Fiber Optic Asset Inventory and Management
Identification of Opportunities

Abstract

Centennial Colorado's existing fiber optic networks initially serviced the Intelligent Traffic System. In its construction little thought was given to future needs unknowable at that time. This report discusses what has been built, approximately 27.433 miles of primary fiber and 28.231 miles of empty and available conduit, and how it might be used. The report identifies recommendations for managing fiber, both in process and tools. It identifies start-to-finish workflows, procedures and protocols. Recommends standards and opportunities in Right-of-Way (ROW) permitting processes and the necessary reporting requirements for those that use and build in those ROWs. This base information is then combined with knowledge gained from citizens in various meetings and market surveys. Adds perspective in identifying the competitive communications environment found in Centennial today. It augments findings with knowledge gained from other municipalities as they have addressed the communication needs of their citizens. Finally, it identifies opportunities that the City may choose to leverage in the years ahead. Support for regionally based Public Safety. Support for fiber access for small to large businesses seeking higher and more reliable speeds. It also proposes how the City may wish to combine these developments with its citizens' desire for fiber-to-the home (FTTH).

Prepared By: Lookout Point Communications
Eric Lampland

New Com Technologies
Jim Petro

April 2015

Table of Contents

1. Executive Summary 1

2. Asset Management and Asset Inventory 4

2.1. Review of Systems & Processes 4

2.2. Fiber Management System (FMS) Recommendations 4

Assessment for Fiber Management System: OSPInSight 6
Human Resource Recommendation to Maintain FO Documentation 7
Hardware and Software Recommendations 8

2.3. Right of Way Permit and Collocation Opportunity Process 8

Review of Current Administrative Regulations 9
Regulations Recommendations 9
Collocation Policy Terms 9
Permit Process 9
Collocation Letter 10
Record of Collocation 10
Process Work Flow 11
Fiber Sheath Usage Agreements 11

3. Identification of Opportunities -- Data Collection 12

3.1. Nationwide Municipal Models 12

3.2. Competitive Analysis 19

3.3. Codified Results of Interviews and Citizen Survey 30

3.4. Summary of Centennial Fiber Infrastructure 41

3.5. Legal Criteria 45

4. Opportunity Considerations 46

4.1. Three Recommendations 47

4.2. Technology Components and Approach 50

Transport Infrastructure 51
Wireless Infrastructure 52
Cloud Based SDN/NFV Management and Control Structure 52
Fiber-to-the-Premises and SMB Business Support 53

Appendix A: 55

OSPInsight Materials Data Sheet 55

Appendix B 1

Collocation Process Work Flow 1

1. Executive Summary

Bold digital entrants disrupt entire industries and business models today. More and more companies are at risk of extinction. Music, retailing, media, travel, not to mention books, bookstores and how we read and collect information, are far along this path, but we are also seeing similar patterns in more traditional industries, such as banking, agriculture, energy, healthcare, industrial goods, and manufacturing. Business model disruption significantly impacts communication service provider industries; ever more so as dependence on these services and providers increase. John Chambers, CEO of Cisco, recently commented about the communications industry saying: "as many as *half of today's service providers could become "irrelevant"* during the next ten years." In a changing society, with market failures and market opportunities so mixed, how do municipal governments respond? It is not an easy question with clear solutions.

The Centennial City Council in seeking solutions issued a request for this study. The intent was two fold. First, gain a better understanding of existing City fiber assets. This is referred to as the Asset Inventory and Asset Management. Second, gather knowledge of the City's communication environment, national municipal models and actions, local completion, inputs from stakeholders and citizens and develop a set of possible choices or opportunities leveraging City fiber – an identification of opportunities.

Asset Inventory and Asset Management is covered in Section 2. In addition to this narrative Esri GIS data has been compiled following extensive review of Centennial fiber build permits, agreements executed with fiber/conduit partners and fiber construction documentation. The City's fiber was documented and then field verified. Additional work is still ongoing to test fiber stand quality, determine actual splice connections and their use. It is hoped that this will be completed soon.

Of particular interest in Section 2 are recommendations for a City Fiber Management System and Right-of-Way permitting process modifications. It is hoped that these recommendations will serve to better ensure future management of this valuable asset.

In Section 3 we discuss what other municipalities have done. What business models have been employed? Who has had success and who has struggled? A competitive review of providers within Centennial examined thirteen fiber providers that support businesses and, of course, the primary legacy providers; Comcast and CenturyLink. Also included in the competitive review are national comparisons. The core observation of Centennial's environment is that services here are *sporadic, geographically inconsistent, varying from poor and inadequate to robust, reasonable and of high quality – and in all cases, provider offerings are priced higher than similar or better services nationally*.

Within this section we add certain detail to highlight this conclusion. A few of those observations are that over fifty-eight percent (58.38%) of Centennial citizens report

Internet speeds that are less than the 25Mbps minimum standard set by the FCC for broadband. Centennial citizens pay more for poorer services than are available elsewhere from both municipal and private sector companies. Although Centennial is served by most of the national fiber providers, only 675 companies out of 3,361 facilities based firms have identifiable fiber to their buildings. Sixty four percent (64.21%) do not. It was not surprising to hear of the needs expressed by residents and businesses.

In Section 3 we also document a series of interviews held with different stakeholders such as Public Safety (Police and Fire), Education, Business Leaders and their Councils, the current legacy providers Comcast and CenturyLink and, of course, City staff. Following discussions with citizens at two District meetings a survey was made available to all citizens. The response was excellent, providing a statistical value that correlates with a 99% confidence level and a 4.7% +/- confidence interval.

The survey confirmed much of what we were uncovering – sporadic, geographically inconsistent services. Residents complained about price and speed. In comparison to other communities their complaints are well founded. It is true – they are receiving less and paying more than others nationally. What was most interesting to observe is that they have solid knowledge. They are technically proficient and aware.

Asked what they would like the City to do. Their answer was resoundingly clear. ***The citizens of Centennial overwhelmingly want FTTH according to this survey by almost eighty-six percent (85.96%).*** More lean toward the City providing services than people who would like to enable partnerships for service, but the direction is clear.

The report then goes on to describe the fiber structure that we now have some confidence in – where is it, what is usable, how can the City leverage this asset. Currently the City has approximately 27.443 miles of fiber, most usable, and 28.231 of available conduit to which fiber can be added relatively inexpensively. We provide detail on pertinent issues in Section 3.4.

Section 4 concludes with recommendations on how to leverage current fiber assets and address the issues that are key to the City's success: economic development through support of the business community and support of citizen desires. We ask you to consider the long view and develop strategies that are in concert with the importance and longevity of fiber communications.

We recommend three tiers to anchor your decisions.

- ✓ Collaborate regionally both to leverage assets and empower public safety and education.
- ✓ Manage communication structures responsibly knowing that what is of interest today will fade, become ordinary, and be replaced by new needs, new ideas. This requires knowledgeable in-house staff, a single point of contact and focused attention.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

- ✓ Focus on inclusion. Everyone needs communications today. The approaches to individual segments of the community may vary, but all sectors require attention. The communities that stand above others – in economic development, quality of life and attraction – build fiber to every home and business today.

We are just beginning to see the changes that are coming. Many others we will not see for a while. Be prepared to adapt. Build structures that can change and morph; ones that are efficient and responsive.

Finally, we end with a set of approaches that we feel will leverage your fiber assets, be of benefit to public safety, to business and to citizens. We recommend using your fiber to build:

- ✓ Transport Fabric: Build series of meshed rings constructed as a transport network. The transport fabric would have strategically placed points of distribution, support the new ITS functions and those capacities mentioned next. The additional capital investment in new fiber is roughly estimated at $855,733. This transport network will serve Centennial for years to come.
- ✓ Wireless Fabric for Public Safety and City Purposes: The transport fabric can be overlaid at a very low cost in support of wireless networks for public safety; both WiFi and LTE signaling can be supported.
- ✓ Support Business: Small to Large: Using the distributed structure on the transport network the City can cost effectively offer a variety of technologies in support of business: carrier WiFi access for very small enterprises to full fiber-based advanced services, such as bandwidth-on-demand, for large enterprises with complex needs. Business support can complement, even partner with, existing providers of fiber and services – filling needs where others do not choose to provide. The City can support business of all sizes – small ones that might grow, big ones that need much.
- ✓ Enable Neighborhoods that seek FTTH; Finally, we recommend that neighborhoods be allowed to build FTTH – supported by this transport network. Let neighbors come together and form "neighborhood centric" commitments to build FTTH. With pre-signup commitments they can overcome the primary hurdle to success: valid take-rates. They can also choose, and change, whom they wish to provide services: local companies or current legacy providers should they choose to partner. Because the City has sporadic coverage, certain neighborhoods will collectivize sooner. The City should support this process technically and provide advice on funding alternatives. Funding and ownership will remain with each neighborhood collective. With knowledgeable City support, citizens will be able to build sustainable infrastructures that will last for decades.

We believe these findings and recommendations will serve Centennial well. They will require asking hard questions. They will take effort and close attention. We wish you well as you consider your actions.

We are called to be architects of the future, not its victims.

R. Buckminster Fuller

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

2. Asset Management and Asset Inventory

The City of Centennial contracted with NewCom to provide services for development and recommendations to provide guidance for the City's Fiber Initiative. Specifically the City requires execution and delivery of a fiber optic asset inventory and asset management program that this Section addresses.

The City of Centennial has installed several miles of fiber optic cable infrastructure for Intelligent Transportation System (ITS) purposes. At the conclusion of the installation, the City was unable to obtain all the information required to fully understand the details of the fiber network; splices, dark fiber, conduit, spare conduit, and hand holes. NewCom Technologies initially examined all City documents related to fiber and conduit information. It then deployed field personnel to perform an inventory verifying all features of the fiber optic network.

The City has also asked for an evaluation and recommendations to City processes for Right-of-Way and Permitting. Finally, the City requested a recommendation concerning fiber management to augment the ESRI GIS systems that would provide the most beneficial process to maintain this vital network data.

2.1. Review of Systems & Processes

NewCom met with the City GIS department November 20, 2014, to conduct an on-site review of the City's fiber optic system documentation, software and hardware systems, GIS data and storage, current uses of fiber network, policies, procedures, and human resources devoted to managing the City's GIS and permitting processes. The results of this review were used to recommend facility documentation, software recommendations and human resource needs.

The evaluation has included review of:

- City Intelligent Transportation Systems (ITS) and databases
- City Information Technology (IT) systems and databases
- Geographic Information Systems (GIS) and databases
- Hardware
- Software
- GIS uses
- GIS data schemas
- Geodatabase storage and permissions/policies

2.2. Fiber Management System (FMS) Recommendations

Best Practices

NewCom has used and developed a full complement of spatial-data applications for documentation and management of critical infrastructure information and utility management. More than 157 clients, including 64 municipalities, have benefitted from implementation of NewCom recommended applications for management of overland assets. From one-acre cemeteries to 30,000-mile fiber optic communications

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

plant, NewCom has always used the latest iteration of overland asset management tools.

NewCom currently uses various spatial data programs to design telecommunications plant. Many are based in CAD, but telecommunications industry norms are moving toward engineering in GIS-based (specifically ESRI) platforms. Centennial also uses ESRI GIS systems. The GIS-based programs provide integrated tools to design, document, operate, and provision for inside and outside plant management requirements.

During our 20 years of spatial data-management and telecommunications engineering we have used or reviewed multiple technology tools. Many of the network data management programs in use are operator specific, as well as adaptations of platforms used in the power industry. However, controlling for reasonable price, ease of use, company stability and measuring our experiences with various FMS platforms, we have listed below the products considered best suited for fiber optic telecommunications network management.

Table 1: Prominent Fiber Management Systems (FMS)

FMS	Description	NewCom Experience
OSPInSight	Esri-based facility engineering tool for fiber optic networks. Used extensively in FTTH design for fiber assignment and tracking. Basic price starts at $10,000	Deployed by Consultant for UC2B and Zayo. Software is also used internally for clients, with no FMS, to design and document initial fiber network connectivity, permit & construction drawings, as well as BOMs
Network Engineer	Esri-based facility engineering tool for fiber optic network. Establishes facility management. Used by Tier 1 multi-system operators for network management, basic price starts at $40,000.	Deployed by Consultant for PAETEC (McLeod)
spatialNet	Esri geodatabase with an AutoCAD user interface. A facility management platform used in broadband industry for design and drafting of networks. Used by Tier 1 multi-system operators for network management, basic price starts at $40,000	Deployed by Consultant for Mediacom, Cable One. Cable One contracts with Consultant to engineer New Build Extensions as well as maintain design data in the FMS

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

3-GIS Web	Esri-based facility engineering tool for fiber optic networks. Used extensively in FTTH design for fiber assignment and tracking. Basic price starts at $30,000	Deployed by Consultant for confidential client

These GIS-based fiber asset management systems provide the ability to archive placement of the support structures such as handholes, manholes, duct banks, and innerduct, as well as the fiber sheath and connectivity. These systems also provide the ability to store test records of the network and provide circuit-tracing capability.

Assessment for Fiber Management System: OSPInSight

We are recommending OSPInSight (please see Appendix A: *Materials Data Sheet)* fiber management system (FMS) for the City's consideration. OSPInSight is an optimal solution to manage the City of Centennial's current and future fiber assets. It is tightly integrated into GIS and the user interface works well for staff with basic GIS skills. It is also moderately priced and integrates well to the SDE environment.

The current system in use by the City for fiber documentation is sufficient for the point-to-point network; however, a transport, wireless or FTTH network will require more sophisticated processes for managing the network assets. OSPInSight supplies functionality, not only for fiber design, but also for operations (e.g. tracing and trouble-shooting capabilities).

OSPInSight is an easy to use and versatile FMS that provides the Operator detailed information about every aspect of fiber optics. Network data is retrieved from a relational database and is displayed in tabular and graphical formats. OSPInSight is a full-service FMS that not only aids the technicians in the field, but also provides essential information throughout entire the network operation.

While a specific database schema is platform specific, there are sufficient user defined fields to enhance the implementation. Also, OSPInSight has a database structure that can be easily manipulated for custom reporting.

NewCom currently uses OSPInSight as an internal fiber design and documentation program for clients with no FMS in place. The platform is used to efficiently design and document initial fiber network connectivity, permit and construction drawings, as well as Bills of Material (BOMs).

OSPInSight is a direct plug-in to ESRI ArcMap. It is a reasonably priced platform by comparison to others NewCom has used and reviewed (please see Table 2). License costs for installing OSPInSight for Centennial are estimated as follows:

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Pricing: FMS Implementation

Table 2: OSPInsight Pricing

Without an ESRI ELA	License	License Renewal
OSPInsight-Edit (1 Seat)	$10,785	$2,050
OSPInSight-View (1 Seat)	$5,745	$1,090
ArcMap Standard (1 Seat) for use with OSPInSight-Edit	$5,000	$1,800
ArcMap Basic (1 Seat) for use with OSPInSight-View	$950	$450
Work Station	$1,800	$0

With an ESRI ELA	License	License Renewal
OSPInsight-Edit (1 Seat)	$10,785	$2,050
OSPInSight-View (1 Seat)	$5,745	$1,090
Esri ELA	$36,000	$36,000
Work Station	$1,800	$0

Human Resource Recommendation to Maintain FO Documentation

NewCom recommends 1 FTE for data management and updates in the FMS. Alternatively the City may wish to contract data entry of the co-locations, new support structure, internal project additions and modifications. NewCom currently manages telecommunications network expansion and as-built services for multiple clients, and we offer that service to the City as well.

The City should consider whether support personnel should be augmented within the existing GIS Department – the normally accepted and recommended approach or contracted to outside personnel. Estimated cost for existing activity is:

- 1 FTE (Weighted Salary) $49,661

or

- Contracted Hourly (~500 hours @ $85 per hour) $42,500

It is important to note that the volume of expected hours will increase dramatically should Centennial consider supporting neighborhood based FTTH.

Data Storage Requirements

Centennial currently has SQL Express 2012, which has a 10GB space limitation, as well as being limited to 10 concurrent users. The City's GIS data is presently consuming approximately 1.5 GB of space with 2 GIS users. We expect the FMS to consume less than 1GB of space, leaving 7.5GB – sufficient storage for future expansion.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

The City's SQL Server 2012 environment has 16TB scalable virtual environment. If the City decides to purchase an ESRI ELA license (as recommended), then the GIS data could be moved to the SQL Server and the SQL Server Express can be retired.

Hardware and Software Recommendations

Having both the fiber network and other city GIS data on the SQL Server would also reduce license maintenance costs if the City purchases an ESRI ELA license. The cost savings from the ELA would be realized by eliminating the necessity to purchase additional basic seats as more of the City's GIS master plan is activated.

The City currently has ArcGIS Server Workgroup Standard, ArcGIS Desktop Basic (4 licenses), ArcGIS Desktop Advanced (2 licenses), and ArcGIS Online. The yearly maintenance cost to maintain the separate licenses is $21,500.

NewCom recommends an upgrade to ESRI Enterprise License (ELA) to accommodate OSPInSight and future planned GIS expansion. The ELA represents $14,000/year in additional maintenance costs compared to the City's current licensing requirements (provided the City uses the Colorado State renegotiated ELA license). However, the City will receive unlimited licenses for both the Server and Desktop, which allows for future expansion with no incremental software costs as you add users.

The FMS will require a dedicated workstation.

OSPInSight-View is recommended for ITS. This viewer gives the user the ability to see specific asset placements, inventories, route and splice schematics. If ITS requires more detail than View allows, that information would come from the GIS department.

2.3. Right of Way Permit and Collocation Opportunity Process

Currently the City of Centennial has within its administrative regulation a collocation policy in instances where construction activities are being proposed within the right-of-way, which involve directional boring, or open trench. The regulation allows the City to evaluate the proposed construction for possible collocation opportunity and as a condition of the issuance of the Permit, direct the Permit Holder to install a conduit system within the intended construction path. The City will bear the incremental cost of the collocation installation and hardware and also provide reductions from the normal permit fees.

Consistent with this policy, the Permit Holder must mark the surface of the collocation path alignment so that the City may verify and record the location of the conduit(s) and pull boxes or vaults.

Our review of city policies related to right-of-way (ROW) utilization and policies show wide variations across the United States. These variations are largely due to the demographics and growth of communities and competition in telecommunications. In an underground environment, cities are developing policy to help manage ROW utilization. In Cities with high development growth, such as

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Sandy, OR and Poulsbo, WA, there are regulations in place which require developers to place a telecommunication conduit system at time of construction and deed the infrastructure to the City. The benefits can ensure all telecommunication providers have reasonable access to the city's ROW reducing the barriers to entry for a competitive environment. Other communities have reserved space under sidewalks to ensure it has a clear path for its own future infrastructure. While others require placement of additional conduits for city use at no cost. From an operators' point of view, these are expensive policies and usually result in litigation by large service providers.

We believe the current policy with the City of Centennial has in place is fair to the operators and advantageous to the City. The policy supports a competitive environment; provide its citizens and business with better services. This policy has great value to the City as it represents a considerable cost savings to install underground support structure in strategic areas. Furthermore, it maximizes the space utilization of the City's public rights-of-way (ROW).

Review of Current Administrative Regulations

The City of Centennial's Public Works Department has its administrative regulations embodied in document *No. 2014-PW-01 Work Within The Right-Of-Way*. This document relates to permit requirements for work planned or otherwise within the City's rights-of-way (ROW). The terms and conditions of the permit are detailed under section 4.0 Permit Conditions. More specifically, Section 4.2 addresses collocation of City infrastructure with the Permit Holder's infrastructure.

The Collocation policy terms seem to be inconsistent with other elements of the permit process, such as the infrastructure required to be placed. In addition, it is silent on such things as as-built drawings reflecting final placement of new infrastructure, even without collocation.

Regulations Recommendations

The following are recommendations, which may improve the regulation, its administration and record management. These recommendations are based on records that have been used to develop the City's conduit support structure and fiber network in GIS and our development of recent field survey findings.

Collocation Policy Terms

1. Supplement the required conduit system to include a pull rope and pull boxes as determined for the specific project.
2. Require installed conduit to be tagged with a City Asset tag.

Permit Process

3. Drawings provided as part of the permit application should be dated. Many drawings did not contain a date within the document set.
4. Require the Permit Holder to provide as-builts of the project within a reasonable period (30-45 days) of City's acceptance of the work performed within the ROW. The as-builts should include the City's infrastructure. As-builts should be dated as well.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Collocation Letter

5. Include a detailed description of the project and its location. Past records either did not accurately describe the project extents or referred to a high level plan provided by the Permit Holder.
6. Recommend minimum conduit diameter of 2".
7. Recommend consistent inclusion of duct "size" with locate wire and pull rope.
8. Consider including a redline of the applicant's drawing that calls out the extent of the collocation and pull box locations. This should be saved as part of the document archive.
9. Formalize acceptance from applicant, agreeing to terms of collocation.
10. Remove automatic date field from letter Word template and hard code it. This field is set to update when the document is opened, negating the ability to track the project chronologically.
11. Recommend a formalized acceptance process. There is not a mechanism to track acceptance of the collocation request by the applicant. Consider a multi-part letter that requires the applicant to execute the terms of the collocation.

Record of Collocation

Once the City has negotiated a collocation agreement, the agreement terms should become a visual record within the City's GIS. This can be a high level digitization of the planned collocation, performed at the conduit level based on the Permit Holders initial plans. By doing so the City will have a graphical representation of the area where the collocation will occur and aid in decision process for other collocation. NewCom suggests that the City adopt a feature LifeCycleStatus in GIS. This will allow features to be coded as to their state. The recommended states are:

- Planned
- Constructed
- As-built
- Abandoned

As the project progresses to completion and acceptance, and field reviews concluded, the GIS system can, and should, be populated with the preliminary plan version or a redlined as-built version of the project. Data should be appropriately attributed to capture the completion date of the project.

GIS data should include the original builder name, date installed, reference to folder containing collocation agreement and as-builts of project.

Findings from our field survey suggest that contractors may not have provided necessary surface markings, or the City had not conducted appropriate follow-up on the acceptance process. We strongly recommend a complete review and documentation of the network once City is provided with a notice of completion.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Process Work Flow

A process workflow provided by the City of Centennial has been edited to reflect recommendations to the permitting/collocation process (please see Attachment B).

Fiber Sheath Usage Agreements

During NewCom's discovery process, it was determined that there was little information in place as ownership of the fiber sheath or who the City had agreements with to use City fiber, or for the City to use another's fiber network.
To this point, it is import to document and maintain in a centralized location, the owner of the fiber sheath and the terms of any usage agreement. Splice closure ownership within the network should be documented as well.

The GIS data schema should reflect Owner, IRU Agreement Contract Number, number of fibers and buffer tubes for City Use, the number of fibers and their buffer tubes used by others.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

3. Identification of Opportunities -- Data Collection

Understanding the competitive markets today is a challenge. Change is swift and often confusing. To properly construct a collection of data, with the intent to inform, presupposes a question or questions. What are the purposes for which the information is valuable? There were a series of such questions arising as this data collection and as analysis proceeded. Some were concerned with reduction of costs or improvements in public services. Others were oriented toward economic development and the long-term viability of the City. When citizens were solicited, the questions were often more direct – not a question, but a statement of need. Their expressions captured the essence of purpose: "How is it that we wish to use communications to enhance our lives and work?" Moreover none of these questions can be answered without contemplating who would be responsible, and using what mechanisms, to affect change once we knew what desirable directions change was taking.

In this section we will first address what others have done. Communities across the United States have had success with various different models. We will attempt to convey this very large body of knowledge and as briefly as possible. Next we will outline the competitive environment in Centennial itself and follow that with data collected in interviews and surveys of stakeholders and citizens. The competitive analysis includes definition of what providers are here, what services do they provide and at what price. It also includes information gathered from the citizen survey, which yields a perspective on the differences between "advertised offerings" and in-practice utilization. Included at the end of this section is identification of some basic trends in communications today. A caution: data collection such as contained in this section cannot cover all that is occurring in the highly dynamic communications markets, nor properly address the ever changing, ever learning, efforts of those pushing forward into tomorrow's landscapes. For the City of Centennial, this is a point-in-time rendering. In contrast, however the City proceeds, it will be a multi-year effort needing constant awareness and adaptability.

3.1. Nationwide Municipal Models

Nearly every municipality that has examined the opportunities in fiber optics began with economic development as its justification. Those that actually built such networks have been rewarded handsomely. In the last few years the tide toward municipal builds has accelerated and morphed under a clearer realization that legacy providers are not particularly responsive to local pressure. The motivation, guiding intentions, of legacy providers is toward profit maximization. To be clear, legacy providers *should* be conscious and focused on total shareholder return (TSR). After all that is what they are in business to do. Consumers, however, have a different perspective. They, and the cities that support them, view fiber optic networks, and all that they provide, <u>as a necessity</u>, not simply as a way for others to make money.

This dichotomy of purpose underlies the frustration felt by many today. Municipalities wish that providers would understand and invest in their communities. Providers have different purposes and do not respond until threatened. Lately the threat has come from Google's efforts, sometimes

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

municipalities must act or threaten to act themselves. Take, for example, the recent improvements in services – increased bandwidth primarily – from legacy providers in Colorado. Providers have been responsive in communities that explore their options. This was true following the vote in November 2013 in Centennial. But make no mistake, when threatened competition wanes, so will provider interest. Elsewhere cities have waited longer – voting to take action, becoming quiescent in the face of promises, and subsequently realizing they never would receive promised commitments other than those to themselves. Then they build.

This mixture of motivations – compounded with needs for economic development and simple necessity – is true in Centennial. It was clear in the interviews with stakeholders and citizens that both economic development and loss of patience with providers pertained. Small business reported paying for T.1 service; a technology so old, so slow and so expensive it has all but disappeared – except here or rural communities. The *majority* of residents are receiving broadband services that are less than the FCC minimum requirements today. Centennial's reputation as a technology literate community is not evident from the services people and business receive. It was also true that areas of improvement to public sector functioning were desired and should be achievable.

For those that have walked this path a few common observations emerge:

- Economic Development improvements are the norm in cities that take action on fiber networks – with substantial contributions in most cases.
- Economic development occurs most strongly in communities that extend fiber to everyone: residents and well as local and new businesses.
- There is a high probability of success. Over four hundred cities have been successful while only a few have not done well.
- People served by municipal networks, especially gigabit networks, report being highly satisfied.
- People without are not – ranking cable and telephone companies low in their esteem.
- Multiple models are possible. There are no one-size-fits-all approaches.

The common models are:

Retail Models

Retail models are those that provide services (telephone, television, Internet access, healthcare, education, home security, etc.) directly to businesses and residents.

a) Municipal Utilities: City public utilities, providing a range of electrical, water, sewer and other services, have created telecommunication divisions and supported their communities. The public utilities have experience in customer service, billing and the operational impacts that telecommunication services require. Utilities are fluent in long-term financing and understand infrastructure. They benefit from the separation of a "services business" and politics; and have separate boards. Some of the most successful municipal networks fall into this category: Chattanooga Tennessee, Lafayette Louisiana, Cedar Falls Iowa and over

two hundred (200) other communities. In Colorado, Longmont Power and Communications is implementing fiber-to-the-home (FTTH) today. Most, but not all, of these communities provide FTTH. Many utilities began in the 1980s and 1990s when Hybrid-Fiber-Coax (HFC) was the best technology available. A good number of these early HFC networks are currently migrating to FTTH.

b) Cooperatives: Similar in nature to public utilities are cooperatives. Cooperatives are often formed by local political action. For example, RS Fiber in Sibley County Minnesota is a collection of ten communities, forming a coop, which began in the same manner as Centennial is currently doing, with an examination of choices. The scope and attitudes of coops are highly similar to public utilities. Their purpose is to serve their communities first and ensuring sustainability over the long haul. Total shareholder return is most often a secondary goal. Chibardun Telephone Cooperative (now Mosaic) led with FTTH in the west central area of Wisconsin. Others such as Federated Telephone Co-op of Minnesota have been instrumental in expanding to surrounding areas providing economic growth to a region. Still others, such as CO-MO Electric Cooperative in Tipton Missouri are just beginning to build. Like public utilities, these models have been highly successful.

c) City Owned and Operated: City owned and operated networks have had good track records; especially when there is a separation between day-to-day operation and oversight requirements. These are often structured as quasi-governmental structures. Powell Wyoming, Wilson North Carolina, Kutztown Pennsylvania, Sallisaw Oklahoma and many more have established municipal networks. It should also be noted that the few communities that are pointed to as having success issues have been within this model type: Burlington Vermont, Monticello Minnesota, and Provo Utah. The lessons from these communities are clear. Be careful of mixing balance sheets, politics, and/or short-term issues into the operation of a municipal network. Get solid technical and operational advice. Be wary of the private sector's motivations to help or hurt. Do not delegate key decisions to managers who do not posses appropriate knowledge and experience. Hire well. In fairness to these few struggling cities, over 6,000 independent competitive carriers have failed during this last fifteen-year period. In contrast then, the publicly supported efforts have experienced a significantly better track record than private business.

Wholesale Models

Wholesale models are those networks that provide connectivity via "lit" fiber or "dark" fiber. "Lit" fiber means that the City buys and operates the network equipment and connects customers. "Dark" fiber means that the customers buy equipment and operate their individual fiber segment(s), or strands; usually the City maintains the fiber. In this model, and in almost all cases, the customers are limited to businesses, governmental entities or occasional non-profit institutions such as healthcare.

a) Non-Profit Cooperatives: Cleveland One is one of the premier non-profits that were assembled in this manner. Now called OneCommunity this non-profit runs lit fiber for the northeast Ohio hospitals, schools, government, public safety departments and businesses. Services include networking and data center capabilities and also dark fiber and wavelength services. Chippewa Falls

Wisconsin, New York State's Open Access Telecom Network (OATN) and other cities have also taken this path. In general, these models usually emerge from the non-profit sector or a regional economic development group with strong support of their municipalities. Being outside the municipal government structure these groups can easily act, and operate, in the interest of their members.

b) Legally Restricted Entities: Conflict between the public and private sector has created a wholesale model defined by legislation. Utopia in Utah is the most well known of these models. Initially conceived as a retail model, and following extensive lobbying by Qwest (now CenturyLink), Utopia was prevented by the State of Utah from operating retail services. Wholesale services, with private providers offering retail services, were the only choice remaining. Utopia has struggled with this model. Washington State too has similar restrictions and networks. While cities like Tacoma Washington can operate network services, public utility districts may not provide telecommunication services directly to customers. Chelan PUD and Grant County PUD have been the most notable, each supporting many cities. There are numerous problems that result from this model: inability to rapidly pay off debt, loss of control over the quality of services and unsatisfactory marketing programs directed at obtaining customers and ensuring sufficient take-rates. Even with these difficulties, this model has brought better service and they are strongly supported by their customers.

c) City Owned and Operated: This model has favor in multiple cities. In Colorado this includes Cortez, Glenwood Springs and Durango. Notable other cities include Santa Monica California and Danville Virginia among many others. Most of these communities begin with dark fiber sales to local business thinking that this would improve economic development. Santa Monica began by offsetting municipal cost, paid to legacy providers, with the construction of a solely governmental network; and then expanded. In some cases this has produced moderate results. In other cases, Santa Monica for example, lit services became necessary and even residential services become attractive as the learning curve increases. Danville has moved to pilot residential services and Santa Monica supports multi-dwelling units for residents. In most cases, these models resulted from external funding (state and national grant programs) or as offsets to local municipal expenditures for communications.

Public-Private Partnerships:

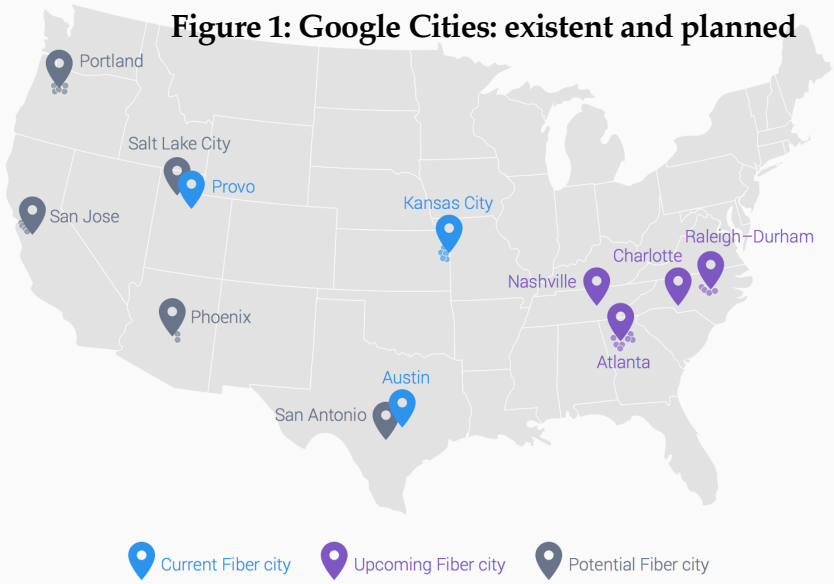
Municipalities have long sought public-private partnerships, most often without result. However, there are signs that this model maybe trending with small successes emerging. The notion, of course, is that the city absorbs the cost of the physical structure or reduces the costs associated with permit or pole attachment fees, enabling entry to right-of-ways, eliminating franchise constraints and so on. The motivations for public-private approaches are easy to see. Building and operating networks requires knowledge and skills often not present in municipalities. Desire to avoid risk and conflict over differing political ideologies also motivates this model. Ironically, when private overbuilders enter a city, market penetration is usually in the mid-thirty percent (33%+), but when cities build and operate those take rate percentages generally exceed fifty-four percent (54%+). Within these models perception dominates.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Note: Beyond the major carriers there exist multiple private companies that build fiber networks for sale to businesses (over 10 alone in Centennial) and/or to residents (FTTH) without the support of local municipalities: ECFiber, Metronet, Paul Bunyan, Sonic.net, Zayo and many more. This section only deals with those business models in which the municipality was significantly involved.

a) Full Retail Build by a Private Provider:
Google is the only provider that does a full outside plant fiber build and provides retail services. Their success is well known. When Google invited cities to bid over 1,200 cities responded, some even offered to change their name to Google something. Such is the demand by cities, for some private "other" to build, operate and provide gigabit service. Yet as powerful as this introduction has been, less than 28,000 Google homes are connected today after three years of effort; less than the number of homes in Centennial itself. The real growth of Google is ahead and the most significant impact to date has been in the reaction of legacy carriers. Today in Austin Texas, AT&T, Grande Communications and Google all compete with gigabit services. In Provo, Comcast reduced pricing drastically. In Atlanta, Comcast announced a two-gigabit service to counter Google, but we are waiting to see how they intend to accomplish this boast.

Figure 1: Google Cities: existent and planned



b) City Owned and Privately Operated: This model has had less success. Powell Wyoming attempted this model with a local telephone provider, but subsequently the private entity withdrew and the city now has full responsibility. Indianola Municipal Utilities Iowa, in concert with a local provider, Mahaska Communications Group, is currently the only known working model of this type. There are two planned communities, Charlottesville Virginia and Westminster Maryland, that have opened discussions with Ting, a Toronto based firm, to pursue this type of model. In each of these cases the city builds and pays for the fiber infrastructure, while Ting will offer at least Internet access. Ting is also investing in Charlottesville. The Indianola effort works well. It is still to soon to know more.

UC2B, the network for the cities of Champaign, Urbana and Savoy Illinois, might also be grouped in this class. UC2B was built with federal ARRA funds, which

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

included pilot projects for FTTH. Subsequent to construction of the core transport rings, UC2B sought private operators of services. ITV-3 has agreed to become that for UC2B with fairly tight criteria ensuring open access FTTH coverage over the long term. We note it separately in this model group as the risk and monetization of the original build is quite different. UC2B will be interesting to watch over the coming years.

It should also be noted that Macquarie Group, of Australia, has begun soliciting investments that might eventually fit into this model type. Currently they have succeeded with the State of Kentucky for a middle mile build out. They have also proposed to Utopia a financial package and approach that has not been accepted.

This model has had some failures too. The Powell Wyoming effort was saved by the city. In the case of a firm called Gigabit Squared, ugly failures occurred in Chicago and Seattle. The efforts of GigU have not been as robust as initially desired and the universities involved have not been motivated to extend their networks to the surrounding communities.

c) Enticement Models: A section on public-private partnership models would not be fully complete without at least a brief discussion about enticements for providers. The most significant work in this area has been performed by Google as they have detailed what cities are required to do for them. Loma Linda California should be credited in opening up these models as far back as 2004. There has been a range of enticements, each deserving of it's own analysis should the Council recommend such a review. They are listed here with relevance for this Identification of Opportunities study.

- Use of City Assets: The City can provide fiber, conduit, building or data center facilities, and/or information sources such as GIS data sets, fiber and utility locations and demographic data useful in marketing. The applicability and use for most of these elements are discussed elsewhere in this document.
- Enabling Efficiencies in Construction: The City optionally may consider dig once policies for any city or private construction; facilitating or streamlining pole access and make-readies; permit clarity and process streamlining; clarity and process requirements for right-of-way applications; clarity, standardization and modification for video franchise agreements; establishing building codes with fiber requirements defining in-building pathways, building entrance criteria and inclusion in utility feeds; and, the pre-vetting of local construction and/or inspection companies. Each of these areas provides clarity of city expectations, cost reduction, and predictability in process and timelines for Centennial's efforts or for private companies that wish to provide communication services.
- City Planning: Planning is fundamental to city departments and actions (IT, public works, code compliance, building and permits, finance, economic development, etc.), local public service providers (fire, police, sheriff, emergency services), educational institutions, and Arapahoe County departments should be considered and, over time, coordinated. Centennial should create and develop a centralized focal point, be that an individual or department, which is knowledgeable in all aspects of communications and is

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

able to advise and facilitate coordination between groups and interests. This recommendation is further discussed under Section 4.2.

Open Access Models:

Open access models have been a municipal desire for well over fifteen years. Naively it seems to solve the dilemmas of establishing appropriate public-private boundaries and relieves municipalities of the responsibility of operating networks, which many do not feel is in their competency. Utopia was the first to attempt this approach, albeit as a consequence of Utah State's legislation. Stockholm Sweden and certain other European cities have actually achieved something approaching the ideal of open access.

The notion is that a consumer, residential or business, can select, or change, a provider virtually by the click of a mouse button. Thus creating a truly free market in supplying and purchasing communication services. Open access creates competition in services, enhances customer responsiveness, reduces service offering costs, increases the types and range of services offered and more. Ideally, this allows consumers to select multiple providers, each for the best service and at the best price: telephone, Internet, video entertainment, home or business security, healthcare and so on. Distinctly each service can be selected from the "best" provider in terms of the consumer's needs and wants. This is in contrast to current models wherein the physical connection to the home defines a single provider and offers only that provider's services. In the open access model "bundled" services may be replaced with "best-of-breed" multiple, and discrete, services harmonized for performance.

Several problems arise in pursuing this ideal. The most significant in the US are business models. Historically we built two physical infrastructures, oriented to their initial service (telephone and video). As services changed and converged the business model did not. When a company owned the physical connection to a home or business, they generally "owned" the customer. We competed with bundles of services, not individual best quality or price. It is still the mind set in most municipal wholesale network models, mentioned above. Municipal approaches that continued this older business model, by leasing or assigning the physical connection to one provider, have often been referred to as open access. In those networks a private company markets to a consumer and the attachment is made via a physical fiber, but then all services to that consumer come from that single provider. This business model is so embedded it is reflected in many of the technologies we use today. Hence, there are technical issues in effecting open access or at least there have been until the emergence of Software Define Networks and newer Operational Support Systems.

True open access can be achieved in the coming years. We are seeing the emergence of companies, usually non-traditional carrier companies, who are becoming interested in this space. Technology is now available to effectuate this model. However, the responsibilities of the municipality increase also. Here the municipality needs to provide the lubricant to allow multiple companies to come and go. The components for this model are further discussed in both the technical opportunities section and the proposed business model section.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

3.2. Competitive Analysis

Competitive analysis is actually quite difficult. The issue derives not so much in the assembly of data, but from constructing consistent and complete understanding and actionable information. Difficulties arise due to the fluidity of market pricing, products offered and differences in the various sectors that need to be understood. Clearly the providers that serve residential services, primarily Comcast and CenturyLink, offer products that are quite different than those providers that serve fiber connections to businesses. We identified ten (10) such fiber providers within Centennial that support local business only. Residential versus business distinction is relatively easy on the surface. Yet even here the growth of home-based businesses, and work-at-home developments for larger firms, create a hard to compare mixture of provider product offerings (services) and consumer importance of use or value. We begin this way to heighten awareness to the "soft" nature of this analysis. Some data will tempt a feeling of firmness and solidity, some is, but please be cautious. Other data is simply the best that could be obtained in the scope of this effort. This analysis is intended to give you the "feel" for the competitive communication markets within Centennial.

To speak about viable communities and local competition, without comparison to the experience nationally, or regionally, is to miss an important and fundamental metric. That CenturyLink, Comcast or other competitive providers offer products and pricing that are superior in other communities elsewhere are clearly competitive concerns. Both CenturyLink and Comcast provide better services at better pricing to other communities than they do in Centennial. Price and service differentiation creates competition between cities and/or regions.

Citizens and businesses that pay more, or obtain better services, create economic disincentives locally – people and companies are beginning to look at these disincentives when they select locations. It has been documented repeatedly by the FCC that in the area of residential pricing alone, competitive municipal markets drive prices down at least fifteen percent on average. That may not seem significant, but numerous studies have shown that a fifteen percent (15%) reduction over five years is equivalent to the capital cost to build a FTTH network. Currently Google is deploying in seven major municipal markets residential Internet service at 1Gbps (one billion bits per second) for $70 a month. Chattanooga Tennessee offers the same and approximately forty municipalities (40) now offer "Gigabit Service." In Centennial that service is yet to arrive and the costs for significantly lesser capability are well above the $70 number (Comcast offers 150M for $114.95, CenturyLink's best offering is 40Mbps at $74).

To begin this analysis service offerings of each primary provider were examined and catalogued. They are listed below and compared with a few cities nationally (see Tables 3 and 4). Second the survey of citizens and feedback from District meetings shed light on the actual practice of providers and, more importantly, on pricing and satisfaction. *The most obvious conclusion of this analysis was that offerings in Centennial are sporadic, geographically inconsistent, varying from poor and inadequate to robust, reasonable and of high quality – and in all cases, provider offerings are priced higher than similar or better services nationally*. It should also be mentioned that where

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

improvements in service have occurred, they are recent and at least partially in response to Centennial's and other Colorado communities recent voter actions. An example of what we mean by sporadic services (see **Figure 2**) can be seen by comparing two properties, selected at random: one in Southglenn and another southeast below East Dry Creek Road. In Southglenn, 40Mpbs services were available from CenturyLink. At the other property, selection of Internet service included a 20Mbps offering by narrative on the web page, but the actual maximum that could be chosen was 12Mbps – 40Mbps versus 12Mbps from the same provider. *These two properties are three miles apart and yet they were offered for different levels of service – one adequate, one inadequate*. Until recently residents could not select Internet service alone from CenturyLink driving up the cost. CenturyLink required that you pay for, if not use, a landline (traditional) phone[1]. Even though only 64% of Centennial residents use such.

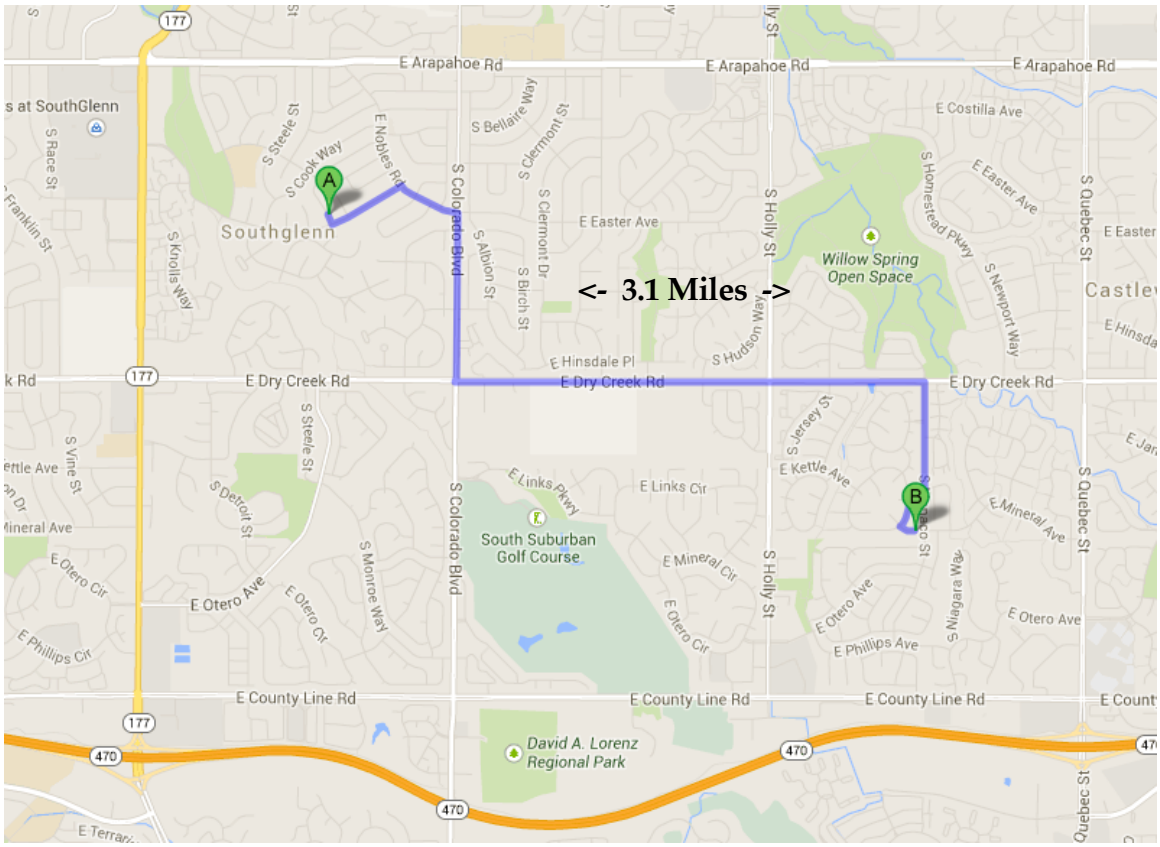


Figure 2: Geographically Inconsistent Services

It is not our intention to isolate one provider; Comcast has similar instances of spotty or non-existent coverage. In conversations with Comcast customer service personnel, they admitted that many areas of Centennial were not served as yet. We did not separately verify this claim. Although a number of Centennial addresses entered to the Comcast web site returned a message of "invalid address." So it seems to be true.

[1] Subsequent to the original analysis, CenturyLink offered an Internet only service at

In terms of competitive, or better comparable, services it was difficult to contrast these two providers. Forty-six (46%) of surveyed households use Comcast television offerings, while CenturyLink is just rolling out their Prism TV offering and only five (5%) use this service in our survey sample. Fifty-seven percent (57%) of residents receive Internet service from Comcast, while only thirty-seven percent (37%) select CenturyLink. However due to provider sporadic coverage, it is not known how many would select another provider were they to have a choice. Comparisons of price may be one guide, but when availability is inconsistent it is difficult to make such comparisons.

Further, products that residents desire are changing. As mentioned CenturyLink required that customers subscribe to phone service, or today charges a significant premium simply to receive Internet service. CenturyLink is a phone company after all. Comcast was not. So it is not surprising that of fifty-seven (57%) of residents who take Comcast Internet only twenty-nine (29%) take Comcast phone service. The view that conflates legacy telephone and legacy cable companies together fails across multiple levels. Today, cable companies have temporarily won the majority of broadband customers due to their higher bandwidth offerings.

When residents were asked why they did not select the highest tier available in Internet speed, forty-six (46%) gave "the price is too high" as their reason not to upgrade. Given significantly higher prices in Centennial than offerings in other municipal fiber networks, that comment is not out of line. Of those residents that knew their speed and selected a valid offering – *fifty-nine percent (59%) received services below the FCC minimum requirement. Many did not have a choice*.

The offered services and their pricing for residential packages are listed in Table 3. Both companies excel at promotional pricing. Promotional pricing contains conditions when you examine the "fine print." CenturyLink lists their condition as: "*a subscription to a qualifying CenturyLink service and will apply for six months (after which the then-current, standard monthly rate will apply). Offer requires a twelve month term agreement.*" Comcast's lists their condition as: "*The offer for the service package you have selected requires a minimum term agreement [usually one or two years]. The agreement will be sent to the mail or email address you provided. Under the agreement, if you cancel or downgrade [including eliminate] any services included with your package before the agreement expires, you will be billed the early termination fee specified in the agreement.*" What is most interesting about these clauses is that complete information is either very difficult to find or, in Comcast's case, only known by mail or email following completion of the order. In other words customers generally do not know what they have agreed to at the point of agreement, at the commencement of service.

A clear pricing comparison is further muddled since residents elect services at different times, during different promotional offers. Longer-term customers may haggle with providers under "loyalty" agreements, which are rarely better that the promotional offers that are not available to them. Some customers know this and some don't. Either way it makes actual comparisons and summaries of probable revenue less precise.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Residential Pricing

Table 3: Local Provider Services and Costs with national comparisons

Single Service						
Company >	**Comcast**		**CenturyLink**		**Longmont CO**	
Phone	$34.95		$45.00		$25.00	
Internet Speed	Price	$/ Mbit	Price	$/ Mbit	Price	$ /Mbit
1.5M			$44.00	$29.33		
6M	$49.95	$8.33				
7M			$49.00	$7.00		
12M			$54.00	$4.50		
20M			$64.00	$3.20		
25M					$39.95	$1.60
40M			$74.00	$1.85		
50M	$64.95	$1.30				
150M	$114.95	$0.77				
1000M/1G					$99.95	$0.10

Two services						
Company >	**Comcast**		**CenturyLink**		**Longmont CO**	
Internet and Phone		Price	Price		Price	
1.5M & 12M			$64.95			
20M & 40M			$69.95			
25M					$64.95	
50M		$88.90				
1000M/1G					$124.95	
TV and Internet						
Channels	Speed	Price	Price	**Google in 7 metros***		
140	1.5M-12M		$69.94	Price	$130	
140	20M-40M		$79.94	Speed	1000M or 1G	
140	50	$110.94		*Only one channel size offering		
200	1.5M-12M		$84.94	**Chattanooga**		
200	20M-40M		$94.94	Channels	Speed	Price
220	50M	$121.44		12	100M	$72.98
260	105	$149.95			1G	90.97
290	1.5M-12M		$99.94	77	100M	107.08
290	20M-40M		$109.94		1G	$117.28
320	1.5M-12M		$129.94	194	100M	$57.99
320	20M-40M		$139.94		1G	$$134.32
Three Services – Triple Play						
Voice included in plans		**Comcast**	**Century Link**	Chattanooga: Triple Play		

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Channels	Speed	Price	Price
140	1.5M-12M		$103.94
140	20M-40M		$113.94
140	50	$109.99	
200	1.5M-12M		$130.94
200	20M-40M		$140.94
220	50M	$129.99	
230	105	$149.99	
260	105	$169.99	
260	105+	$209.99	
290	1.5M-12M		$144.94
290	20M-40M		$154.94
320	1.5M-12M		$174.94
320	20M-40M		$184.94

Fewer Channels, Higher Speeds		
Channels	Speed	Price
12	100M	$98.27
	1G	$108.47
77	100M	$136.10
	1G	$145.94
194	100M	$146.76
	1G	$156.60

Business Services

Within Centennial at least ten (10) providers compete for business services. Comcast and CenturyLink are joined in fiber sales by most of the national fiber companies. Obtaining cost information in this market is nearly impossible as most of the "deals" are individually crafted and include Service Level Agreements (SLAs), fiber construction costs to connect buildings, contract length and other variances that make comparisons less useful. This lack of transparency is less true of the municipal markets. Certain carrier information is becoming more standardized and available.

For example, there is a major carrier in Centennial that is now offering fiber-based service with only a "best efforts" (no SLA) quality across a Gigabit Passive Optical Network (GPON). Pricing for these services and a comparison to Longmont is in Table **4**.

	National Provider in Centennial			Longmont CO	
Speed Mbps	Terms – Asymmetrical Service			Symmetrical Service	
	12M	24M	36M	No Contract	
10	107.00	62.00	50.00		
20	167.00	121.00	107.00	49.95	59.95
40	227.00	197.00	167.00		
50				99.95	129.95
60	272.00	242.00	212.00		
80	337.00	297.00	257.00		
100	360.00	320.00	280.00	179.95	229.95
200	429.00	389.00	349.00		
250				399.95	499.95
300	519.00	469.00	419.00		
400	589.00	539.00	489.00		
500	659.00	609.00	559.00	599.95	
1000	1,120.00	1,035.00	950.00	799.95	

Table 4: GPON fiber Price Comparison

As mentioned there exist multiple types of business services: simple dark fiber leases; complex Quality of Services Agreements (QoS and SLAs); mixture of various types of voice services; and often the most important criteria – redundancy of fiber connectivity. Today business networks simply cannot fail. The costs associated with outages are too great – employees idled, customers lost, regulations violated and more.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

The rise of cloud-based services used by enterprises has created an entirely new service called bandwidth-on-demand. Currently there are no such offerings in Centennial for this important new offering.

The business community in Centennial is technically sophisticated including multiple data centers, carrier meet points and a number of communication carriers. Data Centers are common in and nearby Centennial. Meet points are those locations where multiple providers come together and connect with each other and often make connections to Tier One Internet peering points. Included locally are such companies as:

Table: 5: Local Data Center and Meet Point Businesses	
24/7 Networks	Netstructures, LLC
CenturyLink	SunGard
Clear Channel Satellite	Sunset learning Center
Comcast	Time Warner Telecom -- now Level 3
Equinix	Verizon
Intega (and Electric Lightwave)	Via West
Latisys – now Zayo	XO Communications
Level 3	Zayo

Additional data centers, meet points, ISPs and communication providers can be found throughout the Denver Metropolitan area. The list of advertised Data Centers in the near area of Denver included close to fifty different locations. Denver's primary carrier hotel (aka: meet point) is located downtown at 910 15th Street.

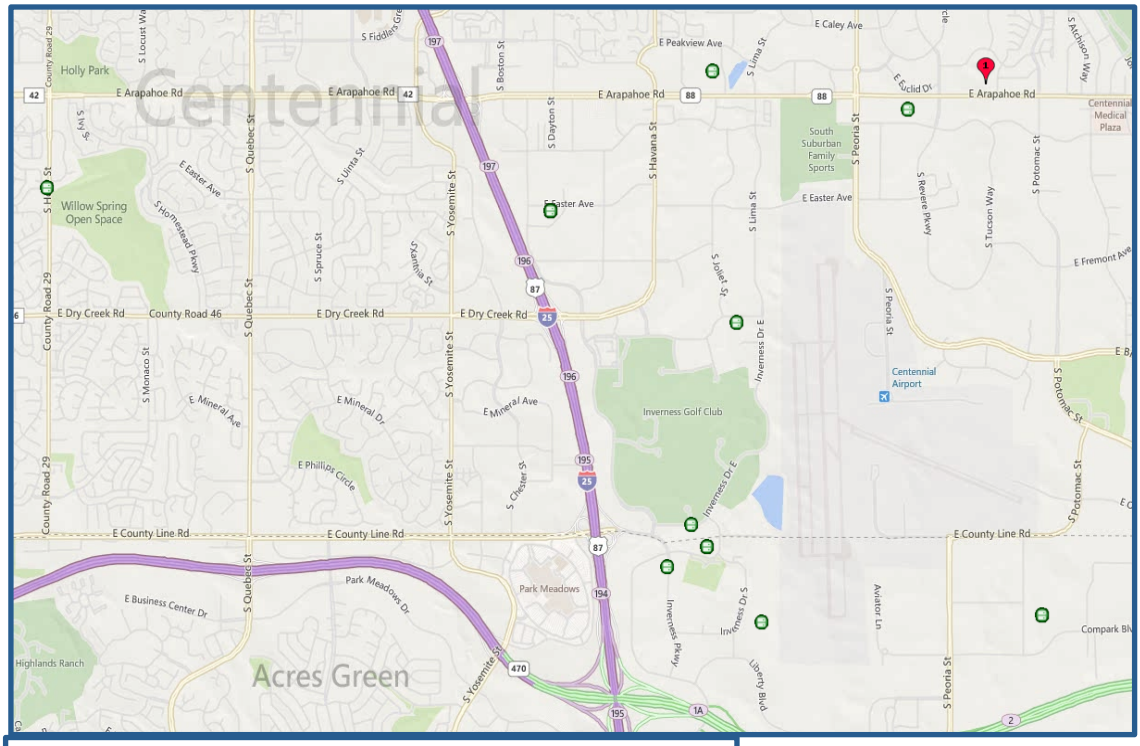


Figure 3: Sample Data Center Locations

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

In the process of this examination over 167 physical locations were identified where business received fiber connections from one of the thirteen (13) provides (see Table **5).** Circuit speeds offered were 100Mbps, 1Gbps and dark fiber.

Table 6: Known Fiber Providers with at least one customer in Centennial	
CenturyLink	TW Telecom
Cogent	United Private Networks
Comcast	Verizon
ForeThought	Windstream
Integra	XO
Level 3	Yipes

In figures 3 through 7 provide a pictorial representation of the location of fiber in Centennial. Spreadsheets of specific detail are available to Centennial concerning this data, should that be desired. The sheer size of that data makes pictorial representation at best somewhat limited. These graphics are offered as indicative.

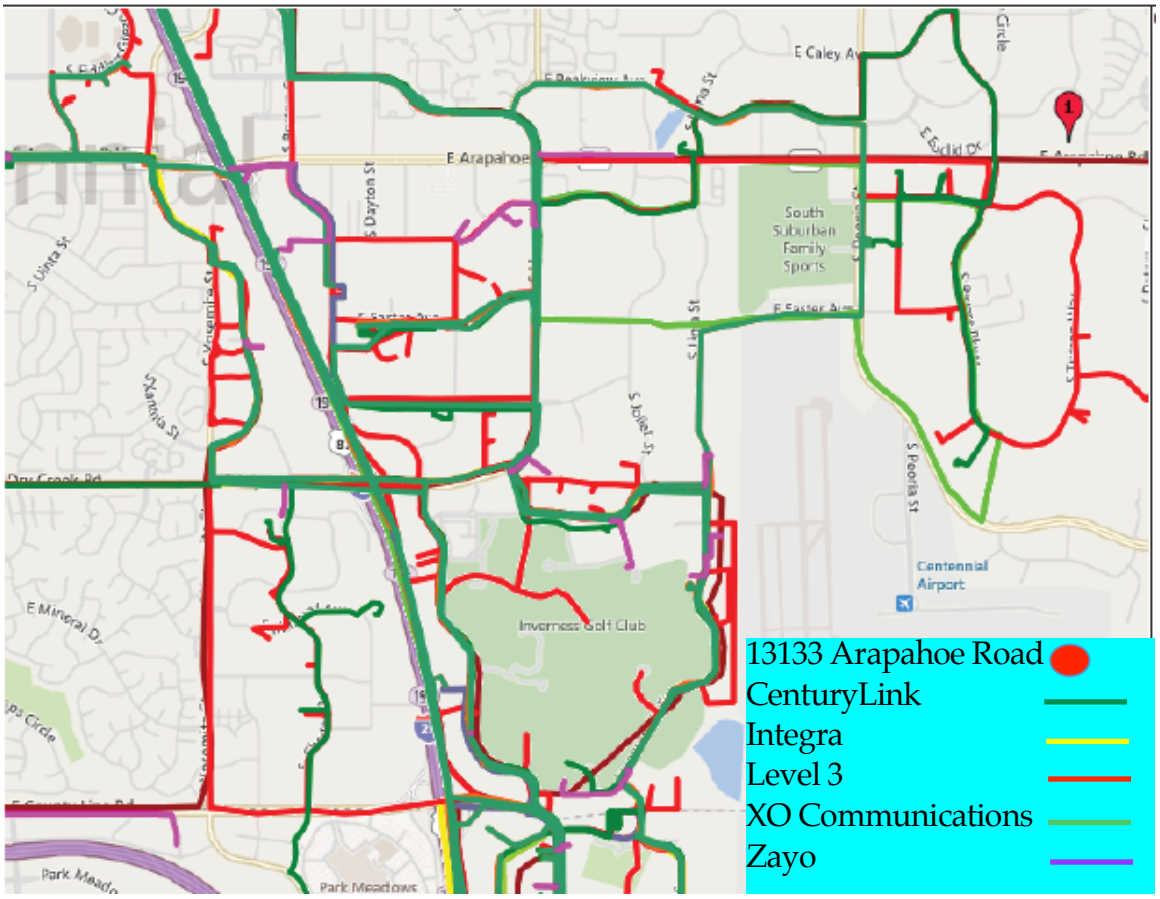


Figure 4: Sample Fiber Locations

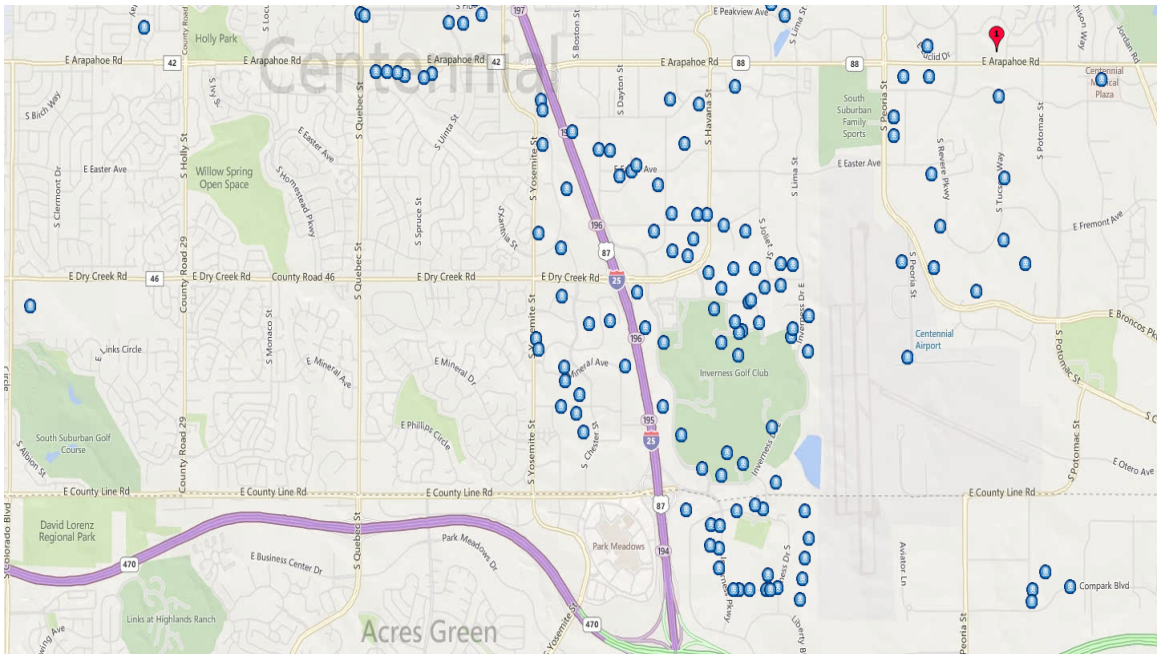


Figure 5: Sample of Lit Buildings in Centennial

For any given provider these maps are slightly more revealing.

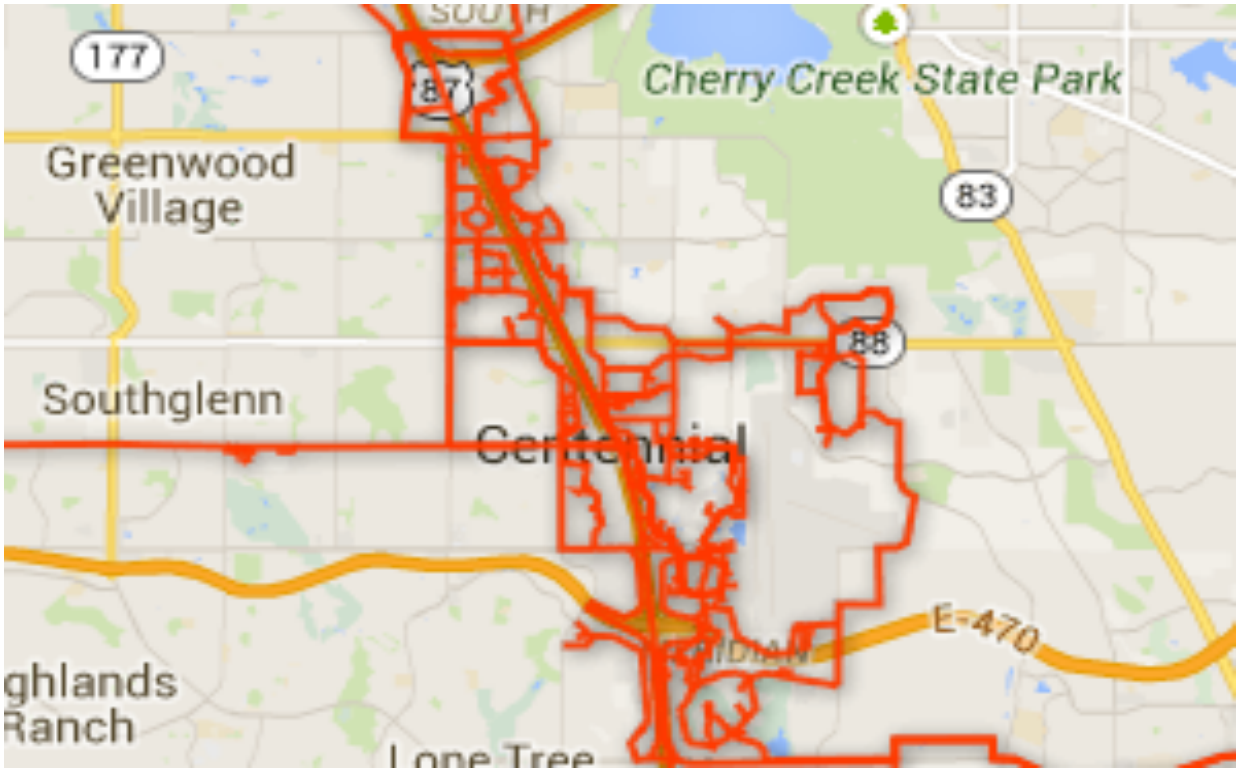


Figure 6 : Partial Level 3 infrastructure

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

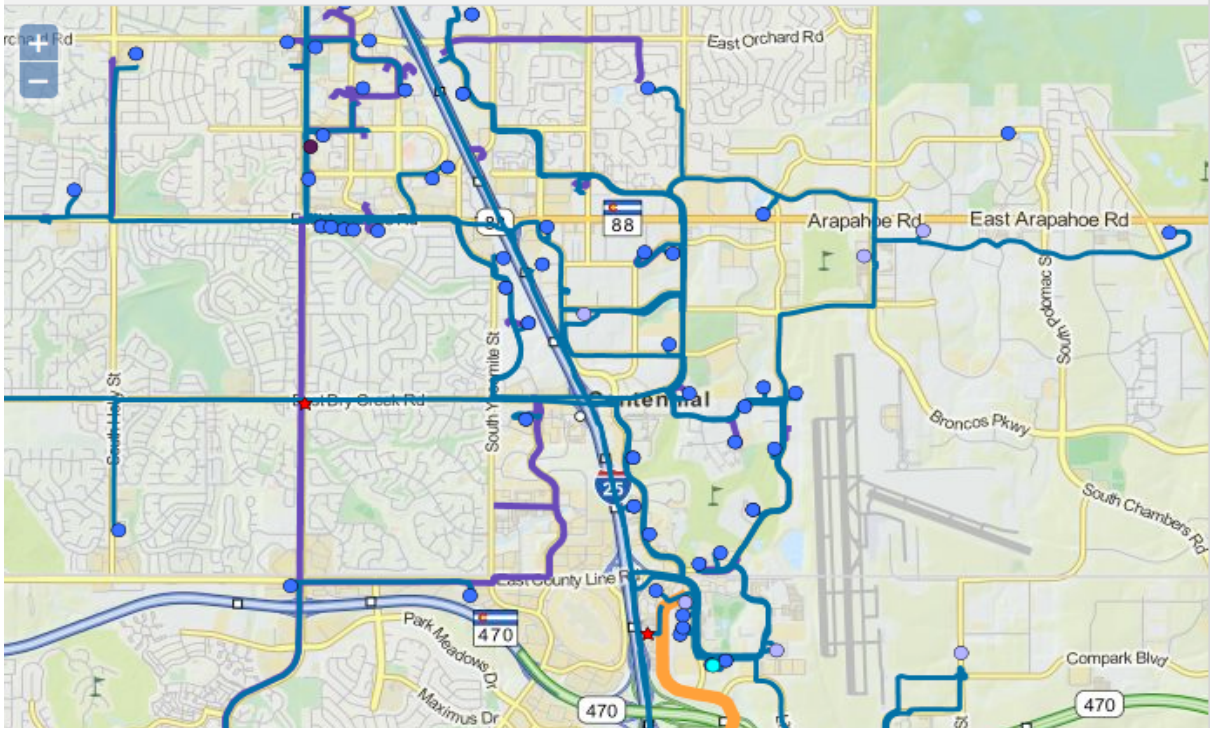


Figure 7: Partial Zayo Infrastructure with certain

Pictorials, such as these, are helpful to some degree. Still it is difficult to appreciate market realities from such general data. Some easy conclusions to draw are that fiber for businesses are clustered around Interstate 25, north in Greenwood Village and south down into the Tech Center.

To gain a better understanding we turned to other analysis. This included discussions with business leaders, the two business chambers, informed Council members and a thorough analysis of the business listings. The listings were particularly useful. As mentioned before, nearly 200 locations (addresses) were identified that had direct fiber terminating those buildings. Several buildings contained multiple businesses; even some were data centers and remote meet points.

Anecdotally what we heard in the two sessions held with the business Technical Advisory Group, local Chambers and individual business was not encouraging. Many businesses are still supported with older high priced T.1 technology, costs to deploy fiber were burdened by excessive construction costs to connect buildings, and basic speed offerings were below par. In meetings with both CenturyLink and Comcast a contrasting view was heard with expressions of real interest in business communications. This quality of *sporadic, geographically inconsistent, varying from poor and inadequate to robust, reasonable and of high quality* seems to apply to the business community as well.

The analysis showed opportunity for small and medium size business communications, which is detailed more extensively in Section 4. Some indication of business coverage could be assessed in reviewing address-by-address listings comparisons. There are interesting statistics that may serve to enlighten this segment:

- 4,297 unique business addresses comprise City demographic listings.
  - ~ 43 represent Centennial City, Arapahoe County, State and federal addresses;
  - ~ 893 represent Home Based businesses, 20.8% of total; and,
  - ~ 3,361 represent traditional facilities based businesses

The ratio of home-based business is slightly below the national average at twenty one percent (20.8%) as reported by the City's data and almost thirty percent (29.71%) as reported by residents. This market generally requires higher speeds and more reliable services. In the group of facilities-based businesses we examined fiber connected addresses to the extent we could validate the data. We should share that the poor quality of this data is a well-known industry issue. That said, identifiable providers claimed approximately 162 fiber connections with 7 more connections, which could not be determined as to the responsible provider:

Table 7: Provider Fiber Connection Sites

Provider	# fiber sites	Provider	# fiber sites
Zayo	23	Level 3	30
Yipes	2	Comcast	16
XO	7	Cogent	2
Verizon	18	CenturyLink	35
TW Telecom	26	Sprint, Integra, Forethought	With 1 each

A closer look identified some informative characteristics. Most businesses of scale today require speeds of 10Gbps (ten billion bits per second) and those businesses usually require redundant physical circuits. Smaller firms are often satisfied with 1Gbps service. Identified speeds ranged from 100Mbps to 1Gbps. For most connections actual speed was not identifiable.

Only Thirty-three (33) structures had multiple carriers. That may be indicative of businesses purchasing physical redundancy, which is often sought by purchasing fiber capabilities from multiple providers. This is a key requirement today.

In Centennial the 169 "sites" (fiber connections) identified represent fewer buildings (note: 23, 2 fiber buildings = 26 fiber connections, 2 buildings x 3 fiber = 6 connections, etc.).

Table 8: Building addresses with	
~ A single fiber connection	69
~ Two fiber connections to the same building	23
~ Three fiber connections to the same building	2
~ Four fiber connections to the same building	5
~ Six fiber connections to the same building	3
~ Ten fiber connections to the same building	1
	103 Buildings

Two of these multi-connected structures are data centers. There are a total of ten identifiable data centers within Centennial. That they do not show up on provider maps suggest that more fiber connectivity, especially to large-scale business, may be constructed by the companies themselves – or the provider data is simply not accurate. In subsequent work the City may consider mapping this data themselves via the permitting process.

Is the business community receiving adequate support? We have the anecdotal comments from attendees at multiple open meetings. Those comments expressed concerns over cost, frustration in having to pay excessive construction costs to connect buildings with nearby carrier circuits, inadequacy of T.1 circuit speeds and the like. The anecdotal information leaned toward low satisfaction and unfavorable support.

Table 9:	**Business Clusters (4 or more Businesses per Building) 2,158 Businesses**			
Buildings	**With Fiber**		**Without Fiber**	
204	**Buildings**	**Businesses**	**Buildings**	**Businesses**
	38	572	166	1,586
	18.6%	26.5%	81.4%	73.5%

To assess anecdotal comments, we then examined the list of individual business addresses and made the not too scientific assumption that any building with four (4) or more businesses should have a fiber connection[2]. Of the 3,361 businesses identified, 2,158 are housed at an address containing four or more businesses. This represents sixty-four percent (64.21%) of all "facility-based" businesses. Those businesses are contained in two hundred and four (204) unique addresses, but only thirty-eight (38) of those addresses are connected with fiber. If we then add the additional 65 non-cluster buildings and businesses (103 buildings in Table 8 minus 38 cluster buildings) we obtain a sum of approximately 636 businesses with fiber out of 3,361 facility businesses. Said another way, *only nineteen percent (18.9%) of businesses in Centennial have adequate service.*

Conversations with fiber providers indicated that it would be unlikely for them to pursue these smaller buildings and businesses. As one provider explained: "We have only one or two sales people covering business in this area. SMB's are not a focus of our attention." Reliance on private providers may provide incremental growth, but it will be slow at best.

Centennial has made significant efforts to promote economic growth. The types of companies currently located in Centennial, or nearby, tend to be technically sophisticated. Centennial has an excellent new business incubator, the Innovation Pavilion, that itself contains three separate fiber connections from differing providers.

[2] If you assume that the FCC minimum for residential service is 25Mbps, it is not too much of a stretch to think that four businesses would require 100Mbps – at which point you would need a fiber connection. This, of course, varies by type of business and their needs.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Unfortunately the prime characteristic remains the same whether viewed as residential or business: *sporadic, geographically inconsistent, varying from poor and inadequate to robust, reasonable and of high quality – and in all cases, provider offerings are priced higher than similar or better services nationally*..

3.3. Codified Results of Interviews and Citizen Survey

The proposed approach intended to gather local information through citizen meetings and meetings with various stakeholders. While this was done, it proved less informative than hoped. To correct that an additional citizen survey was conducted. Overall this combined effort provided a fairly good sense the current market, market deficiencies and, importantly the needs of stakeholders, businesses and citizens. Some of this information is conveyed in other sections, such as the previous section on competition. Some of this data was so normal as to not reveal actionable information – yes people use the Internet in multiple ways; yes, there are individual differences in video services and preferences and so on. The broad scope of this data, normative and exceptional with key highlights, will be discussed in this section. The focus is toward pertinent observations that may bear upon Council decisions. Significant detail was collected and that detail is available should it be desired.

Individual Meetings

Individual meetings were held with:

Public Sector Groups

1. Educational Community: Cherry Creek and Littleton school districts and the Arapahoe Library District
2. Fire Protection and Rescue Services: Cunningham, Littleton and South Metro
3. Public Safety: Arapahoe County Sheriffs Office, Emergency Communications and the Telephone Service Authority (E-911)

Residents and the Business Communities

4. Open Community Meetings were held in District 3 and District 4
5. Two Technical Advisory Group Meetings (TAG) with open meetings for Business Leaders and local business chambers

Centennial Government

6. ITS group and CH2MHill to understand current and future City fiber requirements for traffic systems
7. City of Centennial staff and the Technical Committee
8. One-on-One meetings with Council members

Providers: Legacy, Fiber and Internet Service Providers

9. Primary legacy providers: Comcast and CenturyLink
10. Individual providers and companies exploring interests and needs

Public Sector Groups

There were two primary outcomes from the public sector individual meetings. The first pertained to the overlap of public services with the geography of the region in which Centennial is contained. Each group (Education, Fire Protection, Public Safety, Libraries) spoke of the difficulties in coordination between communities as it pertained to communication networks. *Regional coordination is foundational to extracting maximum benefit for these services.* The second was *strong belief that this*

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

coordination would lead directly to efficiencies, cost reductions and improvements in services. Improvements and benefits that may be obtained within existing budgets or in such cases where coordination can leverage shared investment.

These public sector providers are sophisticated in their use of technologies and aware of shortcomings and/or areas in which they can improve were budget constraints eased. Each of the sectors claimed some owned fiber infrastructure whether it is Cherry Creek School District's campus fiber or the more extensive fiber installed for Emergency 911 services. Sadly, historical attitudes such as reserving fiber strands for a single purpose or single organization make efficient use of resources difficult. Outside of contained areas, most purchased capacity-based communication services from legacy providers. This, of course, is the most expensive method of acquiring capacity.

Most use a combination of fiber transport and wireless end-point technologies. In the schools wireless is used to support Chromebooks with pilots for Bring-Your-Own-Devices (BYOD). In the librarys wireless serves customers, although filtering along acceptable use policies needs further development. Public Safety (Fire and Police) uses multiple forms of wireless (700/800 LMR band emergency radio, WiFi and LTE for data services). In all cases there are shortcomings and opportunities for betterment.

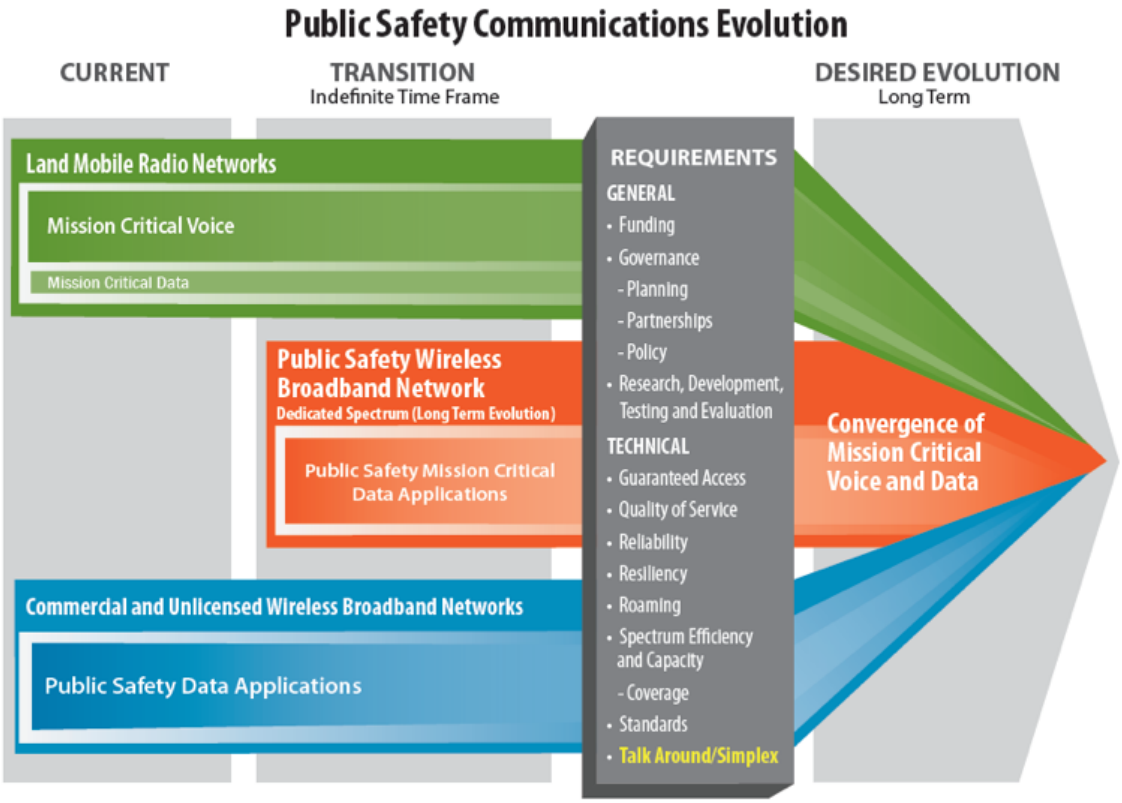


Figure 8: US Department of Homeland Security Wireless Evolution Expectation

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Wireless deserves a particular notice. As mentioned, today's wireless environment is a confusion of technologies. Land Mobile Radio (LMR) has been the foundation of public safety communications for years. It is only suitable for voice and sadly that is often less helpful when real information needs to be delivered to critical locations in an emergency. WiFi is deployed only in fire stations and in some police vehicles or stations. Its lack of deployment makes more expensive equipment and application development that would serve this sector well. LTE is the current choice of remote data services and the focus of the US Department of Homeland Security evolution (see Figure 8). Unfortunately, it is slower than WiFi today and anticipated changes in LTE protocols make deployment of radios short-term and dependent on a few legacy providers. Finally, there continues to exist misunderstandings concerning wireless technologies even in organizations where you would expect better. Wireless is just and "end-point" technology. Connecting wireless technologies today require fiber. As the number of devices and attendant use increases the diameter of any given radio access point (AP) decreases; meaning more APs and more fiber. It is a marriage, not a competing technology.

Returning to the issue of collaboration as foundational for improvements that might provide extraordinary benefits. Clearly the overlap between schools and homes is important in education. Teachers working with students and students working at home with parents are well-understood and necessary to foster real education. Likewise, communication technologies cannot provide maximum benefit if they are only available at a school building. FTTH expands and extends education.

When asking police, the sheriff and fire response teams what they needed from Intelligent Traffic Systems (ITS) a clarifying comment was made: "How many cities do you think we pass through along major corridors?" Coordination needs to be conducted regionally encompassing public safety, hospitals and governmental systems. Intelligent Traffic Systems, such as Centennial is working on today, needs to be coordinated with Englewood's current work and with the City's IT, GIS and communication departments. Surrounding communities that have not yet established ITS need to learn from those that have implemented those systems. We heard a need to coordinate ITS, with high quality video for crash reconstruction, efficiencies in shared data (GIS systems, building permits and information, etc.), e-ticketing and healthcare sensor systems relays. In fact, coming sensor and GPS technologies will spawn whole new areas to improve public safety.

But the most significant comment heard from each of these groups was simple. *None of it makes any difference without highly reliable, redundant networks where issues of capacity and connectivity never interfere with the goals of public service.* Such a network is actually very doable.

Residents and Business Communities

Two evenings were spent with citizens and two mornings with the business community. Both of these communities expressed concerns that they were unable to obtain adequate and affordable communication services. During these sessions there was variance in desired City approaches. Notable in all of the conversations was the intensity of interest. Everyone wants a solution and the individual stories and concerns reflected what we already saw in the competitive reviews. Namely that

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

when it comes to communications in Centennial it is all about where you live or work -- *sporadic, geographically inconsistent, varying from poor and inadequate to robust, reasonable and of high quality – and in all cases, provider offerings are priced higher than similar or better services nationally*.

In the business community concerns were focused mostly on the two ends of the services continuum. Large developers wished to know how to support fiber infrastructure investments in pending projects. These developers assumed fiber optics would support new office buildings and residential construction, but questioned how to integrate these environments with legacy copper infrastructures. Their concerns also spoke to City code and permitting regulations and policies. A much large group, represented by individuals and business chambers, spoke to the inadequacies of communication services for small and medium size business (SMB). T.1 services were common and pricey – a service wholly inadequate and excessively expensive to address today's environments. These inadequate services were experienced during our stay in coffee shops and hotels reflecting poorly on the technically sophisticated community image that otherwise Centennial could lay claim. Even communication services supporting the City itself are currently below the FCC minimum requirements for residential service.

What we heard from the business community was supported by the competitive analysis (Section 3.2), comments from fiber and legacy providers who are not particularly motivated to serve this segment and personal experience. Ironically, cities such as Bristol Virginia and Chattanooga Tennessee have seen significant economic development in this very sector through aggressive fiber-to-the-premise deployment. In Bristol's post-fiber deployment surveys indicate over seventy percent of the communities economic growth came from the SMB sector. Bristol's businesses cite cost savings, adoption of new processes, marketing and sales benefits, operational ease, reduced time to market and improved customer service among the factors that spurred growth – factors attributable to low cost fiber deployment. Harold DePriest, the visionary leader of Chattanooga's FTTH recently cited an economic development study that showed over one billion dollars ($1,000,000,000) of economic development directly tied to the deployment of fiber to all residents and businesses. It is no wonder that the surrounding communities of Bristol, Wilson North Carolina and Chattanooga recently petitioned the FCC to allow those municipalities to extend fiber to them.

Interviews with citizens were enlightening and enjoyable. Attendance spanned all ages and varied points of view. The concern that the City act was consistent. Some argued for FTTH buildout. Some were more interested in enticing private companies or public-private partnerships. The questions and comments that came forward were knowledgeable, informed and showed concern for the community. One Fire Chief talked about the potential savings that a coordinated effort could achieve. Others bemoaned the availability of services, reporting service levels so poor they would be more expected in very rural communities. Attendance was good, but we wished for a greater level of input. So we solicited a large voice by conducting a web-based survey.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Market Survey

The market survey was sent to all email addresses that the City had available. Following that distribution certain neighborhood groups sent email notifications to even more people. The City reported that at least 5,497 emails were sent initially. In addition, the survey was highlighted in the February newsletter, with a link to the survey through the City's web site. The newsletter was sent to all Centennial households. Overall the response was very good.

The individual detail of all fifty-five (55) questions, and numerous spreadsheet analyses, is available separately to the City. The base data is simple too massive to be rendered effectively here. In this section we will try to highlight the correlations we thought of value and certain important results for City decisions.

Statisticians have numerous measures to ensure accuracy of surveys. The two key factors are known as the confidence level and confidence interval. For example, a 95% confidence level with a +/- 5% confidence interval is fairly common. For a population of approximately 40,000 homes in Centennial this would require a random survey of about 380 people. We received responses from 817 people, with disqualifications of 22 surveys (people not indicating that they lived or worked in Centennial) and temporarily removed 55 surveys for people who work in Centennial, but do not live here. The true number of resident responses would then be 740 – more indicative of a 99% confidence level with a +/- 4.7% interval given this population.

The survey requested information about phone, television and Internet services: which provider people used; at what costs; what they like and dislike today or would wish in the future; and, even a bit about what they do with Internet services. We asked the normal set of questions about where they lived, by political district; what was the composition of their household, did they have children; did they work at home, solely or occasionally; and, what age the respondent was. We then asked them questions about what was important to them personally, what did they value about communications services; what was important to the community; and, most importantly, what they thought the City should do. We wanted to know why 76% voted for Ballot Question 2G, overturning Senate Bill 05-152 and what they wanted the City to do.

Phone

The survey showed nothing surprising about phone services. Only fifty-six percent of residents use a landline phone (55.82%). The current national average is nearer fifty-nine percent. Almost everyone uses a cell phone (98.19%).

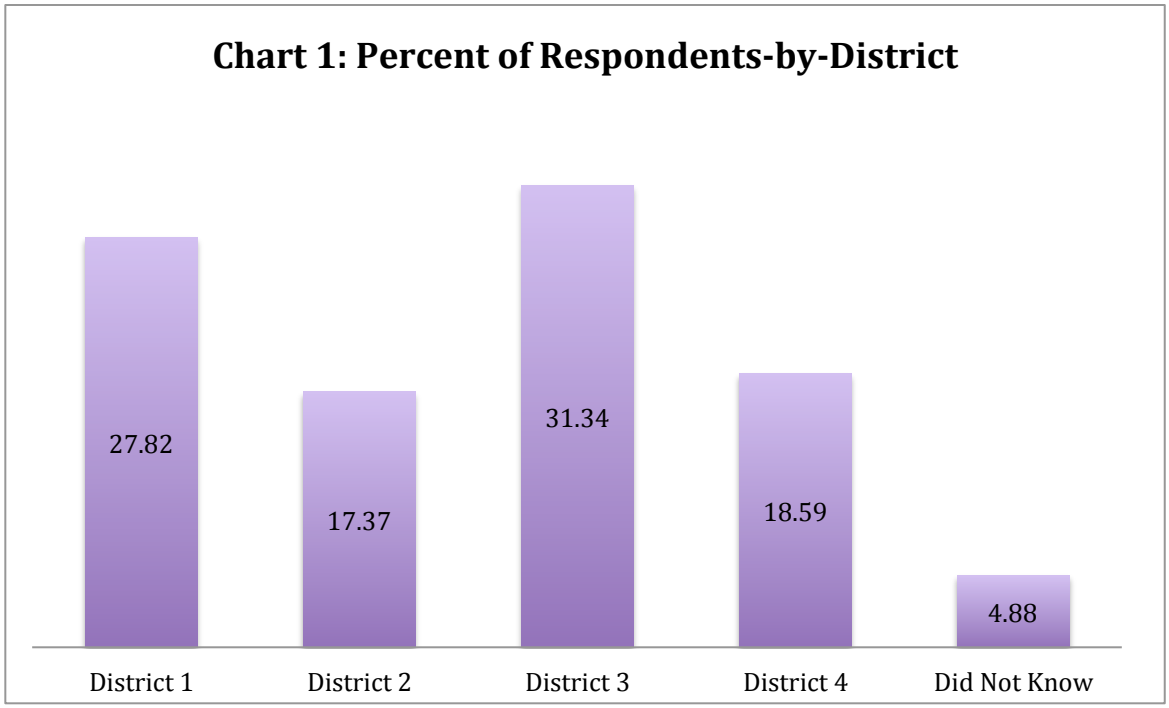
Television or Video Entertainment

Some of the responses were surprising. For example, we asked what services people receive or would like for video services. Most receive current technologies like High Definition (90%), Over-the-Top TV (75%) and DVR (85%). We also inquired whether residents use TV services with ancillary devices, like tablets or smartphones (58%) or get voice calls displayed on their TV (69%). They do use these capabilities and are technically sophisticated consumers. What they wanted was the surprise – over 93% want 4K or ultra-high-definition video services. The correlations are, of course,

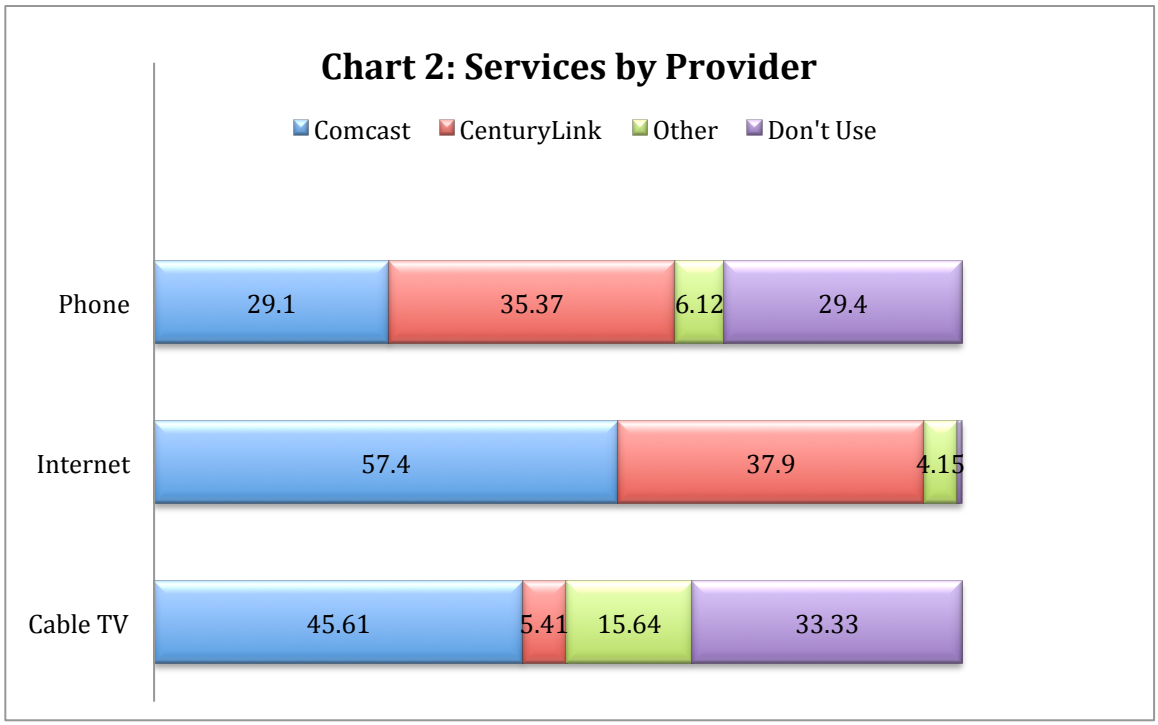
Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

massively greater bandwidth requirements, and if provided, wonderful Christmas TV sales.

Baseline information was captured too.



And we wanted to know who buys from whom?



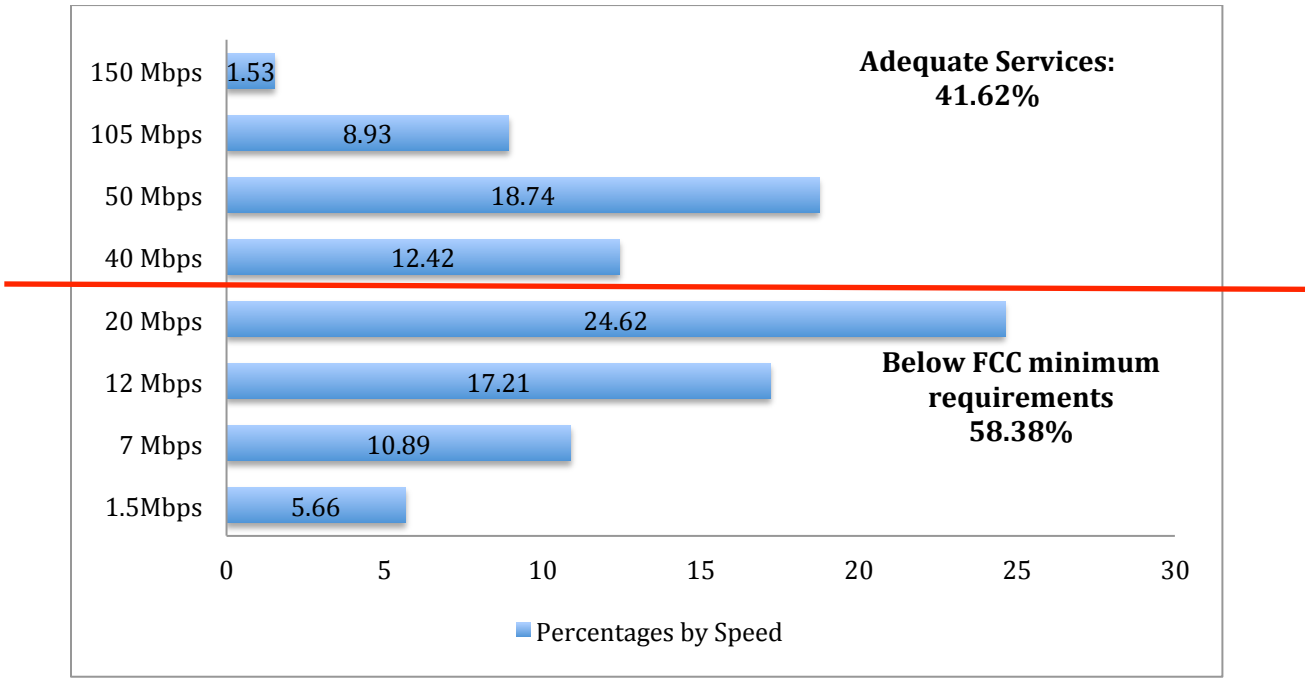
Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

The area of video entertainment is of great concern to the industry currently. Many people are leaving the linear broadcast model and selecting other options. The survey questions confused some people, but the responses were still useful. About twenty-four percent (23.83%) of people have moved to off-air antennas or other means to obtain video. Almost a third (31.82% or 33.33% depending on the way the questions were phrased) use satellite services. Within linear video users (Comcast and CenturyLink services) most receive the basic middle selection of channels. And many (43.98%) who do receive linear broadcast do not like the excessive number of channels offered. Not a majority, but large pluralities, of residents accept the level of customer service when asked about specifics, but more indicate dissatisfaction when asked generally. People like and would use Over-the-Top entertainment services (71.5%). Finally, dissatisfaction centers on price, too many channels, and to a lesser degree customer service, which are common responses among these surveys nationally.

Survey responses for Internet services held no particular surprise save for the low speed offerings that Centennial residents experience. Chart 3 displays reported speeds that people receive. Anecdotal reports suggest that ordered or advertised speeds are often never realized. As noted in Section 3.2, Competitive Analysis and the interviews with providers – advertised or contracted speeds can vary with the

Chart 3: Percentage of residents with known services by speed

technology or services deployed.



Comcast indicated that they have coax node concentrations of up to 550 homes; hence, speed will vary dependent how many people are simultaneously using the

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

network. For example, in the evening, as residents watch streaming TV (OTT), nodes will become congested and speeds will suffer. CenturyLink notes that if you are ordering Prism TV their maximum speed offering is 12Mbps – less than half of the FCC required minimum. Listening to resident reports it is easy to speculate that more significant problems exist in the core or feeder networks. Access speeds can be affected by circuits and equipment when aggregated further "upstream." This is a well-known problem in Comcast's networks and CenturyLink is also known to have these issues in Colorado. If reported speeds are correct it reflects poorly on the legacy offerings in Centennial.

Concerning Internet service in general, the two primary issues in both the survey and the group gatherings are: a) low speed offerings; and, b) the perception that pricing was unfairly high. Both of these concerns are true when compared with services nationally. *Centennial residents pay too much for to little – comparatively.*

When asked what prevented people from moving to higher speeds, if available, the top concern was that the price was too high (45.72% said). The second highest response was that people already had the highest speed available (20.23%). When asked about price in general, almost seventy percent (69.51%) disliked the cost of service. Either there was no option to increase speeds or it cost too much. Again, resident complaints are true when compared with advanced fiber networks.

Other commentary concerning Internet services is the fairly high rate of work at home. The analysis of businesses from City financial reporting showed 893 firms as home based firms, or twenty-one percent (20.8%). When the question was asked on the survey twenty-nine percent (29.71%) declared home-based business, plus many residents primarily work-at-home (their normal location is a home office) for a larger firm – local firms (10.26%), non-local firms (17.95%). Residents also noted that they work at home occasionally – local firms (28.85%), non-local firms (7.37%).

The significance of home-based business is the requirement for higher bandwidth and reliability. Larger files are sent around. Response time is more important. Reliability and mean time to repair are more critical. Video conferencing is common, even using simple Skype applications. Security issues are more relevant. These and other factors affect this segment.

Significant Question – What Do Residents Want the City to Do?

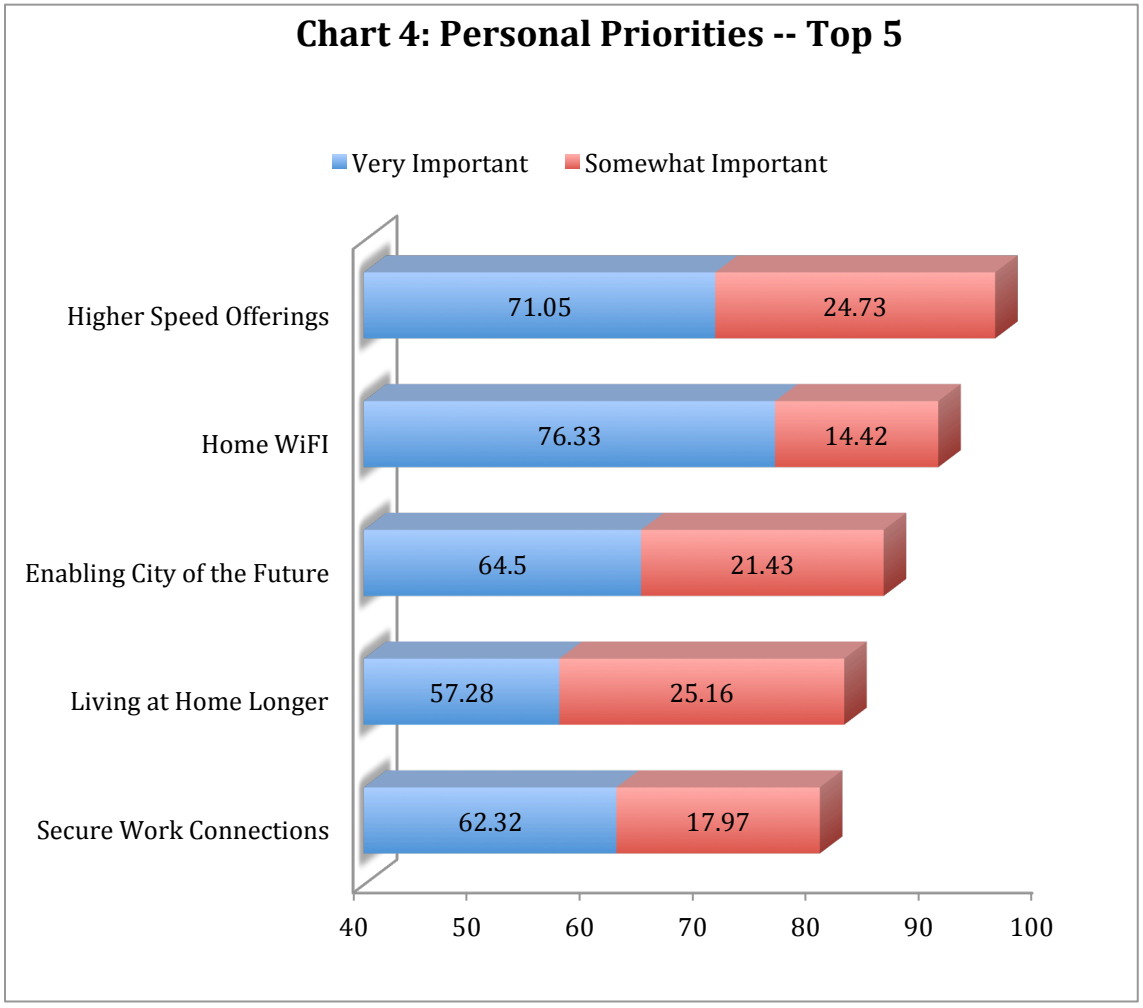
We asked a series of questions to gain a broader sense of these responses. To understand people's comfort with the subject they were asked how they would rank their technical skills. This is a sophisticated community with ninety-one percent (91.29%) saying that they "get along fine," better than that, or even claim to being a "technologist." The technologists were thirty-six percent (36.39%) of the total, leaving a solid majority of fifty-four percent (54.9%) doing just fine. ***Centennial residents are very comfortable and informed on this subject.*** Couples without children (36.97%) and couples with 1 or 2 children (33.7%) predominate. Age is skewed toward the slightly older, but not significantly post working age. Only six percent (6.41%) were under thirty. *Sixty percent (59.85%) were in their prime working years.*

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

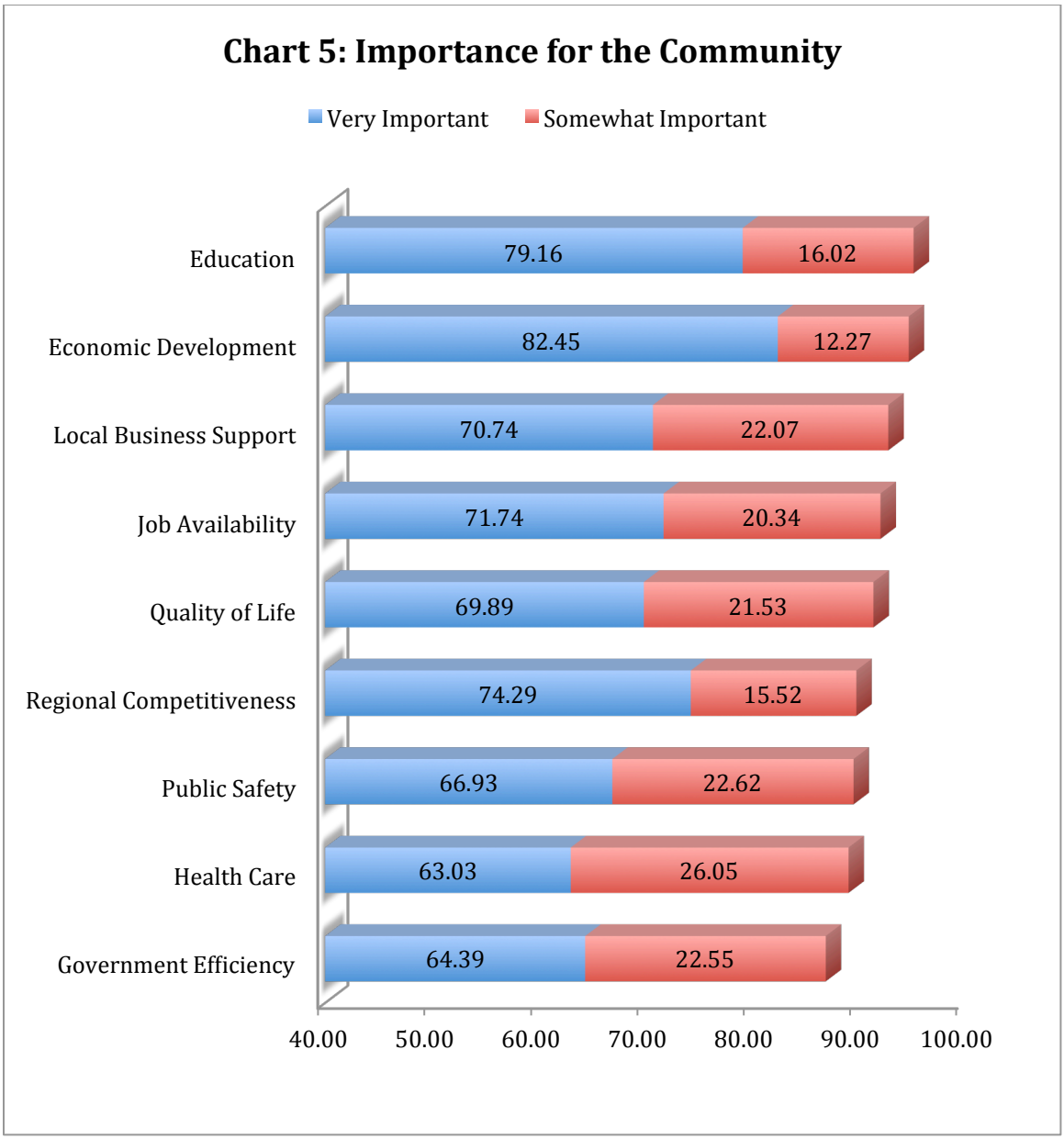
Residents were asked about the impact that communication technologies had for them personally and for the community as a whole. What was important personally is highlighted in Table 11 and what was important for the community is noted in Table 12.

Consistent with other survey findings, the personal emphasis is on improved speeds. Given the fact that slightly more than fifty-eight (58.38%) of residents receive speeds that are below the FCC minimum such a finding is not surprising.

When asked about community importance it was clear that residents valued communications as an integral component of almost every factor. All measures of importance exceeded eighty-six percent, with the top five exceeding ninety-one percent.

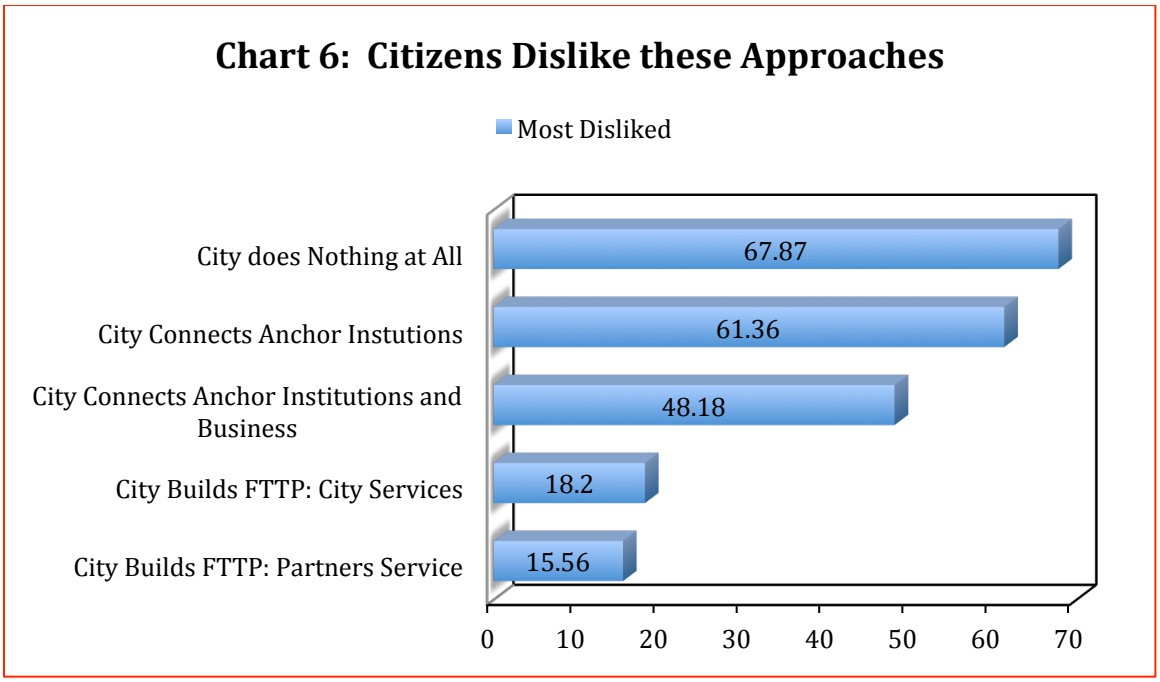


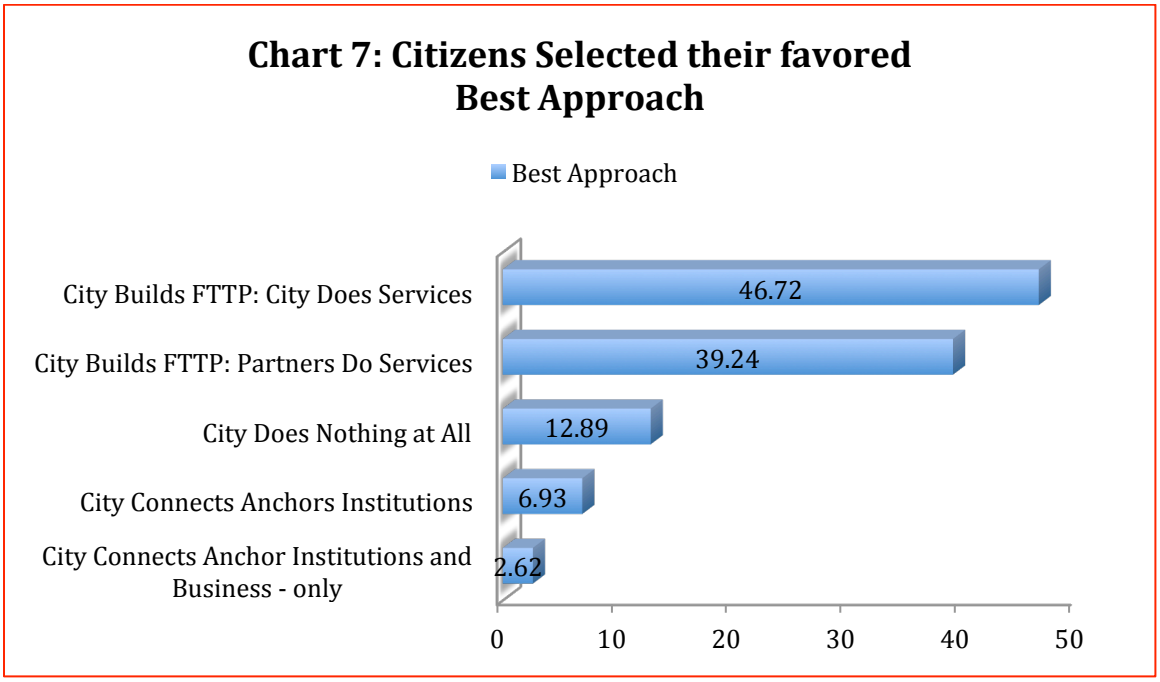
Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado



The most important question, of course, was what do the citizens want the City to do? The answer to that question is *eventually* complex. For now it is a simple question of desire. At this point we don't know what any given approach would cost to build, what services would likely be provided, how long any given approach might take, or whether there are private partnerships that would work with Centennial. There are a host of questions and information to be returned to citizens for their consideration. That said we asked the citizens what approaches they favored and which they disliked. Charts 6 and 7 display the results. The first chart lists the areas not favored (question column was headed "dislike"). The second chart lists the approaches that citizens felt were the "best approach."

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado





It is clear that most citizens would be upset if the City did nothing at all by an overwhelming majority (67.87%). That is to be understood following a vote to do something. Among the choices about what to do, the choice of supporting businesses and the City garnered only two, maybe three percent (2.62%). If fact, although doing nothing would upset most people, doing nothing is preferred over only helping the City and the businesses. These would not be good strategies.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

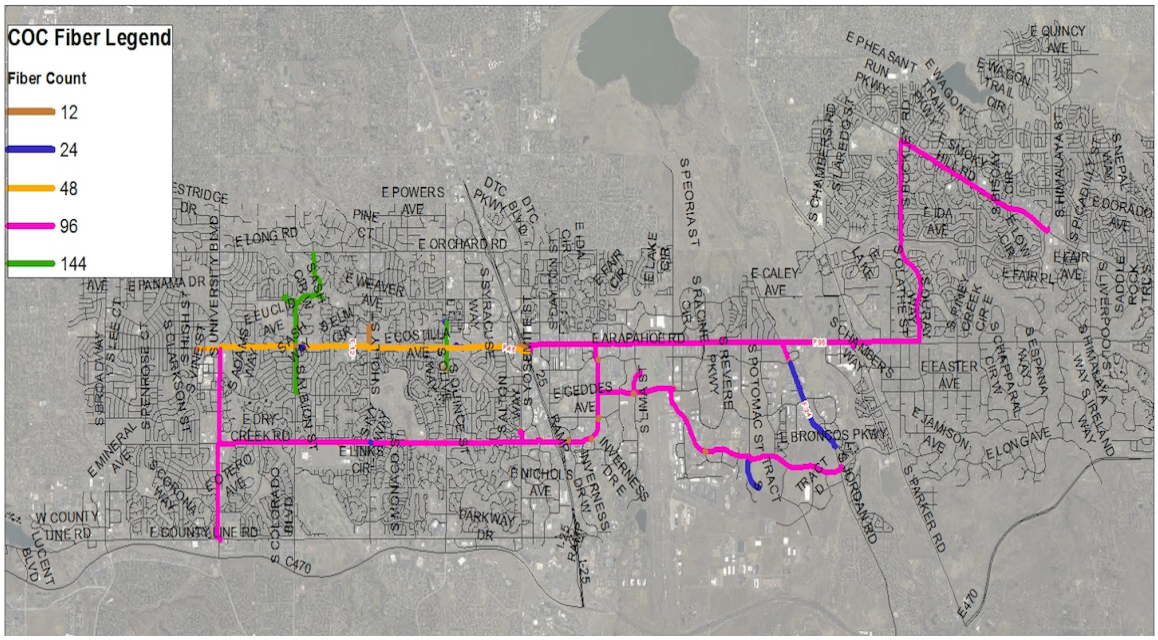
The citizens of Centennial overwhelmingly want FTTH according to this survey by almost eighty-six percent (85.96%). They divide on who should provide services -- partnerships with the private sector (39.24%) were slightly less favored than those that wanted the City to provide services (46.72%).

3.4. Summary of Centennial Fiber Infrastructure

The existing fiber infrastructure was created and intended for use by the City's Intelligent Traffic System. It was not designed as an efficient communications system capable of supporting current and future needs beyond traffic signals. The instinct to bury higher count fiber strands was excellent. The manner in which it was done left much to be desired. In the investigation of this network much confusion of records and original intent was disclosed. Currently, the conduit and fiber infrastructures have been fully reviewed and field verified. As of this report, splicing connections and OTDR testing is not yet complete. There are multiple misuses within this construction. The important understanding, however, is that *this remains a valuable asset of the City's and it can be fixed.*

The splicing review – what is connected to what – is vitally important to correcting and redesigning this network. To understand this, it is important to appreciate the actual requirements of this network of traffic signals. To connect signals requires four strands along any given path or group of traffic signals. In some cases, however, the method used consumes as much as thirty-six or forty-eight strands. In addition there is confusion concerning partner splicing and ownership separation. This is most prevalent with Arapahoe County and the State Department of Transportation. Figure 10 displays existing fiber. From the legend you may see that this network is composed of differing quantities of fiber strands: 12 strands, 24 strands, 48 strands, 96 strands and 144 strands color coded for reference on this map. The map detail is difficult to see in such a small rendering. Map detail has been created on City

Figure 10: Installed Centennial Fiber

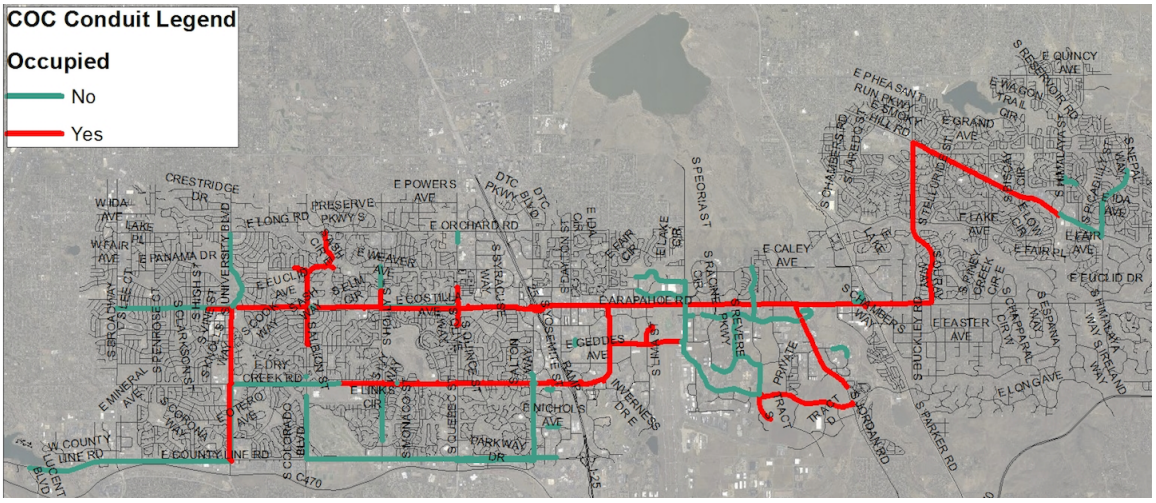


Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

databases and can be examined there for better clarity. Essentially, the fiber proceeds – east to west – from Smoky Hill Road on the north and east, down Arapahoe Road as far west as University Boulevard. There is a southern extension that proceeds from Arapahoe Road, down Havana east along Easter Avenue then to East Broncos Parkway. This Havana extension also travels west along East Dry Creek Road, ending at University Boulevard. There are lateral tributaries extending from this basic structure at various points.

Conduit agreements extend further. Figure 11 displays all conduits the City currently has access to. Conduit in the red has fiber of various size categories within it. Green lines display where conduit is present but contains no fiber.

Figure 11: City Conduit Structures



Significantly clearer maps, with more detail, have been provided to the City on Esri GIS databases and even with Google Earth files (.kmz files) showing various layers of information.

A summary of available conduit is listed in Table 10.

Table 10: City Conduit System

Overview	Total feet	Total miles	Minus New Path Restricted Fiber	Total Miles
Conduit	299,815	56.783		54.736
Conduit with Fiber	150,753	28.552		26.505
Conduit Vacant	149,062	28.231		28.231

Summarization of Size and Usage

Total 1.0" Duct	75	0.014
1.0" Duct With Fiber	75	0.014
1.0" Duct Vacant	0	-
Total 1.25" Duct	143103	27.103
1.25" Duct With Fiber	29628	5.611

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

1.25" Duct Vacant	113475	21.491
Total 2.0" Duct	150705	28.543
2.0" Duct With Fiber	115118	21.803
2.0" Duct Vacant	35587	6.740
New Path	10803'	Not available
Total 3.0" Duct	5931	1.123
3.0" Duct With Fiber	5931	1.123
3.0" Duct Vacant	0	-

The summary of installed fiber is:

Table 11: City Installed Fiber System

Overview	***Total, ft.***	***Total, mi.***
Fiber	169,154	32.037
144 Ct Fiber (1)	13,508	2.558
96 Ct Fiber (2)	119,029	22.543
48 Ct Fiber	23,636	4.477
24 Ct Fiber	9,041	1.712
12 Ct Fiber	3,940	0.746

Of the 32.037 miles listed here, the useful fiber availability is at most 27.443 miles after certain needed reductions (see below).

Note (1)	***Total, ft.***	***Total, mi.***	***Comments***
144 Ct Fiber	13,508	2.558	Note: This fiber count does not represent usable fibers
Owner: New Path	10,750	2.036	New Path IRU for 12 Ct non-commercial use
Owner: CDOT	2,758	0.522	CDOT owned, COC uses of 48 fibers

Note (2)	***Total, ft.***	***Total, mi.***	***Comments***
96 Ct Fiber	23,804	4.508	Construction in progress

To fully understand the fiber available for "other" uses subtractions from the totals in Table 11 must be made. Those subtractions include:

1. All 12-count fiber is only used to connect signal – minus .746 miles.
2. Much of the 24-count fiber is uncertain: -- minus 1.1 miles

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

   a. 1.1 miles down S. Jordon is used to connect the public works structure with 8 strands and 4 strands are used for traffic signals, but the remaining and available quantity has not been able to be verified.
   b. .39 miles down S. Chambers Road may be slightly usable
3. Spurs off of the 96 count fiber is less usable – minus .19 miles
   a. .3 miles along Lima Street used to connect County offices
   b. .16 miles along Yosemite Street
4. Spurs off of the 48 count fiber along Arapahoe – minus 2.558 miles
   a. These are both contained in 144 count fiber bundles (see note 1)

Critically Important Note: It is our understanding that the method of deployment was to interconnect base fiber bundles (12 strands) assigned to a given roadway (e.g. The green bundle is used along the path for Arapahoe; whereas the Slate bundle is used along Havana/Dry Creek). Along those corridors, and in all splice locations, the entire bundle (12 strands) was continuously spliced even though only four (4) strands were required for the traffic signaling system. The extent of this approach, and the unnecessary exhaustion of fiber assets, will not be known in time for this report submission. It is assumed that a proper reassignment of strands, along with an overall architecture, including the breaking apart of these unnecessary splices, will be a part of any future network reconfiguration.

Summary

With these subtractions, **useful fiber availability is 27.443 miles.** This also includes about 4.5 miles that is currently under construction.

There also exists 28.231 miles of conduit that does not contain fiber.

Limitations and a little Math:

- Transport Network: Limited to some number of strands less than 48 count due to the section along Arapahoe. Such a transport fabric could be constructed with a little a four or eight strands. This could be built Citywide and support locations throughout Centennial from which to extend wireless, ITS, FTTH and/or other future services (see estimates in Section 4).
- Support for Small or Medium size business with direct fiber. Perhaps as much as eighty (80) buildings off of any given "leg" of the existing network could be supported. There are currently two such legs that could provide such and one that could add, perhaps, another thirty-six (36) connections. This would provide a total of 196 potentials if optimized. There are currently 166 multi-business buildings without fiber, plus large-scale structures.
- Support for any directly fed FTTH networks would require use of one strand for every 16 or 32 homes. Assuming the same availability of the previous 196 strands that would provide for between 3,000 and 6,000 homes.
- Support for wireless with direct connections to access points (wireless antenna/receivers). There is an estimated landmass of twenty-eight (28.23) square miles in Centennial; hence, coverage would soon become congested at any reasonable higher speeds.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Therefore, while the placement and quantity of fiber is significant, it is not sufficient to build centrally fed alternatives for business support, wireless overlays or FTTH. Building a transport ring is the most likely use of this fiber if the intention is anticipate long-term growth and the addition of services.

3.5. Legal Criteria

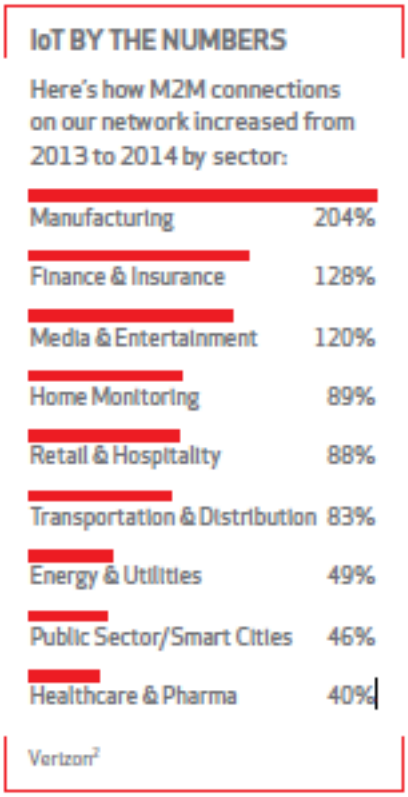
There are few legal criteria that pertain to the opportunities identified herein. Title 29, Article 27 of the Colorado Laws applies and the City has met that criteria. State and Federal Laws and regulations, for the most part, pertain to services offered. For example, were the City to provide telephone services, DORA, Colorado State's PUC and Federal regulations would apply. Were the City to offer video services then a franchise agreement, no more favorable than that offered to Comcast and CenturyLink would apply. Internet services are soon to be subject to a very limited sense of Title II, but that will not be significant. None of these laws and regulations currently applies to the City because it does not currently provide services.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

4. Opportunity Considerations

Opportunity identification in the context of this report is tightly bounded. Presented here are three primary areas for focus. Those areas result from trying to answer two questions. The first stems from the fact that Centennial has underutilized fiber assets created in just the past few years. What then can be done by optimizing, or augmenting, those assets? The second is how to respond to the citizens of Centennial who voted to have the City act on their behalf? What do they seek and can, or should, the City provide newer communications services through its fiber? Also, in this report the consequences of failed planning, failed foresight and too narrow a focus on previous deployments of fiber were discussed. The City would be foolish to not heed that lesson it goes forward. An opportunity strategy needs a broad view.

There are major disruptive forces at play today. We have seen whole industries disappear in a matter of years. New industries, new ways to work, new entertainment, new devices and much more have equally emerged in the same period. Business technologies are rapidly moving towards cloud based services and the expenditures in this new area are staggering. Google alone is spending $3.5 Billion dollars a quarter in building cloud infrastructure. Social technologies and the entertainment markets are in complete turmoil. Facebook, Twitter, Google+ and WebRTC are now "old hat." Brian Roberts, CEO of Comcast, has said: "I believe television will change more in the next five years than in the past 50." Deloitte calls this disruption the "Big Shift" and postures new business models based on niche fragmentation of markets, while leveraging large-scale concentration. Symbiotic and reinforcing cooperative relationships between large scale and small niche players is the tempo of our time.



The Internet of Things (IoT) is so new it must be hype. Wrong. Verizon saw a 45% year-over-year revenue growth in its IoT business in 2014. Verizon now manages over 15 million IoT connections and is predicting that growth rate for years to come[3]. The impact on everyday business can be seen clearly already. Cisco predicts that by 2020 there will be 50 billion connected devices around the world. Verizon expects more. In 2013, IDC Government Insights called it the Internet of Everything (IoE) and said: "Smart City development is a question of when not if, a question of how not what."[4] Homes are installing IoT thermostats, door openers and much more. Over fifteen in-home devices can now connect with a Nest thermostat and manage homes remotely. Such are the many and varied conversations business and residents have today.

[3] Verizon, State of the Market, The Internet of Things 2015.
[4] IDC Government Insights, Smart Cities and the Internet of Everything, October 2013

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Opportunity? It's boundless. *Opportunity strategy is not about how to define a single, unchanging vision for the future, but rather is a way of thinking about how to deal with the future.* Business will change. Citizen needs will change. Cities will change. They have no choice. To move forward we strongly recommend thinking strategically, thinking differently. The fiber will last at least another thirty years. Think adaptability, efficiency, rapid innovation, inclusiveness and close coordination.

So the real question is not whether you will use your fiber. And it is certainly not whether your citizens get better triple-play services at better prices. Both of those should be true by default. It is a question of what ingredients and structures are most necessary to promote the core values that all cities must have to be leaders, to define a high quality of life and to keep on doing this for years to come.

4.1. Overall Recommendations

We recommend that you consider three keys to success: collaboration, responsible manageability and inclusion.

Collaboration

We addressed the needs of public sector stakeholders in their interviews. The prime issue for those groups was geographical overlap in the region. No network capability that Centennial could construct would address this primary issue; hence any given need they express – if done only in Centennial – will not suffice. But Centennial can lead. Collaboration models work well and we noted some cities that do it well, like Chippewa Falls Wisconsin, in Section 3.1. Advanced municipalities are using fiber networks to reach beyond their boundaries: Chattanooga Tennessee, Wilson North Carolina, Bristol Virginia, New York State's OATN and Ohio's OneCommunity. Economic development studies point to regional fiber efforts as returning the best overall results.

Opportunity One: Form a regional group or groups focusing on networking requirements for Police, Fire and Education (at a minimum). Be sure to think about future sensor networks, ways of refocusing delivery of services and new applications of all kinds. Build a transport infrastructure that can deliver aggregation benefits to these groups along with other developments we'll address later. Use the transport infrastructure to support a reconfigured ITS systems, now shared with others (e.g. Englewood is building ITS now) and WiFi and LTE radios of high quality and reliability in support of Police and Fire voice and data requirements. Utilize Software Defined Networking (SDN) to manage the transport structure and self-organizing network (SON) wireless mesh networks to drive three key benefits: reliability, improved security and bandwidth-on-demand services supporting public safety. SDN/NFV is the now current technology that minimizes cost, reduces operational expenses and substantially improves delivery of vital services. Use collaboration to ensure coverage throughout the region and to drive aggregate costs down.

This is very doable with existing fiber and moderate fiber additions. It will require, above all, informed leadership centered in City Staff, negotiation with all nearby non-profit bodies and good counsel.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Manageability
Over the course of the next thirty years – probable life of the fiber network – much will change. We are just now seeing the *beginning* of the communications revolution. Centennial needs to understand that informed Council actions must be supported by informed staff. This is no different than financial budgeting or other core functions of a City. You will need full time, knowledgeable staff. The City also needs to know that the applications that currently create interest – like the ITS developments or FTTH – will become ordinary. New opportunities will arise. Partnerships that the City joins in will need to be dissolved and new ones created.

Opportunity Two: The City needs an informed point of focus, a point of contact, a person or a staff, for all aspects that affect communications: permits and right-of-way changes, focal point for new applications supporting yet unseen needs, management of partnerships and regional collaborations. The simple observation that the current ITS planning, it history and result, is separate from this effort is proof enough of the need. This staff would also be responsible for the operation of a City "hub," described more below, that can act as a manageability point of control.

Importantly, whatever technical architecture is created and whatever uses this fiber is assigned today – they too must have adaptability as a core requirement – or the investment is diminished. In the following section technology alternatives and certain costs are identified. It is important to understand that the history of better and better technology has come with less cost, not more. We speak of a transport network and aggregation of demand. Behind that is the knowledge that aggregation produces cheaper per unit cost. Developing an architectural framework with a logical point-of-presence will allow the City control over quality and change.

Imagine that the City finds a partner to provide a residential service like Internet connectivity. If that partner fails, is purchased by another company with a different focus, or simply wishes to move on – what is the City supposed to do? We recommend thinking about that now, before you enter partnerships, before you are responsible for the next disliked provider. Centennial needs flexibility and control in all aspects affecting the Cities communications infrastructure.

This is very doable. Hiring knowledgeable persons happens all the time. Find one or more. Establish a team responsible for networking communications – all networking communications. They can lead your collaborations that bring benefit not otherwise available. Build a central location – initially – to operate City communication requirements. Design using the newest technology of Software Defined Networking/Network Function Virtualization (SDN/NFV) as it will offer you the needed functionality and some degree of longevity, which is discussed more in the next section. Control partnership quality through a City "hub." Add support for business aggregations via the network – small companies or large. Add support for public safety wireless and education system aggregations. Add support for neighborhoods that wish to provide FTTH for themselves. And keep on growing.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Inclusion

Inclusion, or the lack of it, is a primary source of content and discontent. People and business seek fairness. It may be elusive and it may be difficult to achieve, but it should never be hopeless. Currently in Centennial product offerings from legacy carriers are *sporadic, geographically inconsistent, varying from poor and inadequate to robust, reasonable and of high quality – and in all cases, provider offerings are priced higher than similar or better services nationally*.

Opportunity Three: Inclusion for residents and business can be accomplished. For residents we propose development of City FTTH clusters. For business we propose using distributed access points along the transport fabric.

High-end businesses have ten to thirteen fiber providers available to all six hundred of them in Centennial. The other 2,500 small and medium size businesses have almost no choice -- no one that is interested. The City can act here. The City can also act to spur investments for large-scale companies. Aggregating traffic is how the business of telecommunications works. The City can provide a point of aggregation. With today's technology this point of aggregation can also allow for new and important services, such as bandwidth on demand, needed for cloud access. No carrier in Centennial offers this service yet, but it is available elsewhere.

Homeowners pay Comcast $114 for 105Mbps of Internet access. It costs Comcast less then $6 in peering costs to provide that service. The 1.5Mbps T.1's that small businesses are buying are even more egregiously priced. It is true that there are many other costs from personnel, operations and management and equipment born by theses carriers, but this is a *very high margin business*. Those are simply facts. No disrespect is meant to the providers of those services. They are in business to make money and they do. Inclusion here refers to the national, even regional, picture.

In many cities around the country, supported by municipalities and private firms alike, the retail cost of a 1Gbps connection is $70 or less. That speed is 10 times the offerings from the best local residential carrier and 25 times the best offering of the other. Over fifty-eight percent of Centennial have speeds less than the FCC minimum recommended bandwidth. By price difference the disparity is even greater. Normalizing the comparison on a per megabit basis yields $1.08 (best price) in Centennial versus 14 cents elsewhere. Would you expect such a difference in cost for almost anything else you buy? Centennial residents complain about speed and cost. It is easy to see why.

The investment requirement for the entire City to fully build out FTTH is likely near $100 Million dollars. Estimates will vary in this regard but a high-side and safe rule of thumb number would be $2,500 per home were all 40,000 homes fully connected. The likelihood is that only fifty or sixty present of homes would wish service and others would simply be passed by fiber, but not connected. This would cost less than 100,000 million, but then you need service infrastructure and so on. This figure is given as an very rough order of magnitude. Actual financial feasibility will need to be performed.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Still, almost eight-six percent (85.96%) of the citizens seek this. With normal triple-play services, priced below current retail prices, such a network can be financed and made sustainable. There are significant hurdles to such an approach. Unlike communities in rural America, where legacy provides have shown little interest; competition in Centennial is likely to be quite fierce. That in itself might be good, but it doesn't bode well for a City to face down carriers with deep financial resources.

The issue is whether take-rates, the percentage of customers taking service, can be sufficient to support sustainability. If take rates can be assured, sustainability is not hard. Most feasibility studies we have conducted demonstrate that take-rates above forty percent (40%) are very sustainable. The average take-rate for municipalities nationwide is fifty-four (54%) percent. Yet as we noted repeatedly, coverage in Centennial is sporadic – some neighborhoods are well served, some not. To ensure an across the board City take-rate, assuming heavy competition for legacy providers is more risky than advisable. The good news is that citizens want FTTH. The recommendation, therefore, rests upon neighborhoods themselves ensuring adequate take-rates.

With the City's support, neighborhoods could come together and gather pre-signup commitments for FTTH. Neighborhoods with commitments of 50% or greater would be eligible for a FTTH build. Financing for these builds can be done through property assessments, utility fees or General Improvement District (GID) bond funding as likely financing vehicles. The City's transport network could be used to deploy distributed clusters supporting these neighborhoods. Services such as triple-play, education or healthcare in the home and more can be offered initially or as they evolve. These services can be offered through the City "hub" called for under the manageability component. Several partnerships have been explored with technology companies interested in supplying services. Open structures can be managed through the SDN/NFV architectures that are now in favor. As the number of neighborhood clusters grows, the attractiveness for other providers grows as well. No intent to preclude existing legacy providers exists. They would be welcome to offer services through the "hub" and over the fiber networks. The virtualized structures of SDN/NFV and manageability via the operational support mechanisms coming into play will allow each provider the ability to service their clients without interfering with each other. Providers would have complete visibility to the quality of their network slice. They can add or delete services as they desire and as their customer require. Customers, in turn, can add or delete providers as their needs change.

This is very doable. The City can provide connectivity to business allowing entrance via City distribution points or through neighborhood clusters. Residents obtain the desired FTTH networks and a variety of services from private partners, legacy carriers or even City services. The construct of this network is discussed in the next section.

4.2. Technology Components and Approach

Technologies serve the business needs if properly architected. The three components of the recommended business plan are: Collaboration, Responsible Manageability

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

and Inclusion. What is to be designed must support those criteria. In addition, any architecture must recognize that future needs are not fully knowable. The architecture must be able to adapt, support new services as they become known, operate with efficiency and overall be sustainable.

There are four components of this proposed architecture.

1. Transport Infrastructure
2. Wireless Infrastructure
3. Cloud Based SDN/NFV Management and Control Structure
4. Fiber-to-the-Premises and SMB Business Support

Transport Infrastructure

To optimize the use of Centennial's existing fiber, we recommend developing a metro-based transport structure. This structure would consist initially of three or four interconnected rings: the Smoky Hill ring, the Arapahoe Ring, the Dry Creek Ring and perhaps a University ring to the west. Rings would consume eight fiber strands in each of the current structures. Empty conduit will be filled with larger strand counts that can be determined later. Fiber size will not significantly affect cost.

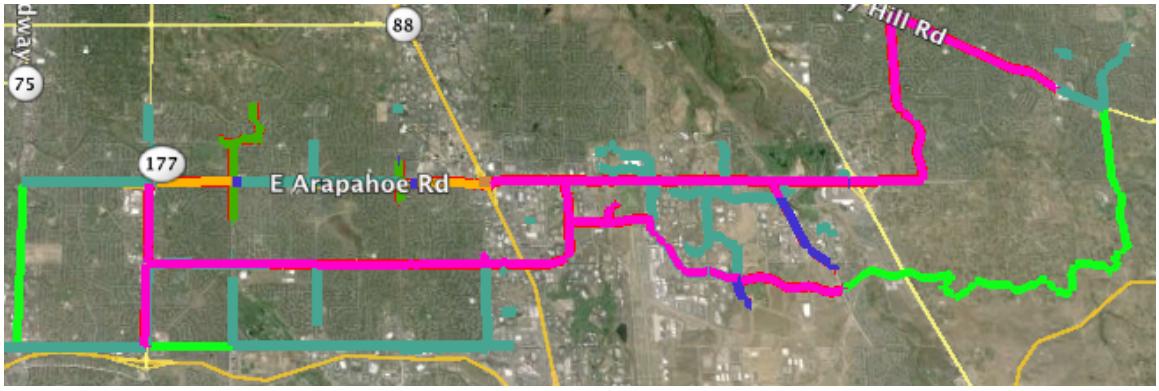


Figure 12: Green highlights note additions to form 4 ring meshes

Costs for this network will need to be determined at some later stage following Councils expression of intent. However as a very rough guideline we calculated the fiber expense likely to be incurred with this build. This estimate only represents the outside plant build cost for areas that need totally new construction and leverages existing empty conduit. Note that the Arapahoe Ring does not need additions.

Section	New Fiber & Conduit	Existing Conduit	Total Costs
University Ring Addition	260,317	11,730	$272,047
Dry Creek Addition	70,600	31,586	$102,186
Smokey Hill Addition	476,832	4,668	$481,500
		Total Estimate	**$855,733**

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Equipment on this ring will need to be determined after more work is performed. There will be a need to determine the correct placement for distribution stations along the ring. In addition, equipment determinations will need to consider what actual support is needed at each location. The control structures for this architecture will be those required by the hubs and the SDN controllers. These can be estimated in time.

Wireless Infrastructure

The wireless infrastructure will need to support both WiFi and cellular LTE networks. The actual equipment will be specified following the collaborative meetings with Public Safety and coordinated with the ITS work currently proceeding. There exist wireless radios currently that support both wireless technologies. Given that the transport network can be designed for very high capacities limitations on throughput will be a function of the radios and protocols employed. This can be significantly better than a normal retail service. Such a network can be built with authentication capabilities that would securely allow for the additions of City mobility functions as well. For example, Public Works mobile units could also benefit. At the same time emergency communications can be secure and protected from infringement.

Figure 13: Older Wireless Units

Figure 14: More Tasteful Units Today

Wireless has improved along with most technologies. However the characteristics of WiFi and LTE are different in many ways, include the range, capacity and quality of services of the signals and signal management. Appearance is also improving as can be seen in figures 13 and 14. Collaborative efforts can improve the overall performance of the public safety sectors by giving them advanced tools. The major costs involved with wireless technologies are actually in the fiber connections that terminate the radios. Fiber connections would be simple terminations from the transport network. Cost, therefore, would be largely contained in the Transport infrastructure above.

Cloud Based SDN/NFV Management and Control Structure

The transport, wireless infrastructure as well as connections to businesses and, potentially, homes require normal management infrastructures. Infrastructures that are used by most legacy carriers are fairly old and cumbersome. Newer technologies such as SDN/NFV are architected with extensive management structures and

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

components. Referred to as Management and Network Orchestration (MANO) this umbrella term refers to carefully thought out structures that assume a high degree of automation, network visibility and, importantly, lay the ground work to add and remove capabilities almost at will – in seconds or minutes. SDN/NFV with MANO is disrupting legacy environments at a pace not seen since the birth of the Internet. Disruptions of this magnitude only occur because they bring overwhelming benefit.

These structures also allow Centennial the ability to precisely and efficiently control environments. Many separate but somehow equal networks can be laid down upon Centennial's fiber infrastructure – on the same strands, with the appearance of complete isolation and separation. Building such a hub will give Centennial protection allowing providers to come and go based on their performance and acceptance by the community. Centennial can add new capabilities be those the addition of cameras, or radar to the ITS network, adding a new business, increasing wireless coverage, adding service to a neighborhood FTTH cluster.

This architecture will need to be defined in the next stage of development should the Council so choose to elect this approach. Costs for this hub area are not significant in comparison to the physical infrastructure, but will need to be assessed.

Fiber-to-the-Premises and SMB Business Support

Having constructed a transport network with distribution points – points of network connection – Centennial may now consider support for business and residents. Business connections are basically simple. Some may prefer to utilize the wireless network. Other wireless capabilities can be added for various purposes. However, the main driving factor here are connections to those building, either standalone or multi-tenant that were discussed in Section 3.1. There are 166 multi-tenant structures in Centennial that do not have fiber access. It is true that fiber will need to be laid to

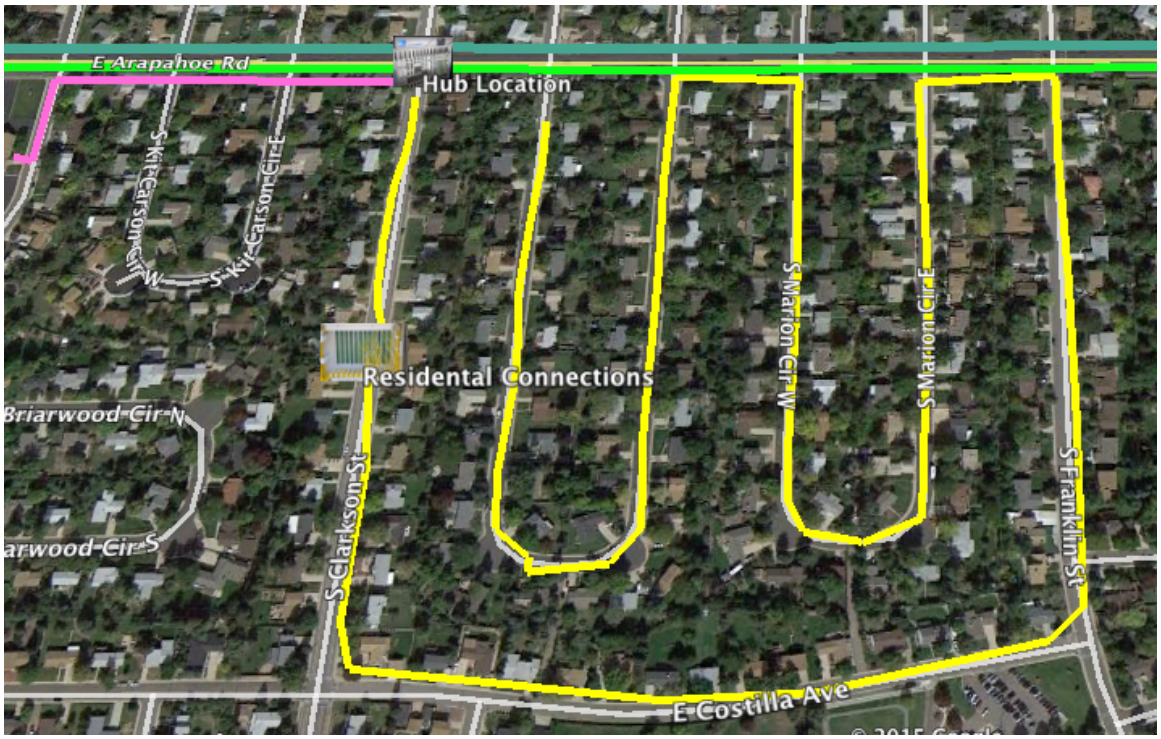
Figure 15: Business Connection from a Transport Distribution Point

the building entrance to support these structures, but the cost of doing so is likely to be substantially less than most carriers charge. Financing of the build is something Centennial may wish to consider. Proper construction of building codes to ensure that fiber is placed on any new building will also help alleviate this cost.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

FTTH is a very high priority for the citizens. In the previous section on Inclusion the idea of building neighborhoods was discussed. With a transport structure in place certain costs can be shared. Residents can assemble pre-signup commitments in groups of 800 or more homes. In general, expected costs would approximate less

Figure 16: Fiber to the Home Neighborhood Clusters



than $2,000 per home. Those costs can be allocated by GID funding for long durations, much like homes do for street assessments. The value of homes with fiber connections is known to increase at least by $10,000 according to past studies by the Fiber To The Home Council. The technology is simple. We would recommend consideration of Gigabit Passive Optical Networks (GPON), Active Ethernet (AE) approaches or some hybrid. This technology has been used for more than eight years. GPON is the standard that is used most frequently. It is also compatible with Wave Division PON (WDMPON), which is the likely successor for FTTH networks. WDMPON is anticipated to be in common production by 2020. The modifications to a GPON network would allow 40Gps WDMPON are the replacement of either end of the connection and optical splitters are replace by optical wave-guides. The standards committees all agree that when migration from GPON to WDMPON is necessary, the requirements must include easy methods for migration and coexistence. This means that Centennial's fiber network has longevity. It will be a good investment.

In conclusion, the technology today will support Centennials ambitions now and in the future.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Appendix A:

OSPInsight Materials Data Sheet

Company Overview and Products

Contact regarding RFP
Seth Straayer Senior Sales Office: 661-251-5500 Cell: 661-644-4300 sstraayer@advancefiber.com

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Company Overview

Established in October 1993, Advance Fiber Optics (AFO) is an S-Corporation with headquarters in Salt Lake City, Utah. The Company is a full-service provider of fiber optic services, specializing in software data management and field services. AFO provides its products and services to over 100 companies throughout the world.

Even in a time when the world economies are suffering, AFO has stayed strong. Because AFO has stayed away from speculative investments and risky ventures and has avoided unnecessary debt (in fact, AFO has almost zero debt), its balance sheet is healthy. AFO's senior staff is conservative and vigilant and will continue to be so, just as they have been since the day they did their first fusion splice in 1993.

AFO's History

· AFO was incorporated in January 1994 by Clay Arnell and Randy Anderson. The Company creation was started to introduce high standards of aerospace fiber optic engineering to the U.S. telecom industry.

• In 1997, AFO introduced its first release of OSPInSight network management software. OSPInSight was created to better serve network-engineering needs with user-friendly features.

• AFO branched out to data services, specifically data conversion, to meet the growing needs of customers that did not have enough internal labor to meet shrinking delivery schedules.

• The Company today has expanded to four U.S. field services offices (Sacramento, Salt Lake City, Portland, and Seattle), one data service office (Salt Lake City), two U.S. sales offices (Los Angeles and New York City), and worldwide network of representatives.

Software Services

OSPInSight is AFO's leading software program that gives customers detailed information about every aspect of fiber optics. Network data is retrieved from a relational database and is displayed in tabular and graphical formats. A detailed review of each application is listed below:

· **OSPInSight Edit** – This is where all the customer's information is populated and where customers can design and edit virtual networks. This package allows users to document with accuracy actual fiber optic build outs and new additions. AFO lists the following features as key items that make OSPInSight Edit a valuable tool for end users:

Quickly obtain an accurate view of your network for maintenance and reporting in order to share the data company wide.

Analyze data with standard and customized reports

Increase network design efficiencies by testing possible routes, installations, and connections before building them.

Provide management with complete, accurate and on-time reports for better decision making.

Develop superior target marketing by pinpointing network assets, their capacity and availability and the specific potential customers within range of these assets.

· **OSPInSight View** – This is an access portal program where everyone in an organization can safely view and use the network information created by OSPInSight Edit without altering it. OSPInSight View lets users view specific asset placements, inventories, route and splice schematics and much more. OSPInSight View is commonly used for sales and marketing and executive planning. AFO lists the following features as key items that make OSPInSight View a valuable tool for end users:

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Quickly and easily obtain an accurate view of your entire network or a single network element to speed maintenance and reporting.

Report changes accurately by sending redlined electronic notes directly to the network editor. Editors can display redline notations along side the network display while updating the main database insuring complete accuracy.

Use OSPM-View's automated "find fault" to locate faults on the network map in seconds, reducing restoration costs and technicians' frustrations, and increasing customer satisfaction and retention.

Control user-access within a network to increase security and database integrity.

Provide management with complete, accurate and on-time reports for better decision making.

Develop superior target marketing by pinpointing network assets, their capacity and availability, and their proximity to specific potential customers.

- **OSPInSight Web** – AFO has created an "anywhere" access network on the Internet so customers can access read-only network information at anytime. Key features include access to OSPM-Admin reports, critical network asset data and fiber optic schematics. AFO lists the following features as key items that make OSPM-Web a valuable tool for end users:

  Quickly and easily obtain an accurate view of your entire network or a single network element to speed maintenance and reporting.

  Use OSPM-Web's automated "find fault" to locate faults on the network map in seconds, reducing restoration costs and technicians' frustrations, and increasing customer satisfaction and retention.

  Provide management with complete, accurate and on-time reports for better decision making.

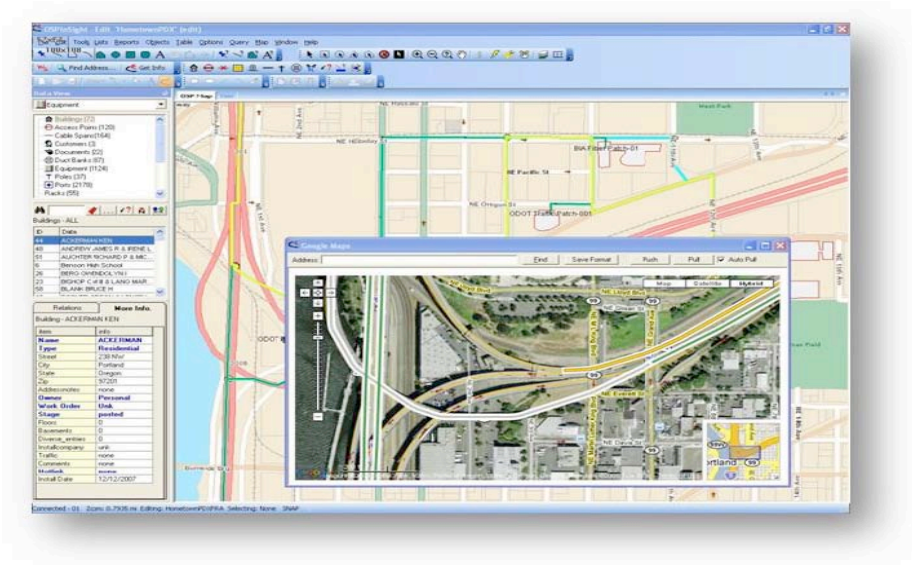
  Develop superior target marketing by pinpointing network assets, their capacity and availability, and their proximity to specific potential customers.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

OSPInSight Technology

⑩ Overview

OSPInSight uses a front end GIS component in concert with a backend database



component to create an easy to use network management platform.

The GIS technologies supported by OSPInSight are ESRI (www.esri.com) and Pitney Bowes MapInfo (www.mapinfo.com).

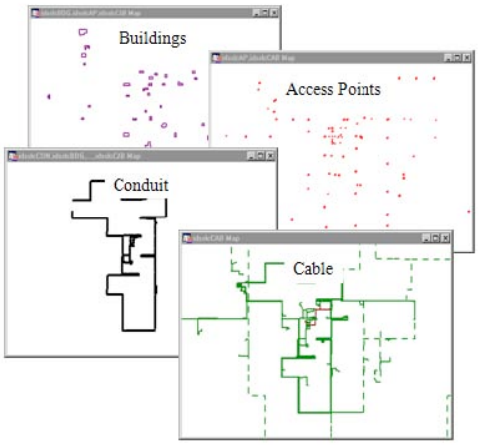
The databases supported by OSPInSight are Oracle and MS Access and SQLServer in 4th Qtr 2013.

OSPInSight also utilizes the features of MS Visio in order to display inside plant equipment in racks as well as associated floor plans.

· Feature Sets

A feature set is a set of features or objects within a GIS layer. A feature set would be something like buildings or cables. These feature sets are stored in the GIS, and in the case of Oracle, the features are also stored within the database. OSPInSight contains the following feature sets:

- Buildings
- Access Points (ie. manholes)
- Termination Points (ie. panels)
- Splice Points
- Cables
- Slack Loops
- Duct Bank (ie. conduit)

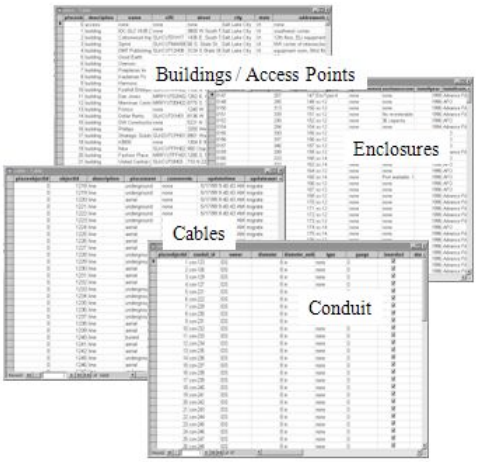


Lookout Point Communications©2015 NewCom Technolc
Release only with the Explicit Permission of the City of

-Poles

· Feature Attributes

Each feature (ie. an individual building, splice point, etc) can have corresponding feature attributes. For example, the building would have a corresponding address. These attributes are stored in the backend database.



· Land base

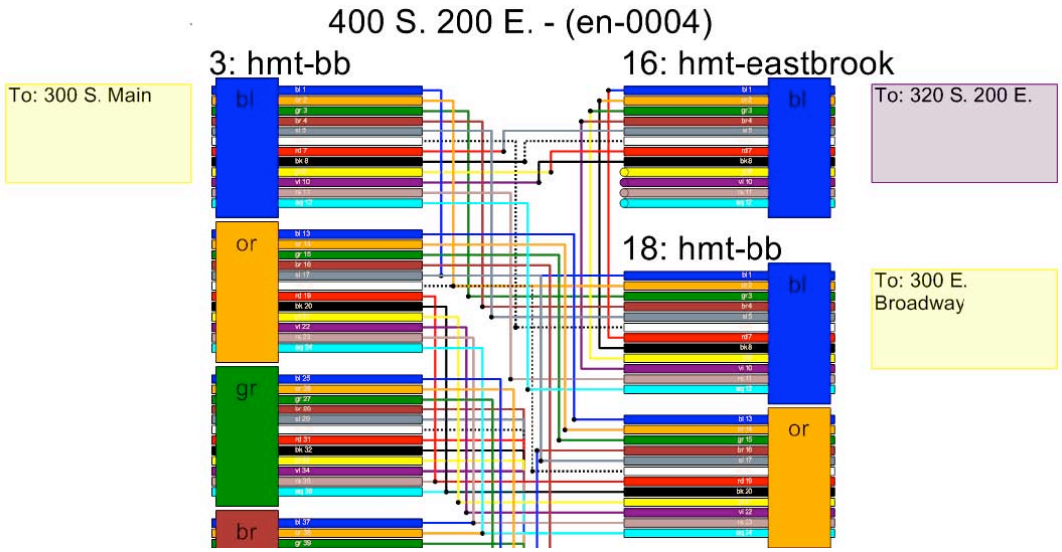
The features will need to be drawn on top of some existing land base. That will typically be off-the-shelf electronic maps, or CAD drawings. The land base is what defines where the features are from a spatial perspective. The land base should conform to a standard earth bound projection system. This will enable the features to have the ability to be posted on popular web based mapping platforms such as Google Earth and Google Maps.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

· Connectivity

The fundamental objects within OSPInSight are strands (ie.fibers) and ports (ie. a port on a termination panel or transmit / receive equipment).

A critical element of OSPInSight is its ability to manage connectivity of ports and strands. Connectivity includes splicing of strands to other strands, termination of strands to a port in a patch panel and patching from port to port of a panel or equipment. The connectivity is stored in the same database as the attribute data.



⑩ Inside Plant Equipment

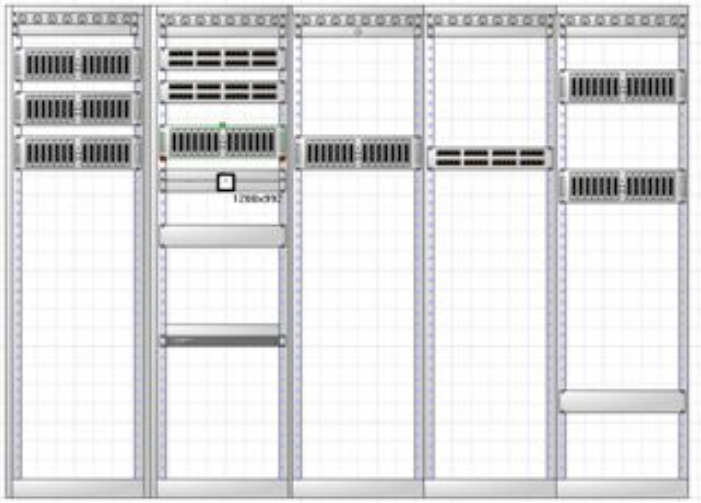
MS Visio is used to store the information for inside plant assets. What is unique about this feature is that MS Visio can be used independently of OSPInSight to create drawings of inside plant assets and record associated attribute data within the MS Visio file structure. Then, when the data within the MS Visio drawing needs to be uploaded to the OSPInSight database, a tool called the Mass Enumerator is used. The data between the MS Visio files and the OSPInSight database is then synced up. This data can then be edited from within either OSPInSight or MS Visio.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Racks with Equipment

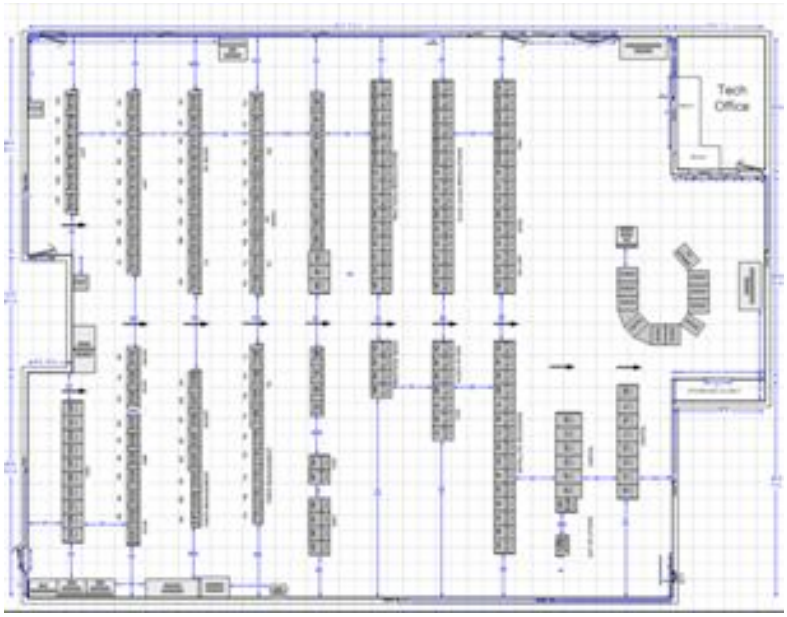
Floor Plans

⑩ Desktop and Web Applications



The OSPInSight desktop applications for ESRI use ArcView and ArcEdit. OSPInSight is integrated within both ArcView and ArcEditor.

The OSPInSight web applications use MapInfo MapXtreme as the GIS component. This component is integrated into OSPInSight. For ESRI users, AFO has created a middleware application to push or pull data from the ESRI format to the MapInfo format for use within OSPInSight Web.



Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

- **Oracle/SQLServer**

  OSPInSight supports and tests with Oracle 10g. However, there are OSPInSight customers who do use Oracle 11g. SQLServer will be supported with the release of OSPInSight 8.0 by the 4th qtr of 2013.

- **Land base**

  OSPInSight can use any source of landbase supported by Esri ArcGIS products.

IT Requirements

- **OSPInSight Desktop Applications**

Hardware Requirements (Minimum)

· CPU: 2.2ghz recommended or higher · Processor: Intel Core Duo, Pentium 4 or Xeon Processors · Memory: 1gb minimum, 2gb recommended · Display: 24 bit color · Monitor: 1024x768 recommended · Disk Space: 2.4gb · Graphics Adapter: 24 bit graphics with at least 32mb of ram or higher but 64mb or higher is recommended

Software Requirements

· Windows operating systems from Windows 8 to XP SP2

Language code is written and open source software

· VB6 and C# .net · The SpliceGui application contains an open source software called Picalo. The license type is MIT.

- **OSPInSight Web Applications**

Hardware Requirements (Minimum)

The following are the minimum hardware requirements necessary to run OSPInSight® Web software. However, the software will perform more efficiently with a more robust computer.

Pentium III 1000 MHz (1 GHz) Processor

256 MB Ram

64 MB Video Ram

Disk Space: OSPM – 500 MB free hard drive space after application is installed

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Software Requirements

The following software is required to run OSPInSight® Web software:

· Windows XP Professional SP2 or Windows 2003 Server (2003 Server recommended) · Internet Information Services · Silverlight 2.0 or greater · Microsoft DotNet 3.5 Framwork

System Requirements · Supported Operating Systems: Windows Server 2003; Windows XP Service Pack 2 · Required Software: · Windows Installer 3.0 or later. Windows Installer 3.1 or later is recommended. · IE 5.01 or later: You must also be running Microsoft Internet Explorer 5.01 or later for all installations of the .NET Framework. · Disk Space Requirements: 280 MB (x86), 610 MB (x64) · MapXtreme 6.8

MapXtreme requires the following software specifications:

· Windows XP Professional SP 2 · Windows 2003 Server Standard Edition (SP1) · Windows 2003 Web Edition (SP1) · Windows 2003 Server Enterprise Edition · (IIS) Internet Information Server web server software · Internet Explorer or Netscape Note: MapXtreme ONLY supports
Netscape 6.0 and 6.1 · An active account on the server using administrator rights

MapXtreme requires the following hardware specifications:

· Memory · Windows Server 2003: 160 megabytes (MB) RAM:
· Windows XP: 160 MB RAM

· Processor · 450-megahertz (MHz) Pentium II-class processor · 600-MHz Pentium III-class processor recommended

· Graphics Card · MapXtreme has minimal dependency on the graphics cards. Any standard Graphics card with 64 or128 MB RAM will be sufficient. Language code is written and open source software

· Combination of Java and C# .Net

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Reference Sites

OSPInSight is used in over 100 different companies worldwide. However, for purposes of this RFP, four reference sites will be given. Contact information has been included. Those people listed below have agreed to discuss OSPInSight with a representative of Customer.

Kris Bremer
Keys Energy Services
(305) 295-1108
Kris.Bremer@KeysEnergy.com

Nolan Young
Q-Life – City of the Dalles
nolan_young@ci.the-dalles.or.us
541-296-5481

Lee Gustavson
Integra Holdings
Lee.Gustavson@integratelecom.com
360-816-3218

Evan Spitzer
Lightower Fiber Networks
espitzer@lightower.com
(978) 264-6022

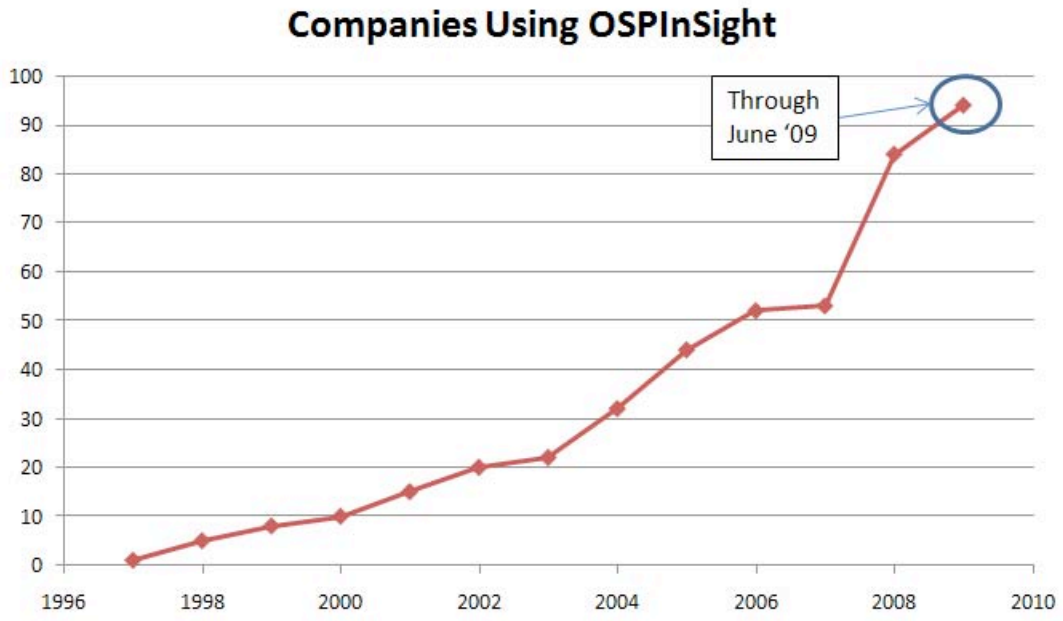
Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

OSPInSight History

The genesis of OSPInSight began in 1995 as a solution to a dilemma had by many AFO clients. Up until then (since 1994) AFO clients had had a difficult time managing their as-built information. AFO, only a field service organization at that time, was often asked to help track down fiber outages caused by broken cables. AFO started to put client information on a map in MS Excel in order to make tracking these breaks easier. In fact, the first OSPInSight application named "DocuCom" was originally written in MS Excel. That was never released as a product. The first production release of OSPInSight was in 1997.

Originally, OSPInSight was designed to find broken cables. But the feature set of OSPInSight has greatly expanded since 1995. Over the years AFO clients have pushed the OSPInSight envelope and have helped to design an application that not only aids the technicians in the field, but also provides essential information throughout entire corporations.

Because of the focus on client satisfaction and innovation of its developers and staff, AFO has experienced a steady increase in companies using OSPInSight since its release. Furthermore, over the past few years OSPInSight has become increasingly popular due in large part to the flexibility of the application and its relative ease of use.



What sets OSPInSight apart from other network management systems is the fact that AFOs core business is fiber optic networks. With the ability to not only develop software, but perform field services and on-site data verification as well as a full-service data services group, AFO can provide the necessary expertise to ensure that a network documentation system will work. Software, in this business, is only part of the equation. Ultimately, AFO has the passion to turn as-builts into intelligence.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

OSPInSight Recent Development

During the past three years AFO has invested heavily in OSPInSight development. AFO has literally changed, deleted, and created tens of thousands of lines of code. Some highlights are listed below.

❿ Released OSPInSight 8.0 This was a complete database and GUI redesign from our popular OSPInSight 7.x version. The main reason behind the re-design of the database was to prepare OSPInSight for more flexibility in regards to passive optical networks. Furthermore, there were tools that our clients had been asking us to redesign for better functionality and ease of use. It has been fully developed on .Net using C#.

- A complete rebuild of OSPInSight Web

  GIS on the web had an extraordinary expansion during this time frame. As such, tools for maps on the web became much more efficient and feature rich. Because of this, AFO completely re-built the OSPInSight Web application to better take advantage of these tools.

❿ Creation of a link between OSPInSight and Exfo's NQMSFiber

AFO was approached by Exfo (www.exfo.com) to provide a mapping interface to its remote fiber test system (RFTS) NQMSFiber. AFO was pleased to partner with an industry leader such as Exfo. During this time, AFO and Exfo have worked together to create a link between our two products in order to give fiber optic network managers a real time look at fiber breaks and a simple to use interface to view where the breaks occurred.

❿ Pre-Sales Analysis Tool AFO had a client that needed a way to make it much faster for sales personnel to determine whether or not a lead was worth pursuing. Typically, this process could take as long as five days and it was causing engineering personnel to waste valuable time. AFO, in conjunction with our client, designed an application to reduce that process time from 5 days to 5 seconds.

❿ Redesigned Integrity Check AFO is very aware of the importance of data integrity within a database. To this end, AFO redesigned an existing tool to be much more accurate and easy to use and interpret. This tool is used not only internally at AFO but also by our clients to ensure data integrity for their OSPInSight databases.

- New OSPInSight Reporting Tool

  As more and more requests for analysis of data would come into AFO, we found it important to create an application that made it simple for us to add reports to.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

That is, we often are asked to create custom reports by our clients. In the past, these reports would be contained within OSPInSight. However, because of the complex testing that has to be performed to release a new version of OSPInSight Edit, it would often take too long to get the report to our clients. In response to that situation, OSPInSight Reports was developed. This serves as a framework that will load .dll files that produce the reports our clients ask for. In this way, we can relatively quickly product accurate and important reports for our clients.

❿ OSPInSight Splice Graphic

A client of ours had approached us asking for a better, more graphical method to splice fibers. In splice locations, the splicing can get very complex. OSPInSight was able to perform that task of splicing, but it was done in a tabular way. This client wanted it all, buffer colors, fiber colors, drag-and-drop splicing, labels on fibers, etc. The task was daunting. However, true to the AFO innovation legacy, our developers came up with our OSPInSight SpliceGui. This application fit the needs for our client and helped them immensely in their documentation tasks.

Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

OSPInSight Future Development

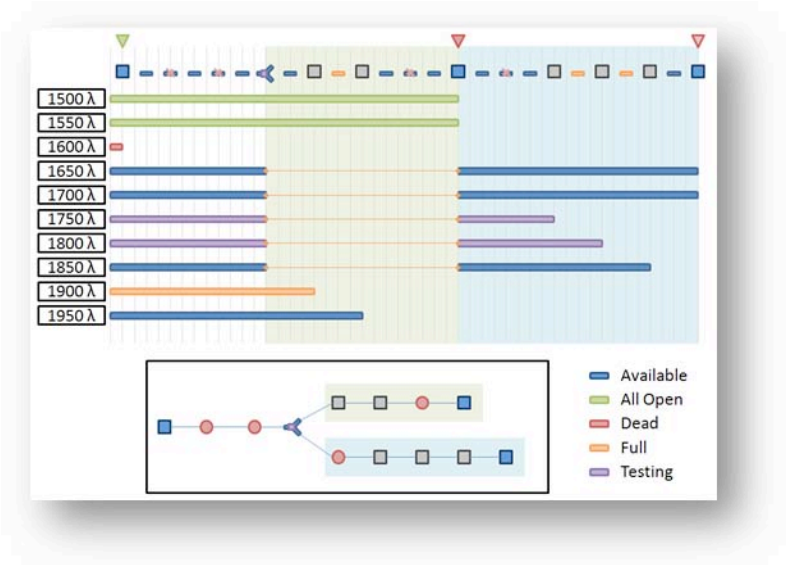
AFO is extremely excited about the new features and applications that are on the drawing board. However, we do not ignore the fact that those who are paying our bills are the current clients. Thus, over and above any new development is our intense desire to ensure that currently released applications meet the expectations of our clients. Thus, our first and primary objective is to ensure customer satisfaction.

Having said that, here are a few items that we are working on for prototype / beta release …

❿ Wavelength Management We are developing an application that will allow the user to link wavelength, circuit, bandwidth, client, and services data to fibers within OSPInSight. The application will aid network designers and technicians to better provision the services on the optical layer.

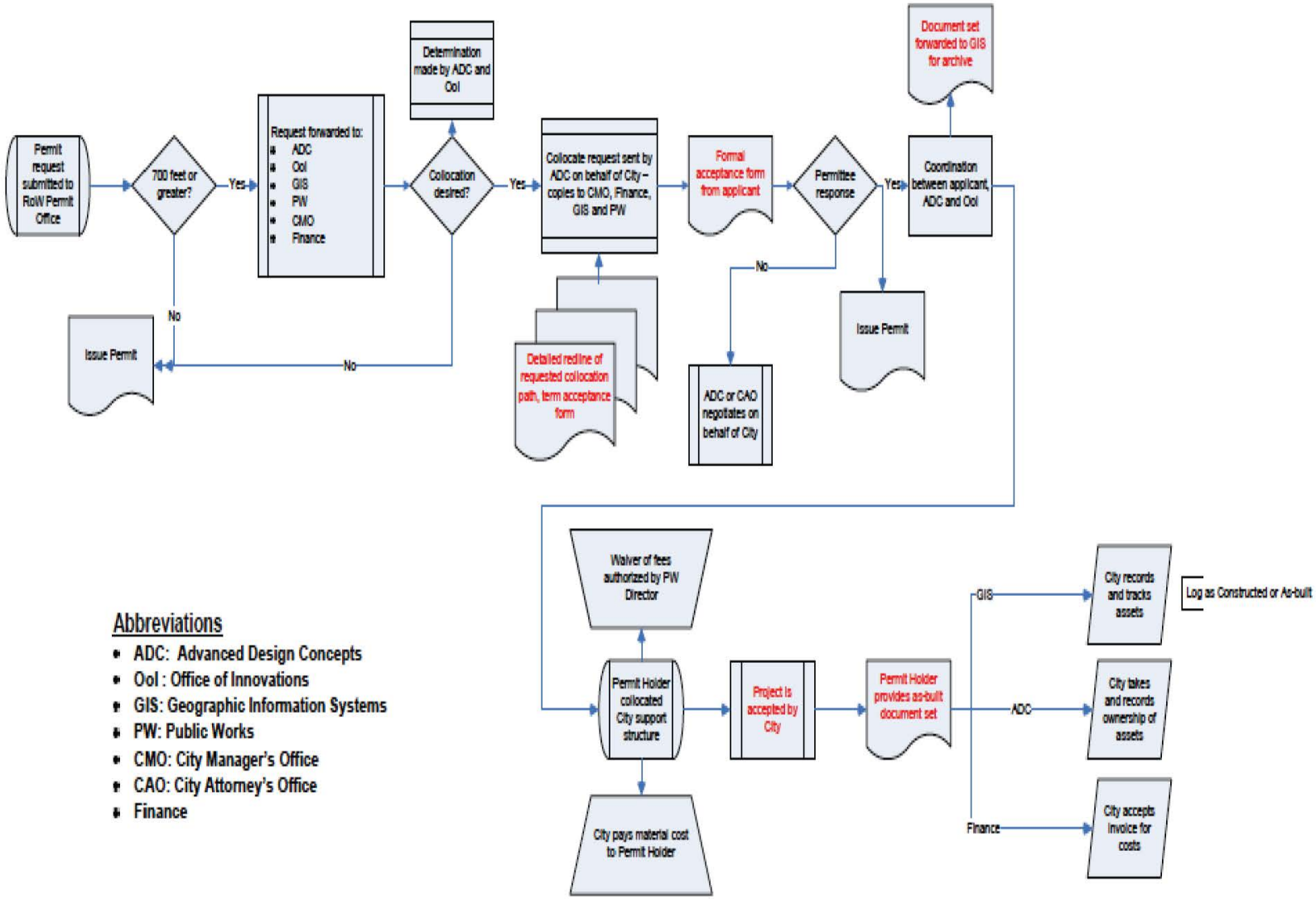
- Network Nesting

OSPInSight will have the capability to reference one network database from another. That is, in many situations, because of the nature of a fiber optic network, one fiber optic network may connect to another one. Or, perhaps an inside plant network is very complex and therefore becomes its own OSPInSight network. This feature will allow those networks to have common points that will then allow the flow of the fiber route to go from one network to another.



Lookout Point Communications©2015 NewCom Technologies©2015 Confidential
Release only with the Explicit Permission of the City of Centennial Colorado

Appendix B
Collocation Process Work Flow



Abbreviations

- ADC: Advanced Design Concepts
- OoI : Office of Innovations
- GIS: Geographic Information Systems
- PW: Public Works
- CMO: City Manager's Office
- CAO: City Attorney's Office
- Finance