheduled and unscheduled maintenance of a leased circuit. The timing of these maintenance downtimes may not correspond to available downtimes in a public safety network. In a City-owned fiber network, maintenance downtimes can be coordinated to minimize downtime and the City can prepare for an outage by adapting operational procedures.

SLAs often guarantee availability and repair time, but typically are not reliable in the event of a major disaster. In addition, service providers usually rely on cash rebates to compensate for network outages to the network—an unacceptable solution in the case of public safety, where cash cannot compensate for lost service.

8.2.3 City-Owned Fiber Offers Independence from Public Networks

A privately owned communications network does not rely on physical infrastructure, equipment, or other resources that also carry public traffic for residents and businesses. Shared resources are used by a managed network service provider to reduce their cost by taking advantage of the statistical nature of communications traffic. In other words, commercial carriers intentionally oversubscribe their networks to minimize costs (maximize profits), because all of their customers are not likely (statistically speaking) to simultaneously use their services to full capacity all of the time. The advantage of an independent network is that increases in public traffic on the network or public network outages do not affect privately owned networks.

Additionally, the only way to ensure that there is adequate bandwidth is to overbuild a network to support maximum capacity demand, not average utilization (while absorbing the cost even if the bandwidth is not used). Some leased managed services will charge only for the bandwidth that is used -- but capacity is limited. Typically, these services are only cost-effective when institutions have a specific understanding of their applications' bandwidth requirements. A City-owned fiber network will provide a more reliable, higher capacity, flexible network infrastructure because it is designed to support a broad range of initiatives and to easily and seamlessly scale to meet new bandwidth requirements.

As is the case in many major public safety incidents, public networks such as the Public Switched Telephone Network (PSTN) and the Internet are often overloaded by the amount of traffic on the network. This can lead to busy signals on the PSTN and a lack of connectivity on the Internet. Privately owned networks typically do not experience the same traffic increases and can be designed to handle any expected traffic increase during a major incident.

Many public networks are in the planning and early implementation stages of providing priority and preemption capabilities for most managed service providers and will not be universally available, however in the event of a crisis, priority and preemption is critical for public safety networks.

A City-owned fiber network can prioritize bandwidth both in the core and at the edge. This capability allows the City to prioritize by location and to preempt all traffic other than public safety traffic, if necessary. More importantly, the City-owned infrastructure can be allocated so that sensitive traffic always has dedicated capacity, because capacity can be readily scaled as needed for other applications.

8.2.4 City-Owned Fiber Enables Control Over Network Security

Implementation of network security on a leased circuit typically occurs at the edge of the network. Many leased networks use end-to-end encryption to securely transmit data over networks that share a core network with public users. Frequently, the provider of a leased circuit (such as AT&T) may dictate what types of end-to-end security are allowed on a leased circuit (IP managed services, for example).

On a City-owned fiber network, the City can control end-to-end security throughout the network infrastructure. The City can offer layered that makes the network robust and secure.

In addition to data security, a City-owned network allows the City to manage physical security as well as network security. This includes:

- Access to facilities and networking rooms
- Passwords to edge equipment and firewalls
- Network access and authentication
- Monitoring of networking rooms, including security alarms, surveillance cameras, etc.
- Desktop security
- Equipment placement and provisioning

9. The Existing Broadband Landscape in San Francisco

This Section of the Report provides a brief overview of the existing broadband landscape in the City and County, including announced future projects and deployments, and evaluates the reach and capability of existing and planned private-sector broadband infrastructure and services.

9.1 User Groups

Our experience and review of market research conducted for other projects have identified distinct groups among users. Figure 34 shows four regions of users.

A. In region “A,” users see limited value in high-speed connectivity services. This region consists of dial-up users. These users may benefit from a wireless alternative because they would be able to experience a high-speed alternative priced competitively with a dial-up service.

B. Cable modem, DSL, and other small business and residential broadband users tend to reside in region “B.” Many of these users are generally satisfied with their level of connectivity today. However, as more and more business transactions and voice and video IP applications mature, these users will demand higher performance. Significantly, there is already considerable discontent among small businesses with the available options for high-speed bandwidth.

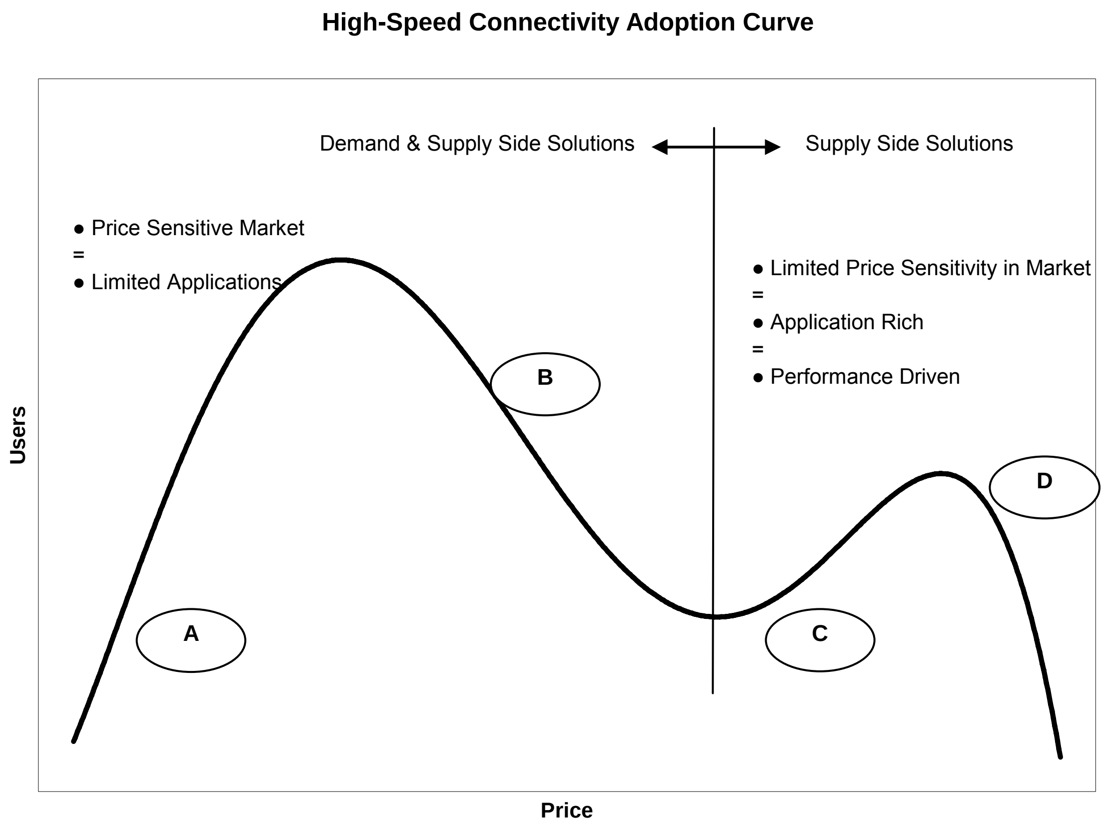
C. Medium data use businesses that use Internet beyond email tend to reside in region “C.” These businesses use connectivity services that have a higher performance than DSL or cable modems (T1 and other). These users are often frustrated with the capacity of the alternatives and the level of service they receive from the providers. In San Francisco these users do have a higher capacity alternative available, but at a cost that can approach $10,000 to $20,000 per month per location.

D. High-end data use businesses tend to reside in region “D.” Users in this region select the service based on performance and reliability. Price, although a concern, has minimal effect on the purchase decision. These users are relatively few, and are the market that AT&T is targeting with their OptiMAN service.

The peak of each curve represents the condition (price compared to perceived value) at which the supply/demand equilibrium is maximized.

In region "B," the perception is that the value of high-speed services is lower than the price offered by the provider. This condition is a "demand gap." Increasing the number of users can be achieved by either lowering the price (movement along the curve) or increasing the perceived value of the services offered. For this user group, concentration on increasing the perceived value, or demand management, will shift the curve to the right.

Figure 34: High-Speed Connectivity Adoption Curve



The business users in region "C" desire increased performance (bandwidth, reliability, customer service, and so on). Smaller businesses that do not have full-time Information Technology (IT) staff are frustrated with the providers' technical support. The providers' technical support tends to assume that their customers have a high-level technical knowledge. Given this, concentration on supply side strategies to improve service performance is the most appropriate approach for this group. Supply side strategies tend to shift the curve upward.

9.2 Broadband Market Patterns in San Francisco

The latest market research that we were able to locate with San Francisco specific data was concluded in late 2003 and early 2004. This study, which was released in March

2004, was developed by comScore Networks with respect to the entire San Francisco Bay Area, not just the City.

The study indicated that, at that time, the San Francisco Bay area ranked ninth in the country in use of high-speed access; 44 percent of the households in the San Francisco Bay area subscribed to DSL or cable modem service.

The percentage of DSL users in the Bay Area was higher than the national average. In 2004, cable modems dominated high-speed use in the United States with 63 percent to the market compared to DSL's market of 37 percent. The exception to this finding was the Bay Area, where 60 percent of high-speed subscribers used DSL.

The comScore study indicated that increased promotion activity and lower high-speed prices accounted for Internet and high-speed internet growth.

The latest market research study that we studied was published by the Pew Internet and American Life Project. The study "Home Broadband Adoption 2006" was published in 2006. The Pew studies are particularly insightful because they have been tracking Internet usage for a number of years.

The 2006 study indicated that home broadband adoption grew by 40 percent from March 2005 to March 2006--a dramatic rate of increase. In March 2006, 42 percent of all households had an internet high-speed connection. In March of 2005, 30 percent of all households had a high-speed connection. Growth of the use of the Internet helped fuel the increase in high-speed penetration over that year and over half of new Internet users subscribe to high speed services.

The study also indicated that use of high-speed Internet is not a high-income household luxury. Growth of high-speed access was strong in middle income households, in African Americans households, and in households with low levels of education.

The study also demonstrated that DSL has overtaken the use of cable modem service. Low cost DSL packages partly explain the strong growth of DSL as users are quite sensitive to pricing and often use other alternatives than an at-home connection--22 percent of dial-up users who do not want to get high-speed at home have a high-speed connection at work.

Significantly, dial-up users who do not want to switch to high-speed tend to be older and have lower incomes than dial-up users who express desire to switch to high-speed options

Table 7 summarizes findings regarding Internet and high-speed Internet use from the comScore Networks and Pew Internet research findings.

Table 7: Internet Use

	San Francisco Bay Area 2004[110]	U.S. Overall 2004[111]	U.S. Overall 2006[112]
High Speed Internet Users	44 percent	25 percent	42 percent
Internet Users	N/A	60 percent	73 percent

The among users of particular services is shown in Table 8.

Table 8: High-Speed Internet Use

	San Francisco Bay Area 2004[113]	U.S. Overall 2004[114]	U.S. Overall 2006[115]
DSL Users	60 percent	37 percent	50 percent
Cable Modem Users	40 percent	63 percent	41 percent
Other Users	N/A	N/A	9 percent

9.3 Connectivity Options in San Francisco

Point-to-point connectivity, especially connectivity based on a T1 hierarchy, has been used by many businesses and public entities in San Francisco for a number of years. Significant data demonstrate that these services are becoming insufficient for many users. There is a growing demand for new services to offer greater bandwidth and speed.

Based on our discussions with the existing providers and review of services offered, it appears that the availability of cable modem and DSL service in San Francisco is typical to other similar sized communities. That is, DSL has spot availability gaps - random in appearance, and cable modem service is available to most residents but has availability gaps for businesses.

---

[110] All data in this column sourced from "Fourth Quarter 2003 ISP Market Share Report Press Release," comScore Networks, March 10, 2004, http://www.comscore.com/press/release.asp?id=439, accessed January 9, 2007.
[111] All data in this column sourced from "Fourth Quarter 2003 ISP Market Share Report Press Release," comScore Networks, March 10, 2004, http://www.comscore.com/press/release.asp?id=439, accessed January 9, 2007.
[112] All data in this column sourced from "Home Broadband Adoption 2006," Pew Internet & American Life Project, May 28, 2006, http://www.pewinternet.org/report_display.asp?r=184, accessed January 9, 2007.
[113] All data in this column sourced from "Fourth Quarter 2003 ISP Market Share Report Press Release," comScore Networks, March 10, 2004, http://www.comscore.com/press/release.asp?id=439, accessed January 9, 2007.
[114] All data in this column sourced from "Fourth Quarter 2003 ISP Market Share Report Press Release," comScore Networks, March 10, 2004, http://www.comscore.com/press/release.asp?id=439, accessed January 9, 2007.
[115] All data in this column sourced from "Home Broadband Adoption 2006," Pew Internet & American Life Project, May 28, 2006, http://www.pewinternet.org/report_display.asp?r=184, accessed January 9, 2007.

- DSL coverage is difficult to project for a given location. A residence or business could be in an area where DSL is offered but is not available at their location due to the quality of the existing circuit or all DSL equipped circuits are allocated.

- Comcast has historically concentrated on providing residential cable modem service, and has not made business services a priority. Comcast, however, has started to more aggressive in serve the business market.

- It is likely that many households would like high-speed service but are unable or unwilling to pay $30 or more per month to acquire it. Market research can be used to understand the market conditions, availability gaps, and demands for high-speed services. Prior to consideration of offering a wholesale or retail residential and small business Internet service, conducting statistically valid market research will provide customer perception detail along with existing take rates of DSL, cable modem, and dial-up services.

- One of the gaps that are often overlooked is the performance and cost of T1 and other connectivity services. In San Francisco today large users are forced to connect 100 Mbps Local Area Networks (LAN) together with 1.5 Mbps T1 circuits. The limited performance of the T1 circuits restrains the types of applications these organizations can consider. When AT&T and other providers are asked for larger capacity circuits, often they either claim that they are not available or often the price they propose is exorbitant. This is the case with AT&T's OptiMAN.

9.3.1 Voice

AT&T is the incumbent local telephone company in San Francisco. In addition, there are other providers of local service in San Francisco, such as Personal Communications Service (PCS) (Sprint), wireless (Verizon Wireless, Cingular, Sprint/Nextel), and web-based VoIP (Vonage, Skype)

9.3.2 Cable Television/Video Programming

While consumers are unhappy with cable television rates and price increases, based on our experience it is important to note that one of the factors of cost increases is due to program content costs rising. Cable and satellite providers pass those costs on to their customers via rate increases. Public entities that look to compete with a traditional offering of video services find that the program content fees they must pay to provide the service make it difficult to have a profitable venture.

Much of the programming is owned by the larger cable companies such as Time Warner and Comcast. The vertical ownership of content makes it difficult for new competitors to enter the market. For example, in San Francisco Comcast and RCN provide cable television services. RCN however found it difficult to compete against Comcast when much of their revenues get sent to Time Warner and Comcast's holding companies

There are an increasing number of alternatives available for video programming in addition to traditional cable television and satellite. Internet-based video services, such as CinemaNow and Movielink, allow users to download and view movies and programming at convenient times and places. This flexibility is usually very appealing to sophisticated users.

9.3.3 Data and Internet Connectivity

There are a number of local and national Internet service providers (ISPs) offering services ranging from dial-up to high-speed connectivity (DSL, cable modem) in San Francisco. There are also a number of higher capacity connectivity options (ISDN, T1) available in San Francisco from providers such as XO Communications and AT&T. There are also mobile wireless connectivity options available from companies such as Cingular, Sprint, and Verizon Wireless. Connectivity speeds and prices vary greatly depending upon the level of service the user requires.

The residential market has considerable choices for connectivity, but the business community may find their options for higher speed more limited.

- Cost is typically an issue for both residents and small businesses.

- Capacity limits of cable access, DSL, and T1 devices are often limiting factors for large data users.
  - As the data needs increase, speed constraints restrict the ability of some entities to accomplish needed applications.

A summary of some Internet providers and their available service options are presented in Table 9. The DSL resellers may need to adjust their offerings as access to AT&T's platform is no longer a regulatory requirement.

Table 9: Internet Providers (partial)

Provider	DSL Facilities Based	DSL Reseller/ Added Value	Cable Modem	Cable Modem Reseller/ Added Value	Satellite	Dial Up Telephone	Wireless	ISDN, Frame Relay, Other
Acorntek Inc							✓	
ANJCOMP						✓		
AOL		✓		✓		✓		
AT&T	✓					✓		✓
Cingular Wireless							✓	
Comcast			✓					
EarthLink		✓			✓	✓	✓	
HughesNet					✓			
Localnet Corp							✓	
Megapath					✓			
NetZero		✓		✓		✓		
PeoplePC						✓		
RCN			✓					
XO Communication		✓						✓
Verizon							✓	

Comcast and RCN offer high-speed cable modem service in San Francisco. Other common providers include AT&T (DSL), America Online, Verizon, Earthlink and others.

We have summarized offerings of several Internet providers in Table 10 and Table 11.

Table 10: Residential Internet Offerings (partial)

Service	Cable	DSL		Wireless Broadband		Satellite		
Provider	Comcast	AT&T	Earthlink	Verizon	Cingular	HughesNet	Earthlink	Megapath
HSD	Up to 4 Mbps / 384 kbps	Up to 6 Mbps / 608 kbps	Up to 6 Mbps	Average of 400-700 kbps / 60-80 kbps	Average of 400-700 kbps / 384kbps	Up to 1.5 Mbps / 200 kbps	Up to 1.5 Mbps / 128 kbps	Up to 1 Mbps / 192 kbps
Pricing	$57.99 for non-cable subscribers.	from 384 kbps / 128 kbps fpr $12.99 to 6 Mbps / 608 kbps for $44.99	$39.95 for 6Mbps, $34.95 for 3 Mbps, $29.95 for 1.5 Mbps	$59.99 monthly access w/ 2-yr customer agreement and qualifying voice plan	Starting from $19.99 for 5MB, up to $79.99 unlimited	$59.99 for home (700 kbps / 128 kbps), $69.99 for professional (1 Mbps / 200 kbps), $79.99 for proplus (1.5 Mbps / 200 kbps)	$69.99 for 1.5 Mbps/128 kbps	150 kbps/64 kbps: $94.95, 500 kbps/128 kbps: $149.95, 1.0 Mbps/192 kbps: $249.95
"Always On"	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Network	HFC	DSL	DSL	Wireless	Wireless	Satellite	Satellite	Satellite
Infrastructure Needed	Hybrid Fiber-Coaxial Cable, COAX wiring indoors.	Proximity to Central Office, Twisted Pair Wiring Indoors	Proximity to Central Office, Twisted Pair Wiring Indoors	Laptop + wireless PC card, handheld devices, cell reception	Laptop + wireless PC card, handheld devices, cell reception	Need clear line of sight to the South, Satellite dish for DirecWay HSD	Need clear line of sight to the South, Satellite dish for DirecWay HSD	Need clear line of sight to the South, Satellite dish for DirecWay HSD
Mobile Use	No	No	No	Yes	Yes	No	No	No
Voice	Yes	Yes	Yes	Yes	Yes	No	No	No

Table 11: Business Internet Offerings (partial)

Service	Cable	DSL			Wireless Broadband		Satellite		
Provider	Comcast	Covad	AT&T	Earthlink	Verizon	Cingular	HughesNet	Earthlink	Megapath
High Spped Data	Up to 6 Mbps / 768 kbps, 8 Mbps / 1 Mbps	Up to 1.5 Mbps / 128 kbps	Up to 1.5 Mbps	Up to 6 Mbps	Average of 400-700 kbps / 60-80 kbps	Average of 400-700 kbps / 384kbps	Up to 1.5 Mbps / 200 kbps	Up to 1.5 Mbps / 128 kbps	Up to 1 Mbps / 192 kbps
Pricing		$39.95 for 1.5 Mbps / 128 kbps	$34.99 for 1.5 Mbps to $54.99 for 6 Mbps	from $59.95 to $114.95 depending on the speed.	$59.99 monthly access w/ 2-yr customer agreement and qualifying voice plan	$44.99 monthly access w/ 2-yr customer agreement and qualifying voice plan	$59.99 for home (700 kbps / 128 kbps), $69.99 for professional (1 Mbps / 200 kbps), $79.99 for proplus (1.5 Mbps / 200 kbps)	$69.99 for 1.5 Mbps/128 kbps	150 kbps/64 kbps: $94.95, 500 kbps/128 kbps: $149.95, 1.0 Mbps/192 kbps: $249.95
"Always On"	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Network	HFC	DSL	DSL	DSL	Wireless	Wireless	Satellite	Satellite	Satellite
Infrastructure Needed	Hybrid Fiber-Coaxial Cable, COAX wiring indoors.	Proximity to Central Office, Twisted Pair Wiring Indoors	Proximity to Central Office, Twisted Pair Wiring Indoors	Proximity to Central Office, Twisted Pair Wiring Indoors	Laptop + wireless PC card, handheld devices, cell reception	Laptop + wireless PC card, handheld devices, cell reception	Need clear line of sight to the South, Satellite dish for DirecWay HSD	Need clear line of sight to the South, Satellite dish for DirecWay HSD	Need clear line of sight to the South, Satellite dish for DirecWay HSD
Mobile Use	No	No	No	No	Yes	Yes	No	No	No
Voice	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No

These services do not meet the high-end data connectivity needs of many businesses. One of AT&T's solutions for the high-end services is OptiMAN, a managed, switched Ethernet network service. The service is designed to provide customers with a solution for communicating across multiple locations within a metropolitan area. It is geared for firms with a campus environment, such as businesses with separate administrative offices and manufacturing locations, local government offices, hospitals or universities. OptiMAN provides broadband capabilities to link buildings in order to share information across employees, customers and suppliers, and other users.

OptiMAN can be configured in a variety of ways, including point to point, point to multipoint and multipoint to multipoint. The service is scalable from five Mbps to one Gbps, providing businesses with added flexibility to choose the exact configuration and bandwidth to suit their current needs, along with the ability to change as their needs change.

OptiMAN does meet the growing need for new capacity. It does however fall short in availability and affordability. Depending upon location, OptiMAN can cost in excess of $10,000 per month, and availability is often limited to certain areas.

10. FTTP Financial Analysis

This Section of the Report is intended to provide City decision-makers with financial data by which to evaluate the feasibility and relative merits of alternative business models for a City fiber network.

It is important to note that this Section details only the quantifiable financial factors that are relevant to the business case for the network. Many of the additional benefits of the network are described in summary in Section 1 above and include such key items as economic development, small business empowerment, job creation, livability, education, increased sales tax and real estate tax revenues, increased property values and other factors that measure the overall benefit of a next generation communications infrastructure such as FTTP.

On the basis of these and other factors, this Report recommends a “wholesale,” or "open access” model because it offers the best balance of technology advancement, infrastructure, future proofing, and encouragement for private sector innovation- and is thereby most likely to facilitate the goals of the City. Specifically:

- In a market like San Francisco, the probability of obtaining the required market share to maintain cash flow is higher with the open access model because multiple providers will promote and sell services—not just the City. It is important to keep this difference in mind -- even though the financial projections for the two different models appear similar because, for comparative purposes, the financial analysis assumes the same market shares for both models.

- The model is likely to stimulate private efforts to offer diverse, cost-competitive services to residents and businesses. The strategy creates a platform for broadband competition and innovation by separating network ownership from operations and service-provision.

- The wholesale model is practical and entails less financial risk. It requires less City involvement in operations than a retail model because it does not require the City to go into the business of providing communications services itself. The model leverages the considerable City’s right-of-way knowledge and utility maintenance capabilities while leveraging private sector strengths in service-provision.

- Finally, our analysis suggests that the wholesale model is more likely to maintain cash flow--to generate enough revenue to meet its own annual expenses--than is the retail model. The model requires a smaller capital investment ($564 million versus $804 million) than does the retail model. In addition, the open access model provides an opportunity to finance a portion of the investment by assessing a fee to all businesses and households.

To reach this recommendation, we examined the two primary models for a municipally-owned fiber network.[116] We evaluated both a "retail" model and a "wholesale" or open access model.

CTC's methodology in evaluating these models was to determine what level of market share would make the retail model cash flow (generate enough revenue annually to cover its own operating and financing expenses). In the financing community, the key measurement for a municipal communications network is cash flow -- the ability to maintain sufficient cash flow to cover debt service (principle and interest), operating expenses, and ongoing network enhancements.

Once we had determined this market share, we applied the same numbers to the wholesale/open access model in order to determine what fees retail providers would need to pay the City for use of the network in order for the City to realize adequate cash flow. We then compared these projections to the limited data available from other municipal communications networks and generally within the communications industry.

In each model we used the Home Run Ethernet technology cost estimate because it is the preferred technical model for San Francisco's needs (discussed in detail above). Use of the Passive Optical Network (PON) technology will slightly impact the financial projections, but will not impact the comparison between the two models or the recommendations made in this section.

10.1 Retail Delivery Model

Under the retail model, the City becomes a competitive provider of voice, video, and data services. This model requires the City to directly compete with Comcast, RCN, and AT&T. It also requires the City to define and update services on an ongoing base, establish consumer level sales and marketing efforts, and establish consumer-level help desk and other support mechanisms.

The retail model requires the broadest range of staff additions, training, marketing, and other activities to run and maintain the business venture. This section provides an overview of the estimated requirements and the projected financial results.

The retail model presented in this section provides a magnitude[117] projection and includes a wide-range of estimates of staffing, operating, maintenance, and other costs. Prior to a decision, we recommend that these projections be refined in a more detailed business plan. In addition, the estimated market shares were chosen to drive a positive cash flow—they are not necessarily obtainable or sustainable.

---

[116] CTC's analysis was limited to municipal ownership by the terms of the Board of Supervisors' resolution discussed above and by the statement of work approved by the City for this project.

[117] A "magnitude" projection provides projected data sufficient for initial planning purposes. Refinement of the analysis is recommended in the business planning phase and prior to using the analysis to obtain required financing.

10.1.1 Market Share

The measure of success for a municipal venture is the ability to maintain a positive cash flow throughout the life of the proposed model. To maintain a positive cash flow, a substantial market share is required. To sustain the retail model, we project the need for the City to acquire market share of:

- 35 percent of residential Internet
- 25 percent of business Internet
- 34 percent of residential telephone
- 19 percent of business telephone
- 42 percent of residential cable television
- 17 percent of business cable television

There exist no empirical data that demonstrate that the City can expect to obtain and sustain these numbers.[118] Frankly, we do not believe that there is any relevant empirical data at all—the existing FTTP networks in the United States are not analogous to a potential network in San Francisco because they are frequently in rural areas or small towns, they are frequently owned and operated by municipal utilities, and they therefore face dramatically different circumstances than a large, urban area.

The success of the retail model generally depends on the government's capability to compete in a consumer market with established and experienced providers. Other municipal FTTP systems[119] have obtained such shares, but they are located in rural or small town communities where competition is limited (or nonexistent) and the local government possesses a strong branding or trust image with its citizens. In addition, many of these municipal networks are owned and operated by municipal utilities—which have clear advantages with respect to existing facilities, operations, construction, brand-name, image, and marketing.

In contrast, San Francisco is likely to face difficulty obtaining such market penetration because it already has two facilities-based cable and Internet providers and a phone company that has signaled intention to initiate video programming. Each of these providers currently offers (or plans to offer) a suite of voice, video, and data service. San Francisco faces the additional difficulty of potential branding-negativity—it will be working against perceptions that the City would not ably offer these services, perceptions that are likely to be highlighted by incumbents.

---

[118] CTC therefore strongly recommends that the City undertake market research to try to determine potential penetration rates. See recommendations in Section 1 above.

[119] For example, see the Reedsburg, WI and Jackson, TN case studies presented in this report.

10.1.2 Financing Costs

As is discussed in detail above, our engineering analysis estimates total capital requirements to be $804 million for the retail model. For financing, we assume two bonds:[120] first, a $404 million bond[121] to cover the cost of new fiber. This bond is issued at an interest rate of 4.50 percent and is paid off in equal principal and interest payments over the 20-year depreciable life of the fiber.

Second, we assume a $400 million bond to cover the remaining implementation costs, including headend equipment, operating equipment, customer premises equipment and other miscellaneous costs. All of this equipment initial investment is depreciated over seven years and the financial projections includes reinvestment and upgrades to keep the equipment useful over a twenty year life. This bond is paid off over 20 years at an interest rate of 5.00 percent.

We assume that the bond issuance costs are equal to 1.0 percent of the principal borrowed. For each bond, a debt service reserve account is maintained at five percent of the total issuance amount. An interest reserve account equal to years 1 and 2 interest expense is maintained for the first two years.

Interest earned on excess cash is assumed to be 4.0 percent of the previous year's ending cash balance.

The projected Income Statement is shown in Table 12.

[120] The scope of work for this Report does not include a review of the City's bonding capability or review of local or state bonding restrictions. A more detailed review of bonding capability and restrictions is recommended in the business planning phase.
[121] Experience suggests that the financial community is unlikely to offer the required bonding based on the projected voice, video and data revenues. Securing the bonds through existing revenue streams (water utility, sales tax, other) or through the general obligation of the City may be required.

Table 12: Retail Model Income Statement

Year Income Statement		1	10	20
a. Revenues				
Video		$ 17,092,872	$ 68,195,118	$ 68,195,118
Internet		15,501,503	55,007,755	55,007,755
Voice		10,078,642	23,442,259	23,442,259
Provider Fee		-	-	-
Ancillary Revenues		11,303,406	107,185	-
	Total	$ 53,976,423	$ 146,752,318	$ 146,645,133
b. Content Fees				
Video		$ 10,023,804	$ 40,230,060	$ 40,230,060
	Total	$ 10,023,804	$ 40,230,060	$ 40,230,060
c. Operating Costs				
Labor Expense		$ 4,050,000	$ 8,869,500	$ 8,869,500
Operation and Maintenance Expenses		8,769,793	12,330,644	12,329,036
Pole Attachment Expense		120,000	120,000	120,000
Depreciation		41,841,473	38,348,410	36,760,966
	Total	$ 54,781,266	$ 59,668,554	$ 58,079,502
d. Operating Income		$ (10,828,647)	$ 46,853,704	$ 48,335,571
e. Non-Operating Income				
Interest Income		$ -	$ 1,583,998	$ 3,645,518
Interest Expense (Headend and CPE Bond)		(20,000,000)	(13,330,563)	(1,528,430)
Interest Expense (Fiber Bond)		(18,180,000)	(11,920,085)	(1,337,424)
	Total	$ (38,180,000)	$ (23,666,651)	$ 779,663
f. Net Income		$ (49,008,647)	$ 23,187,053	$ 49,115,234
g. Taxes (Franchise Fees & In Lieu Tax)		$ 854,644	$ 3,409,756	$ 3,409,756
h. Net Income After Fees & In Lieu Taxes		$ (49,863,290)	$ 19,777,297	$ 45,705,478

10.1.3 Operating and Maintenance Expenses

Years 1, 10, and 20 operating and maintenance expenses are presented in Table 8. These expenses are in addition to the cable television (video) content fees, pole attachment expenses, and labor expenses shown in the Income Statement (Table 12).

Table 13: Summary of Operating and Maintenance Expenses

Year	1	10	20
Annual Fixed Operating Expense			
Insurance	$ 400,000	$ 400,000	$ 400,000
Utilities	200,000	200,000	200,000
Office Expenses	300,000	300,000	300,000
Contingency	400,000	400,000	400,000
Billing Maintenance Contract	50,000	50,000	50,000
Fiber Maintenance	2,022,400	2,022,400	2,022,400
Legal Fees	300,000	150,000	150,000
NCTC Start-up	410,000	-	-
Marketing	1,000,000	750,000	750,000
Annual Variable Operating Expense			
Education and Training	162,000	354,780	354,780
Customer Handholding	63,831	174,786	174,786
Customer Billing (Unit)	31,916	87,393	87,393
Allowance for Bad Debts	809,646	2,201,285	2,199,677
Internet Connection Fee	2,500,000	5,000,000	5,000,000
PSTN Connection Fee	120,000	240,000	240,000
Total	$ 8,769,793	$ 12,330,644	$ 12,329,036

Facilities: The addition of new staff and inventory requirements will require allocation of office and warehousing space:

- Expand office facilities for management, technical and clerical staff
- Expand retail "storefront" to facilitate customer contact and their experience with doing business with the City
- Provide warehousing for receipt and storage of cable and hardware for the installation and on-going maintenance of the broadband infrastructure
- Establish location to house servers, switches, routers, and other core-network equipment

Training: Training of existing City staff is important to fully realize the economies of adding a business unit.

Cable Programming: To provide retail cable television service, the City will need to obtain programming and join the National Cable Television Cooperative (NCTC). NCTC has some stringent membership requirements and entry fees are substantial for a municipal entry. Among other fees, the City would pay $20,000 for freedom of information purposes, though this fee is waived if the City indemnifies NCTC and NCTC information from any information requests. The City will also pay one-time fees of $1 per home passed and a one-time application fee of $25,000 (these numbers assume the City is designated as a start-up for purposes of these fees; fees for established providers are higher.) Given the estimated number of homes passed, this analysis assumes NCTC entry fees of $410,000. These costs are in addition to the on-going programming fees. On-going cable programming fees are the highest expense[122] in the retail model.

[122] See line b of the Income Statement in Table 7.

Billing and Collections: The City of San Francisco already has billing software and capabilities. The estimated incremental cost of billing for the new broadband utility is five cents per bill. In addition, we have included $400,000 for upgrade or purchase of a billing module. Maintenance of billing software is estimated to be $50,000 annually.

Marketing and Sales: It is important to be proactive in setting customer expectations, addressing security concerns, and educating the customers on how to initiate services.

Staffing Levels: Skills in the following disciplines are required:

- Sales/Promotion
- Internet and related technologies
- Staff Management
- Strategic Planning
- Finance
- Vendor Negotiations
- Networking (addressing, segmentation)
- Marketing

Based upon our experience, the recommended staffing levels for the technical employees are shown in Table 14.

Table 14: Recommended Staffing Levels (Technical)

Position	Metric
Headend Technician	2
Telephone Technician	2
Internet Technician	2
Service Technician	1 per 100 miles of plant
Subscriber Technician/Customer Service Representative	1 per 3,000 subscribers (per shift)

The expanded business and increased responsibilities may require the addition of new staff. The initial additional positions, staffing levels and base salaries are shown in Table 15. These numbers are based upon the levels indicated in Table 13, and assume that 24x7 support is provided. Changing the support to 7am to 8pm (or other reduced hours) will decrease the required number of staff.

Table 15: Estimated Staffing Requirements

Service Position	Year 1	Year 2	Year 3+	Year 1 Salary
Business Manager	1	1	1	$ 100,000
Market & Sales Manager	1	1	1	$ 85,000
Broadband Service Manager	1	1	1	$ 85,000
Headend Technician	1	2	2	$ 70,000
Telephone Technician	1	2	2	$ 70,000
Internet Technician	1	2	2	$ 70,000
Customer Service Representative	54	135	138	$ 40,000
Service Technicians	9	9	9	$ 40,000
Sales and Marketing Representative	0	0	0	$ 40,000
Total	69	153	156	

For purposes of this analysis, benefits in the amount of 35 percent of base salary are assumed.

10.1.4 Summary of Assumptions

Key annual operating and maintenance assumptions include:

1. Content fees are estimated based on current fees paid to content providers by cable television providers.
2. Salaries and benefits are based on estimated market wages. See Table 15 for the list of staffing requirements. Benefits are estimated at 35 percent of base salary.
3. Insurance is estimated to be $400,000 in years 1 through 20.
4. Utilities are estimated to be $200,000 in years 1 through 20.
5. Office expenses are estimated to be $300,000 in years 1 through 20.
6. Contingency is estimated to be $400,000 in years 1 through 20.
7. Maintenance of billing software is estimated to be $50,000 in year 1 through 20.
8. Fiber maintenance fees are assumed to be $5,000 plus 0.5 percent of total fiber implementation cost annually.
9. Legal fees are estimated to be $300,000 in year 1 and in year 2, and then are reduced to $150,000 in years 3 through 20.
10. NCTC start-up costs are assumed to be $410,000 in year 1. There are none thereafter.
11. Marketing and promotional expenses are estimated to be $1,000,000 in year 1 and $750,000 in years 2 through 20.
12. Education and training are calculated as four percent of direct payroll expense.
13. Customer handholding is estimated to be 10¢ per subscriber per month.
14. Customer billing (incremental) is estimated to be 5¢ per bill per month.
15. Allowance for bad debts is computed as 1.5 percent of revenues.
16. Internet connection fees are estimated at $2.5 million in year 1 and $5 million in year 2 and thereafter.
17. PSTN connection fees are estimated at $120,000 in year 1 and $240,000 in year 2 and thereafter.
18. Pole attachment fees are estimated to be $120,000 per year. This is computed as 6,000 poles at $20 per pole per year.
19. Customers will pay the costs of the set-top box and internal wiring. These payments are shown as ancillary revenue in the income statement.
20. Franchise fees are estimated to total five percent of cable television revenue annually.

Inflation and salary cost increases were not used in this analysis as it is assumed that cost increases will be passed on to customers in the form of increased prices.[123]

[123] Models that add the same escalation factor on revenues and expenses will overstate the anticipated gross margins (revenues less expenses) in the out years. For example: in year 1, $2 in revenues and $1 in expenses results in a gross margin of $1. Increasing each by 10 percent results in $2.20 in revenues and $1.10 in expenses, yielding a gross margin of $1.10. In other words, gross margins will also increase by the escalation factor.

10.1.5 Pricing

Pricing is a critical part of the retail model[124] for obvious reasons, because it impacts the consumer's cost/benefit analysis and its willingness to purchase the product -- and thereby impacts the provider's market share. It is important to keep in mind that maximizing market share is not necessarily the same as maximizing revenue--a very inexpensive product can drive market share but the revenue generated could not maintain operations and make financing payments. As a result, our model assumes pricing at a level that maximizes revenue generation rather than market share. Specifically:

- The model prices cable television packages slightly below Comcast's current package pricing.
- Internet packages are priced to be competitive with existing area Internet service providers while offering higher capacity connections. Specifically:
  - 1 Mbps - $19.95
  - 5 Mbps - $39.95
  - 10 Mbps - $79.95
  - 20 Mbps - $139.95
  - 100 Mbps - $1,299.00
- The model prices telephone packages to be competitive with AT&T.

10.1.6 Cash Flow Results

Examining a stand-alone Income Statement is not a sufficient analysis. This analysis also examines the cash flow after principal[125] payments are made, accumulated unrestricted cash balances, and restricted[126] cash balances.

Year-end net income and cash flow results are compared in Table 16:

Table 16: Base Case (Retail) Net Income and Cash Flow

	Year 1	Year 5	Year 10	Year 15	Year 20
Net Income	$ (49,863,290)	$ (29,695,135)	$ 19,777,297	$ 32,281,158	$ 45,705,478
Cash Flow	$ 130,615,233	$ (5,182,819)	$ 5,598,687	$ (10,769,998)	$ 8,190,650
Unrestricted Cash Balance	$ 130,615,233	$ 9,488,073	$ 4,998,627	$ 21,206,742	$ 59,128,591
Restricted Cash Balance (Debt Service Reserve)	$ 40,200,000	$ 40,200,000	$ 40,200,000	$ 40,200,000	$ 40,200,000

---

[124] CTC recommends that market research be conducted by the City to provide data on how willing residences and businesses would be to switch to a new service provider at various price levels.
[125] The Income Statement accounts for interest expense but not principal payments on debt. The cash flow statement adds in non-cash expense such as depreciation and includes principal payments.
[126] The restricted cash balance is the debt service reserve fund, and is held in escrow until the last bond payment is made.

The cash flow balances are quite sensitive to the projected market shares. If the voice, video, and data market shares are reduced by half, cash flow balances drop considerably. This impact is shown in Table 17.

Table 17: Reduced Market Share (Retail) Net Income and Cash Flow

	Year 1	Year 5	Year 10	Year 15	Year 20
Net Income	$ (62,942,105)	$ (48,079,784)	$ (15,187,757)	$ (4,073,369)	$ 8,592,320
Cash Flow	$ 156,534,258	$ (37,457,835)	$ (29,452,733)	$ (47,124,708)	$ (28,922,508)
Unrestricted Cash Balance	$ 156,534,258	$ (22,728,003)	$ (201,471,179)	$ (364,285,920)	$ (508,898,461)
Restricted Cash Balance (Debt Service Reserve)	$ 40,200,000	$ 40,200,000	$ 40,200,000	$ 40,200,000	$ 40,200,000

The sensitivity of and the ability to obtain the required market shares is the largest concern with the retail model in San Francisco.

10.2 Wholesale/Open Access Model

The wholesale or open access model separates the infrastructure from the retail service. In the open access model, the City addresses the high cost of market entry for potential retail providers -- the cost of the FTTP infrastructure. The result is the potential for new competition-delivering, enhanced services. In the open access model, the City's customer is not the consumer—rather, it is the service provider.

The open access model requires fewer staff additions than does the retail model because it does not require consumer level support, sales, and marketing. The staff additions are geared towards operating and maintaining the FTTP network, promoting the network to potential service providers, and managing those providers leasing network access.

The open access model presented in this section provides a magnitude projection and includes a wide-range of estimates for staffing, operating, maintenance, and other costs. Prior to a decision, we recommend that these projections be refined in a more detailed business plan.

For comparison purposes, this analysis maintains the same market shares used in the retail model. We are not projecting these market shares are obtainable or sustainable. However given that multiple providers will seek market share, the probability of capturing sufficient market share is increased. Frankly, we believe that in a market the size of San Francisco, the FTTP network has a greater chance of achieving higher aggregate market share if many providers are actively competing for customers than if only the City is out marketing as in the retail model.

Our wholesale model assumes that San Francisco operates and maintains the fiber and the transport electronics. Contracting these activities to a management partner is a variation that reduces the required number of staff, while still allowing San Francisco to maintain control of network availability and encouragement of new services and competition. Using a management partner has little impact on the required market shares to maintain cash flow. In this variation, San Francisco owns the fiber network and transport electronics, a management partner is contracted to provide network maintenance and operations, and the retail services supplier is chosen by the consumer. Further exploring this and other variations is an important step in business plan development.

10.2.1 Financing Costs

Using the same market share assumptions used in the retail model, and charging each provider a connection fee of $31.50 per month per customer, the City will have an unrestricted cash balance of approximately $55 million by the end of year 20. An increase of $1 per month of this fee increases the year 20 cash balance to $104 million.

As is discussed in detail above, our engineering analysis estimates total capital requirements of $564 million for the wholesale model. For financing, we assume two bonds: first, a $404 million long-term bond to cover the cost of new fiber. This bond is issued at an interest rate of 4.50 percent and is paid off in equal principal and interest payments over the 20-year depreciable life of the fiber.

Second, a $160 million bond to cover the remaining implementation costs[127], including headend equipment, operating equipment, and other miscellaneous implementation costs. All of this equipment initial investment is depreciated over seven years and the financial projections include reinvestment and upgrades to keep the equipment useful over a twenty year life. This bond is paid off over 20 years at an interest rate of 5.00 percent.

We assume that issuance costs are equal to 1.0 percent of the principal borrowed on the long-and short-term bonds. A debt service reserve account is maintained at five percent of the total issuance amount. An interest reserve account equal to years 1 and 2 interest expense is maintained for the first two years.

Interest earned on excess cash is assumed to be 4.0 percent of the previous year's ending cash balance.

The projected Income Statement is shown in Table18.

[127] The open-access model allocates the CPE costs to the provider or consumer. Applying the CPE costs to the wholesale provider (the City) results in increasing the bonding requirement by $140 million, and increasing the fee per subscriber to $37.50 per month. However, the resulting net cash flows see little impact. Development of CPE ownership and other policy issues is an important task in preparation of a business plan.

Table 18: Open Access Model Income Statement

Year Income Statement		1	10	20
a. Revenues				
Video		$ -	$ -	$ -
Internet		-	-	-
Voice		-	-	-
Provider Fee		20,106,765	55,057,552	55,057,552
Ancillary Revenues		11,303,406	107,185	-
	Total	$ 31,410,171	$ 55,164,737	$ 55,057,552
b. Content Fees		$ -	$ -	$ -
Video		$ -	$ -	$ -
	Total	$ -	$ -	$ -
c. Operating Costs				
Labor Expense		$ 978,750	$ 1,032,750	$ 1,032,750
Operation and Maintenance Expenses		3,486,550	3,163,710	3,163,710
Pole Attachment Expense		120,000	120,000	120,000
Depreciation		31,851,707	26,925,378	26,378,968
	Total	$ 36,437,007	$ 31,241,838	$ 30,695,428
d. Operating Income		$ (5,026,836)	$ 23,922,899	$ 24,362,124
e. Non-Operating Income				
Interest Income		$ -	$ 1,654,217	$ 3,093,226
Interest Expense (Headend and CPE Bond)		(8,000,000)	(5,332,225)	(611,372)
Interest Expense (Fiber Bond)		(18,180,000)	(11,920,085)	(1,337,424)
	Total	$ (26,180,000)	$ (15,598,093)	$ 1,144,429
f. Net Income		$ (31,206,836)	$ 8,324,806	$ 25,506,553
g. Taxes (Franchise Fees & In Lieu Tax)		$ -	$ -	$ -
h. Net Income After Taxes		$ (31,206,836)	$ 8,324,806	$ 25,506,553

10.2.2 Operating and Maintenance Expenses

Years 1, 10, and 20 operating and maintenance expenses are presented in Table 19.

Table 19: Operating and Maintenance Expenses

Year	1	10	20
Annual Fixed Operating Expense			
Insurance	$ 400,000	$ 400,000	$ 400,000
Utilities	200,000	200,000	200,000
Office Expenses	150,000	150,000	150,000
Contingency	200,000	200,000	200,000
Billing Maintenance Contract	25,000	25,000	25,000
Fiber Maintenance	2,022,400	2,022,400	2,022,400
Legal Fees	300,000	100,000	100,000
NCTC Start-up	-	-	-
Marketing	150,000	25,000	25,000
Annual Variable Operating Expense			
Education and Training	39,150	41,310	41,310
Customer Handholding	-	-	-
Customer Billing (Unit)	-	-	-
Allowance for Bad Debts	-	-	-
Internet Connection Fee	-	-	-
PSTN Connection Fee	-	-	-
Total	$ 3,486,550	$ 3,163,710	$ 3,163,710

Facilities: the addition of new staff and inventory requirements will require allocation of office and warehousing space:

- Expand office facilities for management, technical and clerical staff.
- Provide warehousing for receipt and storage of cable and hardware for the installation and on-going maintenance of the broadband infrastructure.
- Establish location to house servers, switches, routers, and other core-network equipment.

Training: training of existing City staff is important to fully realize the economies of adding a business unit.

Billing and Collections: billing is simplified under the wholesale model. We estimate that billing costs are $25,000 per year for billing of service providers.

Marketing and Sales: marketing efforts in the open access model are directed towards encouraging new providers to enter the San Francisco market place rather than at the consumer as in the retail access model.

Staffing Levels: staff is required to maintain the core network. The retail providers will handle day-to-day subscriber inquiries. Table 20 shows the estimated staffing levels.

Table 20: Estimated Staffing Requirements

Service Position		Year 1	Year 2	Year 3+	Year 1 Salary
Business Manager		1	1	1	$ 100,000
Market & Sales Manager		0	0	0	$ 85,000
Broadband Service Manager		1	1	1	$ 85,000
Headend Technician		0	0	0	$ 70,000
Telephone Technician		0	0	0	$ 70,000
Internet Technician		2	2	2	$ 70,000
Customer Service Representative		1	2	2	$ 40,000
Service Technicians		9	9	9	$ 40,000
Sales and Marketing Representative		0	0	0	$ 40,000
	Total	14	15	15	

We assume benefits equal to 35 percent of base salary.

10.2.3 Summary of Assumptions

Key annual operation and maintenance assumptions include:

1. Salaries and benefits are based on estimated market wages. See Table 20 for the list of staffing requirements. Benefits are estimated at 35 percent of the base salary.
2. Insurance is estimated to be $400,000 in years 1 through 20.
3. Utilities are estimated to be $200,000 in years 1 through 20.
4. Office expenses are estimated to be $150,000 in years 1 through 20.
5. Contingency is estimated to be $200,000 in years 1 through 20.
6. Billing is estimated to be $25,000 in year 1 through 20.
7. Fiber maintenance fees are assumed to be $5,000 plus 0.5 percent of total fiber implementation cost annually.
8. Legal fees are estimated to be $300,000 in year 1 and then are reduced to $150,000 in years 2 through 20.
9. Marketing and promotional expenses are estimated to be $150,000 in year 1 and $25,000 in years 2 through 20.
10. Education and training are calculated as four percent of direct payroll expense.
11. Pole attachment fees are estimated to be $120,000 per year. This is computed as 6,000 poles at $20.00 per pole per year.

Inflation and salary cost increases were not used in the analysis as it is assumed that cost increases will be passed on in the form of increased prices.

10.2.4 Cash Flow Results

These assumptions lead to the year-end net income and cash flow results summarized in Table 21.

Table 21: Base Case (Open Access) Net Income and Cash Flow

	Year 1	Year 5	Year 10	Year 15	Year 20
Net Income	$ (31,206,836)	$ (10,969,911)	$ 8,324,806	$ 16,454,900	$ 25,506,553
Cash Flow	$ 2,505,594	$ 2,649,757	$ 4,400,660	$ (10,358,674)	$ 6,004,859
Unrestricted Cash Balance	$ 2,505,594	$ 13,395,089	$ 17,556,093	$ 27,333,630	$ 55,135,500
Restricted Cash Balance (Debt Servive Reserve)	$ 28,200,000	$ 28,200,000	$ 28,200,000	$ 28,200,000	$ 28,200,000

The cash flow balances are quite sensitive to the projected market shares. If the voice, video, and data market shares are reduced by half, as in the case of the retail model the cash flow balances drop considerably. This impact is shown in Table 22.

Table 22: Reduced Market Share (Open Access) Net Income and Cash Flow

	Year 1	Year 5	Year 10	Year 15	Year 20
Net Income	$ (44,859,877)	$ (32,303,793)	$ (17,060,521)	$ (9,951,587)	$ (1,357,550)
Cash Flow	$ 1,162,516	$ (22,530,694)	$ (21,024,370)	$ (36,765,245)	$ (20,859,245)
Unrestricted Cash Balance	$ 1,162,516	$ (76,176,214)	$ (199,227,134)	$ (319,429,357)	$ (423,725,580)
Restricted Cash Balance (Debt Servive Reserve)	$ 28,200,000	$ 28,200,000	$ 28,200,000	$ 28,200,000	$ 28,200,000

This sensitivity to market shares is again a concern, but—unlike in the retail model--the City is serving multiple providers that are selling to consumers. With more retail providers, the probability of obtaining the required market shares increases.

10.3 Summary Comparison of Retail and Open Access Models

Table 23 summarizes the comparison between the open access and retail models.

Table 23: Comparison of Open Access and Retail Models

	ADVANTAGES	DISADVANTAGES
Open Access	• Sales and marketing directed towards new providers entering the San Francisco market • Allows consumers choice of providers • Removes incumbent providers' market control to limit capacity • Removes incumbent providers' market control to manipulate or monitor transmissions	• Network management more complex • Less established business model
Retail	• Network management relatively straight-forward • Easier concept to present to consumers	• City responsible to manage customer expectations for technical and other support • Requires sales and marketing at a consumer level • Infrastructure-based providers are already based in San Francisco which will limit the ability to obtain required market shares required to maintain cash flow

10.4 Financing

Financing is one of the largest challenges for publicly or privately financed FTTP infrastructure. To date, municipal FTTP projects have been financed through bonds secured with established municipal electric or water revenues, or by the general obligation of the community. Efforts to attract private FTTP infrastructure deployments by Seattle and Palo Alto are in a proposal evaluation stage, and required municipal commitments are unknown at this time.

Assuming, as this Report does, a municipally-financed FTTP build, there are two primary approaches for obtaining revenue streams to finance the infrastructure.

10.4.1 Access Fee Model

Under this model, service providers are charged an access fee per month to cover the required FTTP infrastructure investment, customer drops, and installation costs. As these costs would presumably be passed on to consumers, only subscribers that use the network are charged. This is the method used in the open access financial analysis above.

The determination of the rate charged of the provider is based upon estimated market shares. As a result, failing to meet projected market share results in cash flow shortages and exceeding projected market share results in cash flow reserves

Significantly, under this model, general obligation of other secured bond financing is likely to be required. The investment community has been leery of securing bonds only based on anticipated new revenues.

10.4.2 Property Owner Assessment

Under this model, the City assesses all property owners for proportionate shares of the costs of the FTTP infrastructure (excluding consumer drops, customer premises equipment (CPE), and installation). Consumers pay for fiber drops, CPE, and installation when they subscribe to a voice video or data service (one time charge, amortized fee, or combination), and consumers pay for services directly to the provider of their choice.

The assessment approach to financing FTTP infrastructure arises from the growing consensus that broadband constitutes essential infrastructure for the viability of the community. Roads, water supply, wastewater are all considered essential infrastructure and are publicly financed through an assessment-type approach. In the case of water and waste water, the infrastructure is "bundled" with the service. In the case of the roads, infrastructure costs are “unbundled” from use in a mechanism comparable to that contemplated here for FTTP infrastructure.

It is prudent, however, to expect that assessment-based financing of an open access FTTP infrastructure is likely to receive regulatory, legal, and political challenges from incumbent providers.

10.4.3 Cash Flow Results Under Potential Assessment Financing

The assessment financing option consists of a charge to all homes passed for the FTTP infrastructure, and the per-subscriber fee to cover operational expenses and subscriber drops. This analysis leaves all other assumptions the same but adding the following assumptions:

1. A per home passed assessment of $9 per month

2. A monthly subscriber fee of $10

Adding these factors results in a year 20 cash balance of $148.5 million. These assumptions lead to the year-end net income and cash flow results summarized in Table 24.

Table 24: Base Case (Assessment) Net Income and Cash Flow

	Year 1	Year 5	Year 10	Year 15	Year 20
Net Income	$ (5,515,361)	$ (6,643,301)	$ 12,672,427	$ 20,857,712	$ 30,863,248
Cash Flow	$ 28,197,069	$ 6,976,367	$ 8,748,281	$ (5,955,862)	$ 11,361,554
Unrestricted Cash Balance	$ 28,197,069	$ 59,038,118	$ 84,689,849	$ 95,902,360	$ 148,505,164
Restricted Cash Balance (Debt Service Reserve)	$ 28,200,000	$ 28,200,000	$ 28,200,000	$ 28,200,000	$ 28,200,000

As a result, assessment financing reduces the sensitivity of cash flow balances to market share. In fact, the sensitivity can be eliminated by increasing the assessment. In this model, reducing market share by half reduces cash flow balances--but they remain positive. This impact is shown in Table 25.

Table 25: Reduced Market Share (Assessment) Net Income and Cash Flow

	Year 1	Year 5	Year 10	Year 15	Year 20
Net Income	$ (12,306,737)	$ (9,139,012)	$ 4,928,654	$ 11,387,930	$ 19,341,708
Cash Flow	$ 33,715,656	$ 634,088	$ 964,805	$ (15,425,728)	$ (159,986)
Unrestricted Cash Balance	$ 33,715,656	$ 50,032,851	$ 39,774,493	$ 7,142,517	$ 6,401,798
Restricted Cash Balance (Debt Service Reserve)	$ 28,200,000	$ 28,200,000	$ 28,200,000	$ 28,200,000	$ 28,200,000

Table 26 compares the advantages and disadvantages of these financing approaches.

Table 26: Comparison of Financing Approaches

	Advantages	**Disadvantages**
Assessments	• Supports position of FTTP being an essential infrastructure • Lowers investment risk of FTTP	• Potential for legal, political, and public relations challenges
User Fees	• Fees apply only to consumers acquiring services	• Likely to require General Obligation (GO) bonding for financing; in other words, risks are still absorbed across the entire community • May discourage or reduce participation

11. Provider Perspectives

This Section of the Report summarizes and evaluates the perspective of representatives of communications service providers with whom CTC met. These discussions and this analysis are intended to identify and evaluate the industry's perspectives on the following questions:

1. Deployment/Upgrade Plans

What is the provider's perception of market and other barriers that it believes limits its deployment of broadband services in San Francisco?

2. Interest in City FTTP Network

What is the provider's interest in potential leasing of City-owned fiber infrastructure under an open access plan?

3. Perspective regarding City FTTP Network

What is the provider's support for, or objections to, City-owned and/or operated broadband facilities?

11.1 Comcast

CTC staff interviewed Johnnie Giles, Comcast Vice President of Government Affairs for the Bay Area, and Lee Ann Peling, Government Affairs for the West Bay/San Francisco/Peninsula on October 3, 2006. All content in this section is based on that interview unless otherwise noted.

1. Deployment Plans

Comcast does not believe that there is a need in San Francisco for additional connectivity and believes that the market is adequately meeting existing demand. According to Mr. Giles, the existing Comcast networks in the Bay Area contain fallow fiber capacity that is currently unused and could be used at a later date if the demand arises. Comcast has the ability to segment its nodes and thereby increase capacity by increasing the fiber available. Comcast "feels very comfortable that we can meet future market demands," according to Mr. Giles.

Mr. Giles acknowledges that Comcast's traditional footprint is in the residential areas of the City, as is the cable industry's footprint nationally. He notes however, that Comcast is taking steps to enable it to offer some services to businesses, including its "Workplace" product, which is offered to small businesses of up to 25 employees. Comcast also has a national commercial sales team that searches out larger commercial customers and has identified the business market as a prime future customer base.

Even an FTTP network will face a significant bottleneck, according to Mr. Giles: the internal wiring at the customers' homes. Comcast has the capability to upgrade that wiring but has not identified the demand to do so in the current market.

2. Interest in City FTTP Network

Comcast would certainly consider leasing connectivity from the City *if* it ever had the need, according to Mr. Giles, and so long as the fiber connectivity is offered by the City on an open-market, non-discriminatory basis.

3. Perspective regarding City FTTP Network

Comcast's position is that these services and infrastructure should be offered based on market demand and investment interest, and Comcast does not see that situation here. In a context without a commercial rationale for a City-owned system, Comcast insists that the City would have to justify to taxpayers any effort toward fiber deployment.

Comcast's primary concern with the broadband market in San Francisco concerns its relationship with AT&T: specifically, Mr. Giles noted the unfairness of AT&T "locking up housing complexes" with exclusive service agreements.

Comcast is also concerned about some City activities that it perceives as bars to fast, efficient deployment, including permitting issues and the opportunity to locate cabinets of electronics in the public rights-of-way.

Comcast is also uncomfortable with the prospect that the regulator of the public rights-of-way would also be the owner of the infrastructure (or potential system operator or service carrier).

11.2 RCN

CTC staff interviewed David Hankin, RCN's Vice President for Regulatory and Government Affairs, on November 14 and December 11, 2006. All content in this section is based on those interviews unless otherwise noted.

1. Deployment/Upgrade Plans

RCN does not currently have deployment or upgrade plans for San Francisco. RCN received approval from the City to transfer its franchise to Astound Communications, and completed the sale of its Bay Area cable systems to Astound in early 2007

2. Interest in City FTTP Network

Mr. Hankin notes that a facilities-based provider such as RCN would be enormously benefited by the availability of open access fiber such as that contemplated by San Francisco in the context of this study and related efforts. Construction of fiber optics is extremely expensive, in particular in those areas where the fiber has to be built underground. In those areas, a new entrant could quickly and cost-effectively compete with existing providers by leasing open access fiber rather than facing the potentially-crippling cost of building an additional fiber network in the public rights-of-way.

According to Mr. Hankin, RCN's experience demonstrates the difficulty of a competitive provider reaching customers in areas where underground construction is necessary. If the City could give access to either conduit or fiber, Mr. Hankin says, it would facilitate more extensive competitive coverage at economically-viable expense to the competitor.

RCN's preference would be to lease dedicated fiber rather than shared fiber or conduit.

Mr. Hankin notes that RCN appreciates the City's recognition of the expense and complexity of new, competitive network construction. He notes that Comcast built out its initial network in an environment where the rights-of-way and utility poles were less crowded, there was no competition, and it was the first and only cable provider.

According to Mr. Hankin, RCN was the first competitive provider of telephone service in San Francisco since the original phone system was built a century ago, and the first competitive cable provider since the cable system was built 40 years ago. RCN offered a combination of voice, video, and data services from the time it began operations in San Francisco and, according to Mr. Hankin, Comcast has increased both speed and capacity in response to RCN's competitive products.

3. Perspective regarding City FTTP Network

RCN believes that significant financial and policy analysis is merited if San Francisco is to build a fiber network, but does not state any objection at this time. RCN itself would be interested in leasing capacity over a City FTTP system assuming agreement on terms and conditions.

11.3 AT&T

CTC staff interviewed AT&T External Affairs Area Manager Kenneth Mintz on November 14, 2006. All content in this section is based on that interview unless otherwise noted.

1. Deployment/Upgrade Plans

AT&T does not recognize a need for San Francisco to consider either wireless or FTTP infrastructure. The circumstances that would justify a municipal broadband project simply do not exist in San Francisco. Service gaps are perceived, not real, according to Mr. Mintz, because AT&T gives San Francisco residents and businesses access to:

- DSL , T1, and other copper based services from AT&T
- Fiber based services such as OptiMAN that deliver 100Mbps to 1 Gbps connectivity to businesses that will pay for it

According to Mr. Mintz, DSL is available in 95 to 98 percent of the community. In addition to having 10 Central Offices equipped with DSL capability, DSLAMs were deployed in many neighborhoods as part of project PRONTO.

Mr. Mintz does acknowledge that some areas do not have DSL, including Hunters Point Shipyards, but he represents that take rates for DSL in San Francisco are higher than in other parts of the country. Pricing for residential DSL starts at $14.99 per month for a 768 kbps service. No contract term is required with the service, however it does requite that the subscriber receives a local and long-distance telephone service (in other words, this price is only available as part of a higher-priced "bundle").

AT&T's planned U-Verse project will build fiber-to-the-curb in some selected areas and FTTP in new development (greenfields) areas. With U-Verse, AT&T anticipates that it can offer 20 to 25 Mbps (downstream) at some point in the next several years.

2. Interest in City FTTP Network

AT&T does not anticipate an interest in leasing or otherwise using City fiber.

3. Perspective regarding City FTTP Network

According to Mr. Mintz, where municipalities enter the broadband area, it is in response to a lack of broadband options from the cable and telephone companies. That is not the case in San Francisco, according to Mr. Mintz.

AT&T does not consider City involvement in leasing of dark fiber or fiber capacity to be a fair practice. It believes there is a conflict of interest because the City has regulatory control and yet will to compete with existing providers. In Mr. Mintz's opinion, the City can prevent or delay deployment of infrastructure by its competitors. (Mr. Mintz is extremely critical of the City's permitting processes and its concerns about large electronics boxes placed by AT&T on private lawns and in the public right-of-way.

AT&T also believes a City network to be a deterrent to investment. If the City deploys fiber, he asks, why should AT&T bother with any investments in the community?

In addition, Mr. Mintz notes that FTTP is not necessary to meet communications needs and a City project is therefore even more unnecessary.

Appendix 1: Technical Description of Carrier FTTP and FTTN Architectures

The following is a brief description of the carrier architectures for FTTP and FTTN. Section 1 describes Verizon's FTTP systems—many of which are already operational. Verizon has been constructing these systems in select areas for a number of years.

Section 2 describes AT&T's stated FTTN architecture known as "Project Lightspeed." It is significant to note that this technology has, by AT&T's own account, been activated only in portions of San Antonio and Houston, TX. AT&T will not disclose what other areas are currently being upgraded with this technology.[128] Given that AT&T has been touting the technology for a number of years, there is cause to doubt whether widespread deployment is actually imminent.

1. Carrier FTTP Architecture

Verizon is deploying FTTP in limited parts of the US – in other areas, it has chosen to rely on its current copper plant and DSL technology. FTTP is planned for deployment by AT&T only in new build areas (including the Mission Bay area of San Francisco), at least to date.

FTTP is a flexible and capable technology. Compared to other forms of communications transmission, it boasts the highest theoretical capacity per user. It makes possible a wide range of potential applications and services, and enables the RBOC to constantly upgrade capability and capacity simply by upgrading end equipment and software, while using the same fiber cable.

Localities that experienced recent Verizon builds underwent the largest communications builds in the ROW since cable systems were first deployed in the 1970s and 1980s. In these builds, fiber is constructed down every street, major or minor, where there exist potential customers – both business and residential.

Network designs call for expanding existing RBOC backbone fiber rings to deploy fiber throughout the system, replacing existing copper all the way to the curb (and into the homes of those customers who subscribe). This scope is significantly more burdensome to the ROW than were the cable upgrades of the late 1990s, which deployed fiber deeper into the systems but tended to touch only major arteries, not all rights-of-way. In Montgomery County, Maryland, for example, a community of just over 900,000 people, Verizon constructed more than 1,000 miles of fiber in a couple of years, in a densely-populated suburban area.

[128] CTC interview of Ken Mintz, AT&T Area Manager, External Affairs, November 14, 2006.

FTTP Architecture

At the neighborhood level, the usual FTTP architecture calls for backbone fiber on the primary arterial streets, which meets the local distribution fiber at a cabinet placed in the ROW. The local distribution fiber then travels from the cabinets to pedestals or pole enclosures in front of the homes and businesses throughout the community. Depending in part on whether they are backbone or distribution plant, the cables typically contain 24 to 432 strands of fiber.

With respect to new electronics in the ROW and at customer premises, this architecture generally calls for:

- Optical Network Terminal (ONT) boxes on the outside of subscribing premises
- Passive (non-powered) Fiber Distribution Terminals (FDT) in pole enclosures or pedestals
- Passive (non-powered) Fiber Distribution Hubs (FDH) in cabinets

FTTP Services

FTTP systems are capable of delivering a wide variety of high-bandwidth applications and services, including analog and digital **video** (viewable with or without a set-top converter, depending on whether IP or cable-based technologies are used). Standard cable-style signals are available from a port on the ONT.

These FTTP systems are theoretically capable of providing up to 1000 Mbps of **data** per customer, though current Verizon plans call for five to 30 Mbps downstream and two to five Mbps upstream. Hardware and software changes make possible increases in throughput without modification of outdoor fiber plant.

The systems are capable of both circuit-based and IP **voice** services of quality comparable to traditional phone services. The system is powered from both the Central Office (CO) and the home, but the customer is now ultimately responsible for powering – an important distinction from traditional phone networks, which powered the phone line from the CO down the copper phone line. Fiber does not carry electrical current, so backup powering is now required at the customer premises—if power goes out, the system's only backup is a battery located at the home that will typically last four to six hours.

FTTP Construction

Aerial construction entails overlash of fiber to the existing strand, spliced at new splice enclosures. For new subscribers, the technicians install new drop cable (and remove old copper lines) at the time of installation. They also install an ONT at the premises and connect to existing power, home cable, and telephone wiring.

Underground construction entails construction of new conduit in public utility easement and to the home and installation of fiber cable in that conduit. In addition, there is installation of cabinets for FDH, new pedestals for FDTs, and an ONT on the customer premises.

2. FTTN

The FTTN architecture planned by AT&T Project Lightspeed (and potentially by Qwest and Bell South[129]) is actually the next generation of Digital Subscriber Line (DSL) technology known as VDSL or enhanced DSL.

VDSL Architecture

In many existing areas (as distinct from new "greenfields" developments, which, like Mission Bay, may see FTTP construction), AT&T has stated that it plans to deploy this VDSL architecture. Fiber will be deployed to the node, but this architecture calls for retaining up to 3,000 feet of existing copper lines from the node to the home or business. The reason for implementing VDSL is clear—AT&T is avoiding the enormous expense (and time) to construct fiber down the majority of rights-of-way and to the premises. The actual fiber construction contemplated is a fraction of what Verizon is doing in its FTTP builds.

AT&T represents that it plans to build backbone fiber on primary arterial streets. The fiber will terminate at a powered DSL Access Module (DSLAM), which will be housed in a large cabinet comparable to the size of a refrigerator. The DSLAM provides the interface between the backbone fiber and the existing copper, which travels from the DSLAM to the home or business. A Home Gateway at the dwelling or business will connect with existing cabling in the premises. The cabinets will house the DSLAM, batteries, and fiber/copper terminations.

The cabinets will be placed in the ROW approximately every 3,000 feet or so in order to make feasible an architecture that requires up to 3,000 feet of existing copper from DSLAM to Home Gateway. These cabinets are far larger than those necessary for the FTTP builds described above.

VDSL Services

Voice, video, and data will be transmitted (actually, streamed) in Internet Protocol (IP) packets. IP represents the best mechanism for trying to stretch the limited capacity of AT&T's dated copper plant. Additionally, voice may be provided simultaneously over the line using analog telephone technology.

The planned systems will require an IP set-top converter for each television and will offer very limited bandwidth for video. The copper lines carry only a few channels at once—and perhaps no more than one HD channel at a time.

---

[129] As of this writing, AT&T and Bell South have recently received regulatory approval of their proposed merger. Once the merger is completed, some Bell South systems would potentially be included in the same upgrade plans as AT&T networks.

The theoretical data capacity of this architecture is up to 25 Mbps per customer. At the moment, however, AT&T plans to offer one to six Mbps downstream and up to one Mbps upstream. The remainder is required to offer video.

IP voice services will convert to standard telephone signals at the Home Gateway, which interfaces with existing phone, data, and video cabling. It also contains a built-in wireless interface. Power for IP voice will be inserted at the CO, the DSLAM, and at home, and--as with FTTP—the customer is responsible for powering in the event of an outage. Built-in battery backups at home will last only four to six hours. If voice is provided using analog telephone technology, however, the voice service will continue to operate in the event of an outage.

3. How Does Cable Compare?

A rapid evolution is expected for all these technologies, but it's safe to say that cable systems (which use a mix of fiber and coaxial cable) and FTTP systems (which use fiber) will not require the same future construction as will VDSL (which relies on that old copper).

With respect to current services, cable modem **data** speeds are currently faster than VDSL but slower than FTTP. This hierarchy is likely to remain true, because fiber has the highest theoretical speed limit. In the area of **video**, cable and FTTP operate similarly in that they simultaneously bring all channels to each premises, and the subscriber can choose among all available channels. VDSL is somewhat different—it uses IP video to stretch the transmission capacity of copper and therefore provides only up to a few channels at once—those selected by the subscriber at that moment.

With respect to **voice**, all these networks are capable of carrier-grade quality. All FTTP voice systems require power to be inserted at the home, as do some cable voice products. Generally, cable voice provided over IP will require home powering. In contrast, for the most part, circuit-based cable voice will draw power from the cable system and not require home powering. Similarly, voice provided over VDSL using analog telephone technology will not require home powering.

The limitations of VDSL are likely quickly to be reached. From a technical standpoint, "Project Lightspeed" is a short-term solution in a market where bandwidth needs are growing exponentially and high, symmetrical capacity is increasingly needed for popular emerging applications like gaming, video-gaming, video-downloads, and video-conferencing. AT&T's 100 year-old copper plant is not capable of meeting these needs in the long-run – no matter how sophisticated the electronics become.

Appendix 2: Columbia Telecommunications

Columbia Telecommunications Corporation is a public interest communications consulting firm, specializing in business, policy, and engineering consulting services for public sector and non-profit clients. Since 1983, CTC has worked with the full range of existing and emerging communications technologies to provide services in strategic technology planning and deployment; communications network assessment and implementation; and project management.

During that time, CTC has provided communications engineering and other consulting services to such jurisdictions as Los Angeles, New York, Washington, DC, Seattle, Milwaukee, Cincinnati, Pittsburgh, Philadelphia, and San Jose—as well as numerous other communities. We have assisted many of these jurisdictions to plan, negotiate, and deploy state-of-the-art broadband networks – and to maximize public and community benefit from communications projects. As the technology and business models have evolved, our work has evolved to include numerous community broadband networks—both wired and wireless—throughout the country.

As a matter of policy and in order to provide clients with independent and unbiased advice, CTC declines any financial relationship with communications carriers and equipment manufacturers.