November 2018

Connectivity Report

Gateway Development - Forney Texas

PREPARED FOR

Report Background

NEF is a professional services firm that provides research, analysis, consulting and planning for large infrastructure projects, such as fiber optic network deployments, municipal conduit systems, data center site selection and more. The information in this report is based upon data obtained from a wide variety of sources, including, but not limited to: service providers, in-house resources, historical records, interviews with subject matter experts and facility owners/operators.

For the network portion of the report, NEF focused primarily on facilities-based providers. Facilities-based service providers are those that own and operate their own fiber network. Some service providers routinely lease fiber from other service providers; others lease fiber when they are out of their own operating area. Of the facilities-based service providers, some will lease dark fiber to other service providers or end users, while others only sell telecommunications or "lit" services. The telecommunications industry is evolving quickly and the best source for information about what the service providers are currently selling will always be from the service providers directly. Likewise, metro networks are constantly expanding, and new buildings are being lit by service providers every day.

NEF's team of analysts strives to be accurate and thorough in the research and creation of this report; and while reasonable care has been taken in the preparation of this report, there is the possibility of errors and omissions in facts, figures or material. Information, statistics and data from a wide span of time has been included for the directional and historical value it represents. The intent of this report is to provide data and analysis that would be valuable in the data center site selection process and is not meant to take the place of any due diligence, specific investigational work or similar fact-finding endeavors.

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Physical Site Location

The Target Area is identified as a master planned development (MPD), comprised of a sizable amount of acreage centered coordinates **32°44'24.42"N 96°24'59.64"W.**

The Target Area is a mixed use, greenfield site. From a telecommunications standpoint, the site is considered rural. This classification means that there are fewer service providers available and the network/fiber systems are less dense as compared to more urban areas.

Multiple paved access roads service the Target Area. Additionally, the site benefits from a wide combination of utility service pathways.

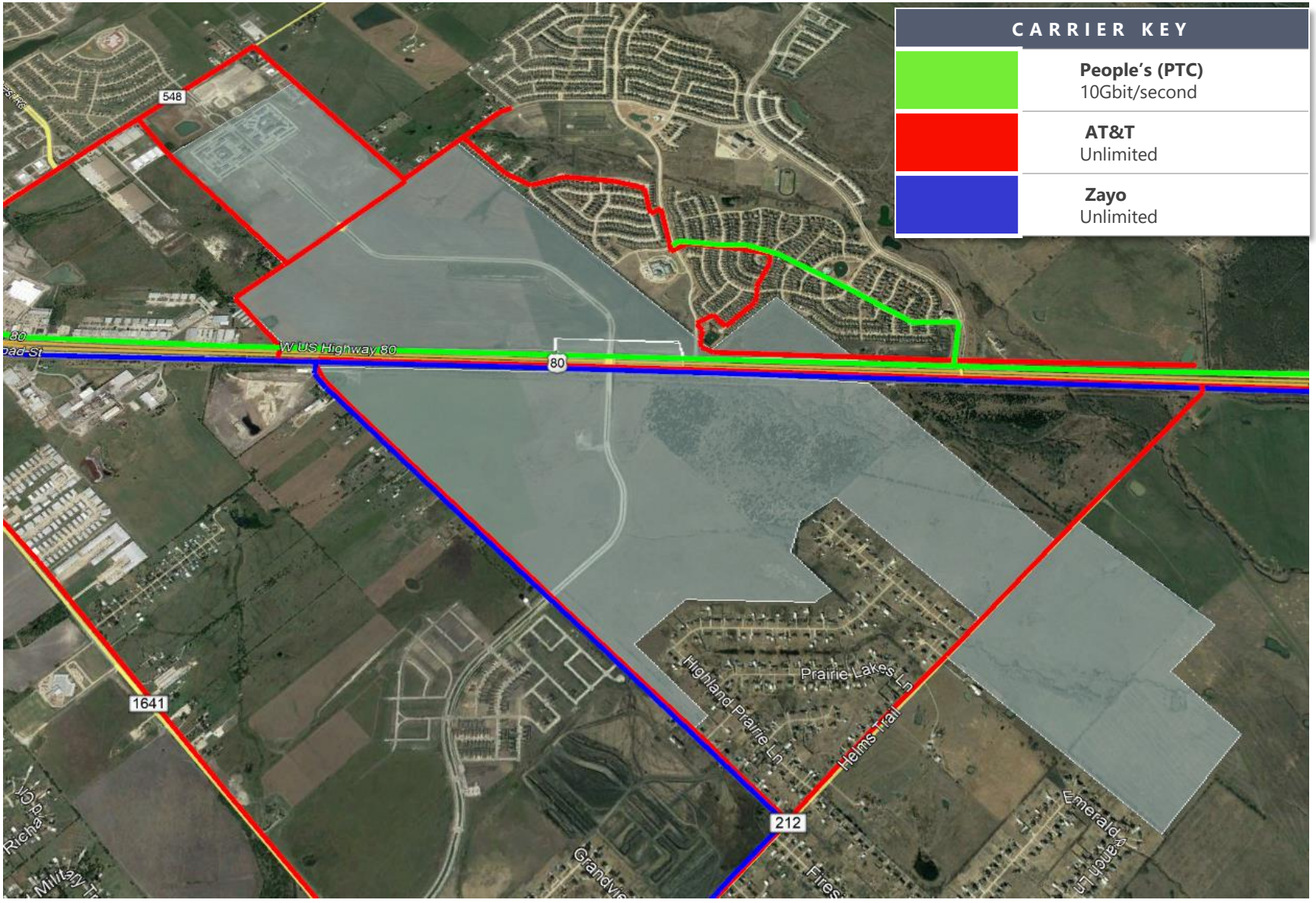
The site, situated in Forney, Texas is located approximately 30 fiber route miles from downtown Dallas and the core telecommunications infrastructure that supports the entire Southwest region. Forney is considered part of the Dallas-Fort Worth Metropolitan Statistical Area (MSA), which is the fourth largest MSA in the nation based on population.

Relational View

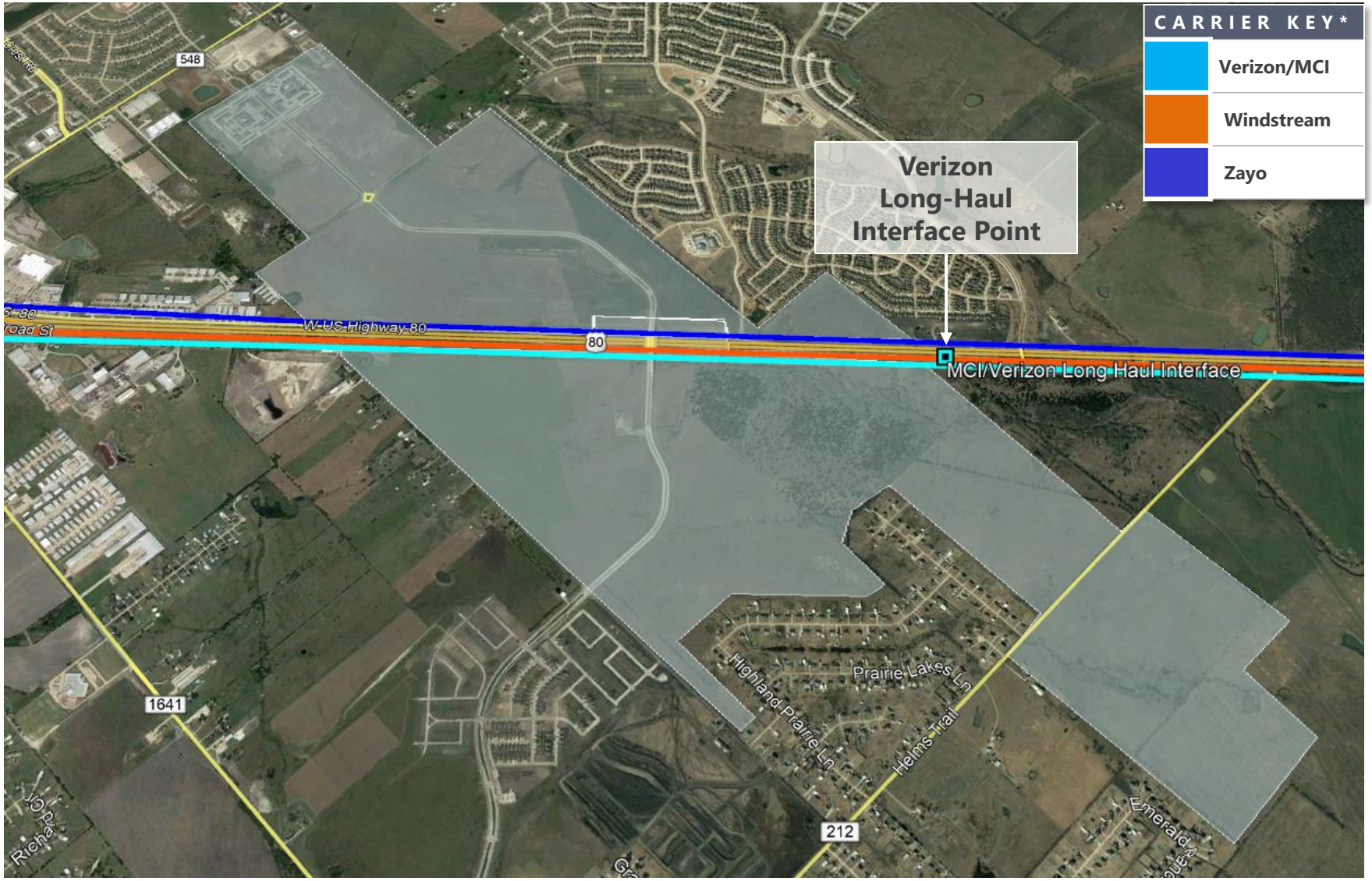
Relational View

Target Area: Gateway Development, Metro Fiber

SITE DETAIL



Target Area: Gateway Development, Long-Haul Fiber



Immediate Fiber: Map Only Inclusive of FiberLocator Data

Target Center-point: 32°44'24.42"N 96°24'59.64"W

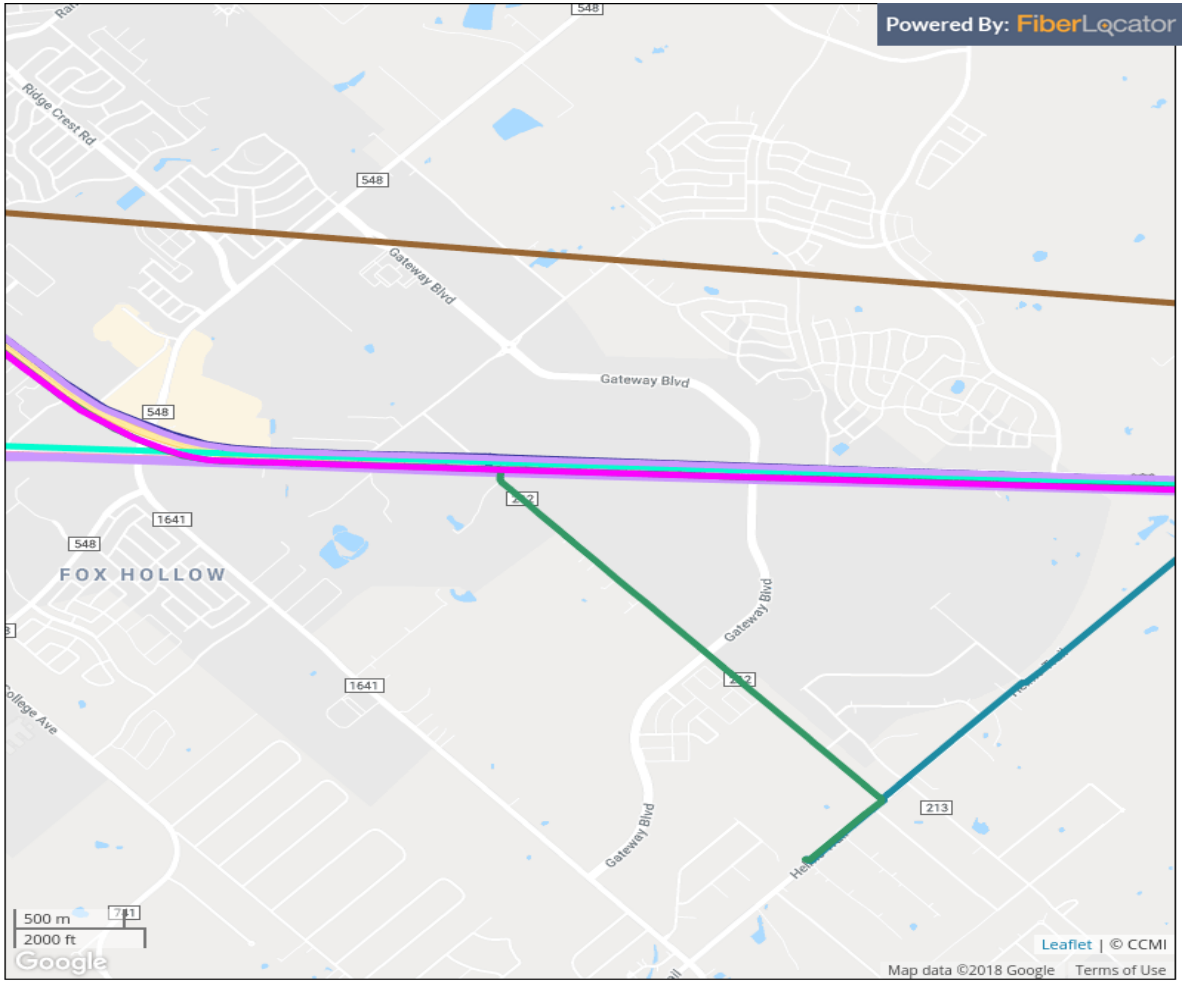
Forney, TX 75126, USA

Metro Networks

- Texas Lone Star Network
- Uniti Fiber
- Windstream
- Zayo Metro
- Zayo Planned Routes

Long Haul Networks

- Level 3 Long Haul
- Windstream Long Haul
- Zayo Long Haul
- redIT



OVERVIEW

Connectivity Overview – Target Area

Long-Haul Networks
Metro Networks
Carrier Hotels
Data Centers
IXPs

Connectivity Overview

Telecommunications Infrastructure

Telecommunication networks are made up of three distinct components, with the first being the long-haul fiber-system, the second being the local access interface points (also known as carrier hotels or Points of Presence – POPs) and the third being the metropolitan fiber system.

Forney, Texas is considered part of the enormously robust DFW telecommunications infrastructure system, which in telecommunications terms is a mere microseconds away. Forney's close proximity to Dallas ensures excellent connectivity characteristics to international data systems, all major cloud providers, hundreds of service providers and thousands of applications.

The area has more than 100 data centers and two of the largest carrier hotels in the United States. The DFW MSA has exceptional connectivity; the market is considered the second largest data center market in the nation trailing North Virginia, and by measurement of total fiber miles, DFW comes in at number two, second only to New York City.

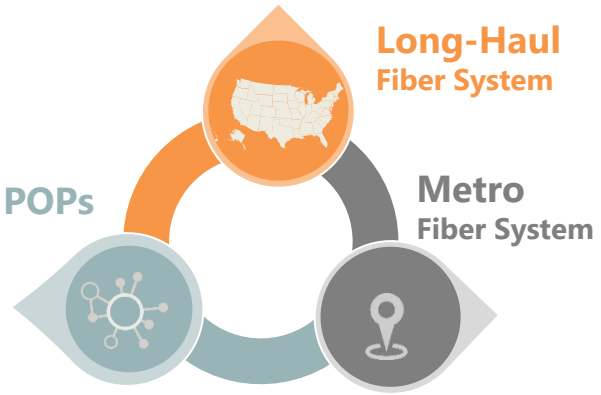
The data center leasing and construction activity remains strong in Dallas due to the ever-increasing consumption of data, alongside highly competitive business incentives offered in the area. The growth of the data center market in Dallas and surrounding suburbs also drives additional fiber optic networks growth.

Although further growth is anticipated, the region's fiber infrastructure already claims one of the densest footprints in the United States. The incumbent ILEC (AT&T) and Cable MSO (Suddenlink) have the most fiber-system density in the City of Forney; both systems are interconnected to Dallas' core metropolitan infrastructure. The primary method of construction in this area is underground fiber cable networks , which is often viewed as a more desirable option compared to aerial deployment.

Top 5 MSAs

Measured by Total Fiber Miles

1. ***New York**-Newark-Jersey City*
2. ***Dallas**-Fort Worth-Arlington*
3. ***Atlanta**-Sandy Springs-Roswell*
4. ***Los Angeles**-Long Beach-Anaheim*
5. ***Philadelphia** –Camden-Wilmington*



Connectivity Overview

Long-Haul Networks

Long-haul networks are fiber optic based networks that provide a standardized method of transporting data, voice and video traffic from state-to-state and city-to-city. They can be visualized like the highway system that crisscrosses the United States.

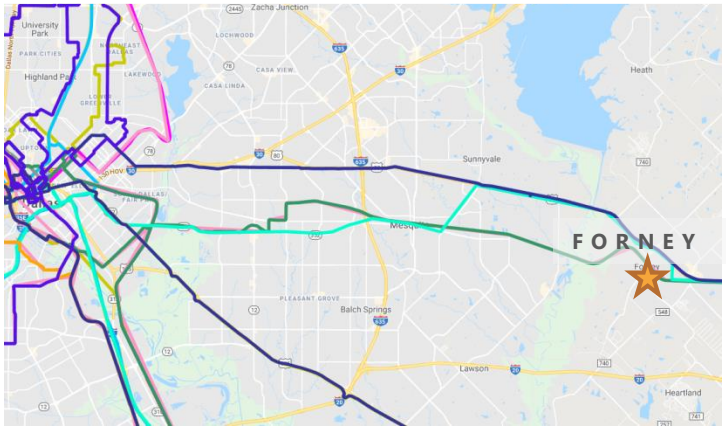
In relationship to data centers, long-haul networks are the key backbone for transporting data and voice services, as they "mesh" with the local metro networks to ensure traffic is successfully delivered. Most of these systems follow the railroad, highway, high-tension power lines or pipeline pathways. In essence, long-haul network elements are the basis of the physical infrastructure that powers the modern day Internet.

The DFW MSA has exceptional long-haul capabilities which can be interconnected to the Target Area.

Additionally, there are several long-haul networks that traverse through the Target Area, potentially providing immediate access.

National Long-Haul

Target Area Long-Haul



Connectivity Overview

Long-Haul Fiber Specifics

The DFW MSA's long-haul fiber system is comprised of dozens of fiber systems that have been deployed on railroad right-of-ways, byways, high-voltage power systems and pipeline right-of-way. The multitude of long-haul paths ensures that excellent network diversity and resiliency can be maintained.

Since Forney is included in the DFW MSA, the city benefits from access to various long-haul networks. More importantly, several long-haul providers have networks that run directly through Forney on Route 80, and along the Union Pacific rail line that runs east-west through the Target Area.

The following domestic long-haul provider systems are available for access:

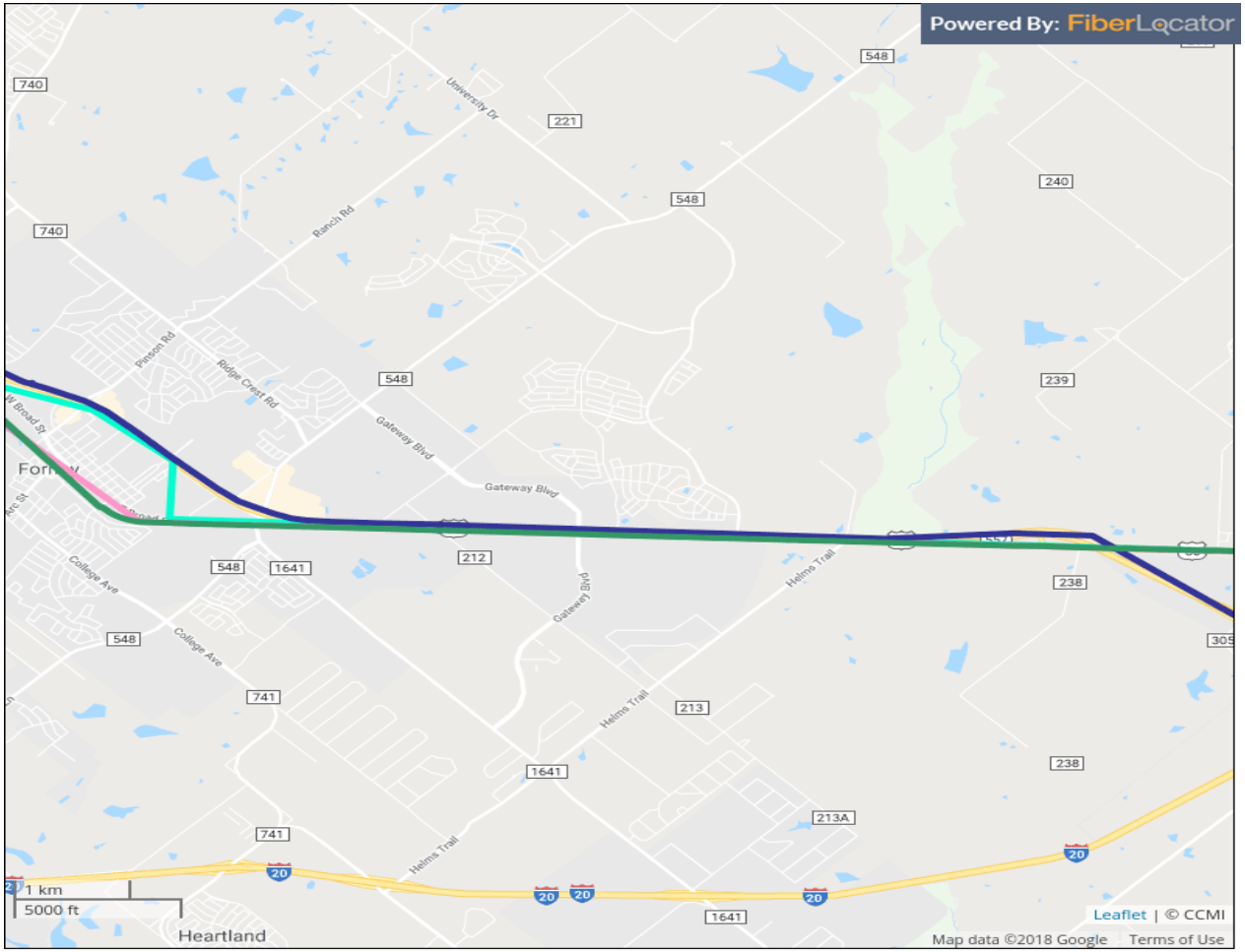
Sprint
NTT Communications Transform. Transcend.
AT&T
gtt
Telia
windstream communications
verizon
CenturyLink
zayo

Virtually every long-haul system is available at 1950 Stemmons or 2323 Bryan Street, the two premier carrier hotels.

Connectivity Overview – Target Area

Area Connectivity: Long-Haul Networks **3 Mile Radius**

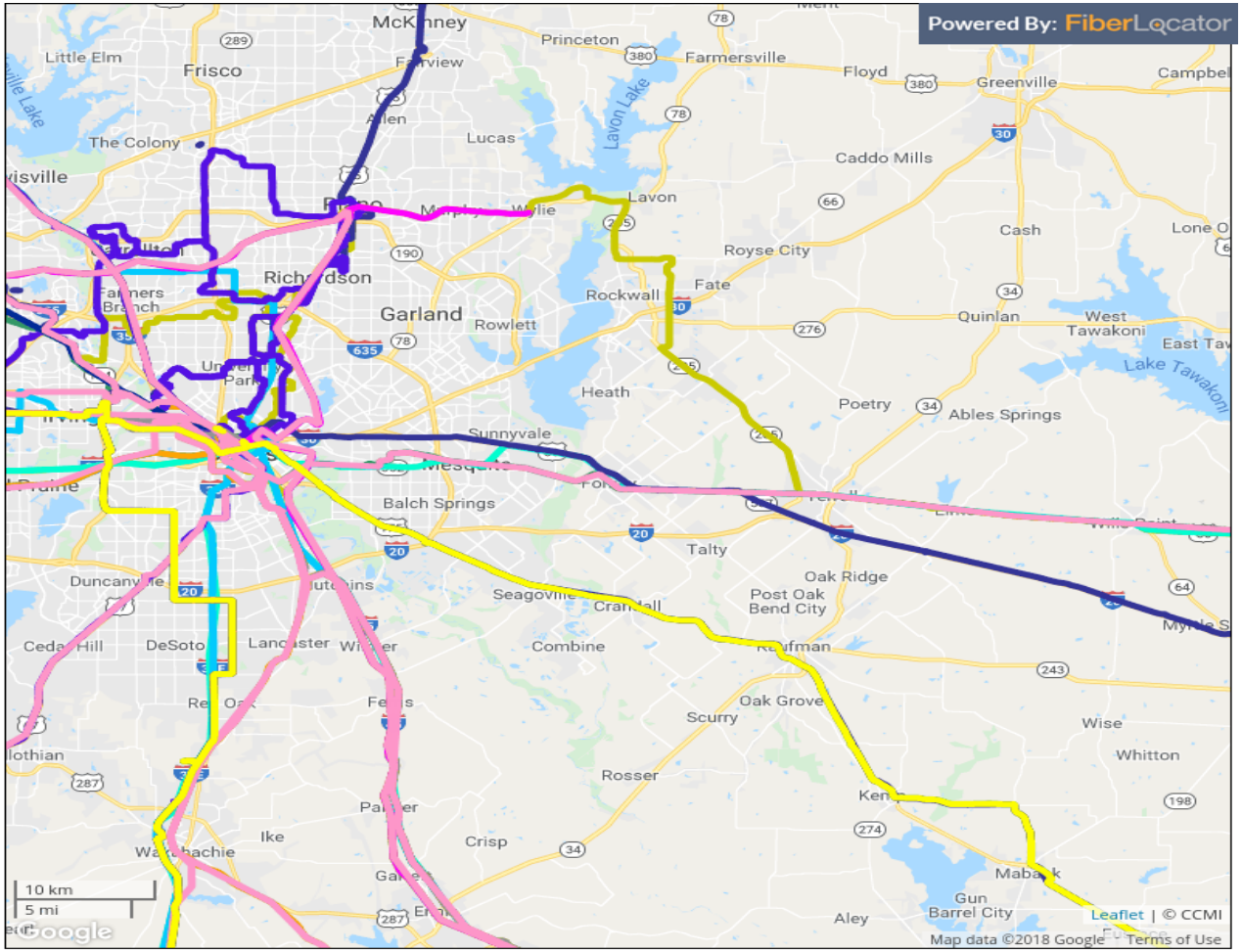
Long Haul Networks
- Level 3 Long Haul
- Sprint Long Haul
- Windstream Long Haul
- Zayo Long Haul
- redIT



Connectivity Overview – Target Area

Area Connectivity: Long-Haul Networks **30 Mile Radius**

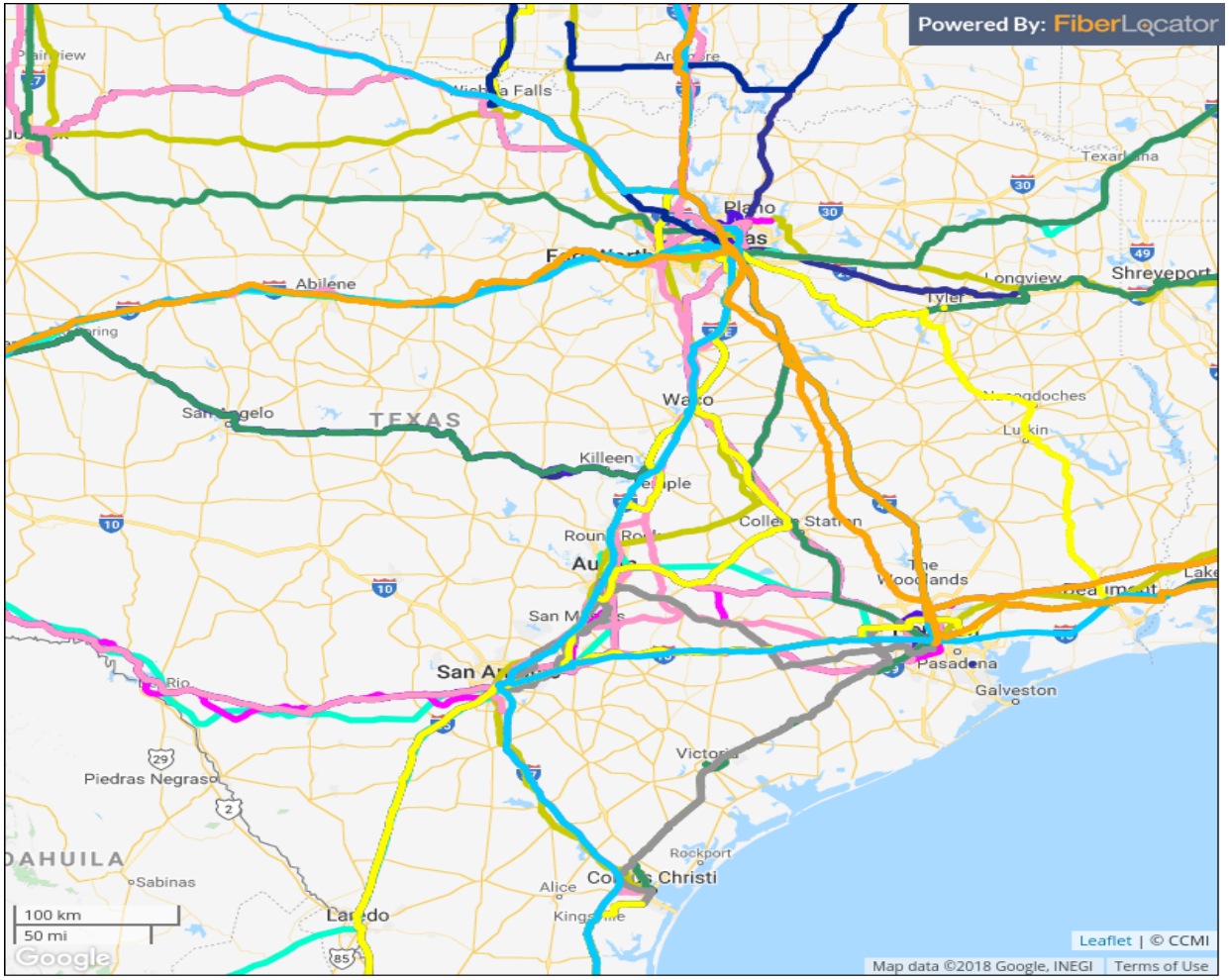
Long Haul Networks
- AT&T Long Haul
- Alpheus Long Haul
- CenturyLink Long Haul
- FiberLight Long Haul
- Hilliary Communications
- Hudson Fiber LH Leased
- Level 3 Long Haul
- Sprint Long Haul
- Telia Carrier
- Windstream Long Haul
- Zayo Long Haul
- redIT



Connectivity Overview – Target Area

Area Connectivity: Long-Haul Networks **Regional View**

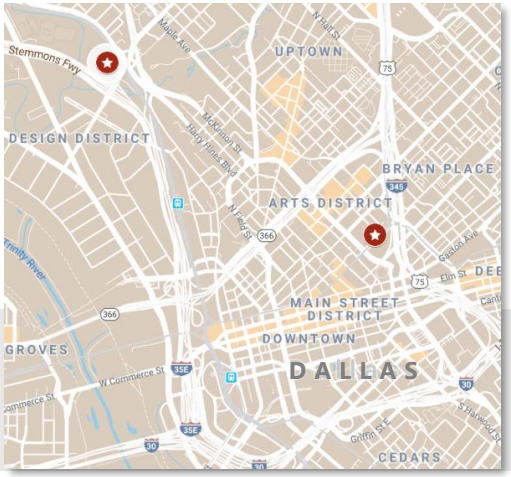
Long Haul Networks
- AT&T Long Haul
- Alpheus Long Haul
- CenturyLink Long Haul
- FiberLight Long Haul
- Hilliary Communications
- Hudson Fiber LH Leased
- Level 3 Long Haul
- SCT Broadband LH
- Southern Telecom Long Haul
- Sprint Long Haul
- Telia Carrier
- Windstream Long Haul
- Zayo Long Haul
- redIT



Connectivity Overview

POPs, Carrier Hotel and Data Centers

Every major city has at least one key hub or carrier hotel location where all of the elements of the networks meet. Virtually all data, voice, and video traffic run through modern day carrier hotels, truly making them the hubs of the Internet. While the routing and paths of traffic are constantly changing with the addition of new data centers, it is important to recognize that it took decades for carrier hotels to accrete the fiber networks, attract the providers, and evolve the power and space infrastructure to mature into what they are today.



The region's key interconnection points are:

1950 Stemmons Ave., Dallas , TX
2323 Bryan St., Dallas, TX

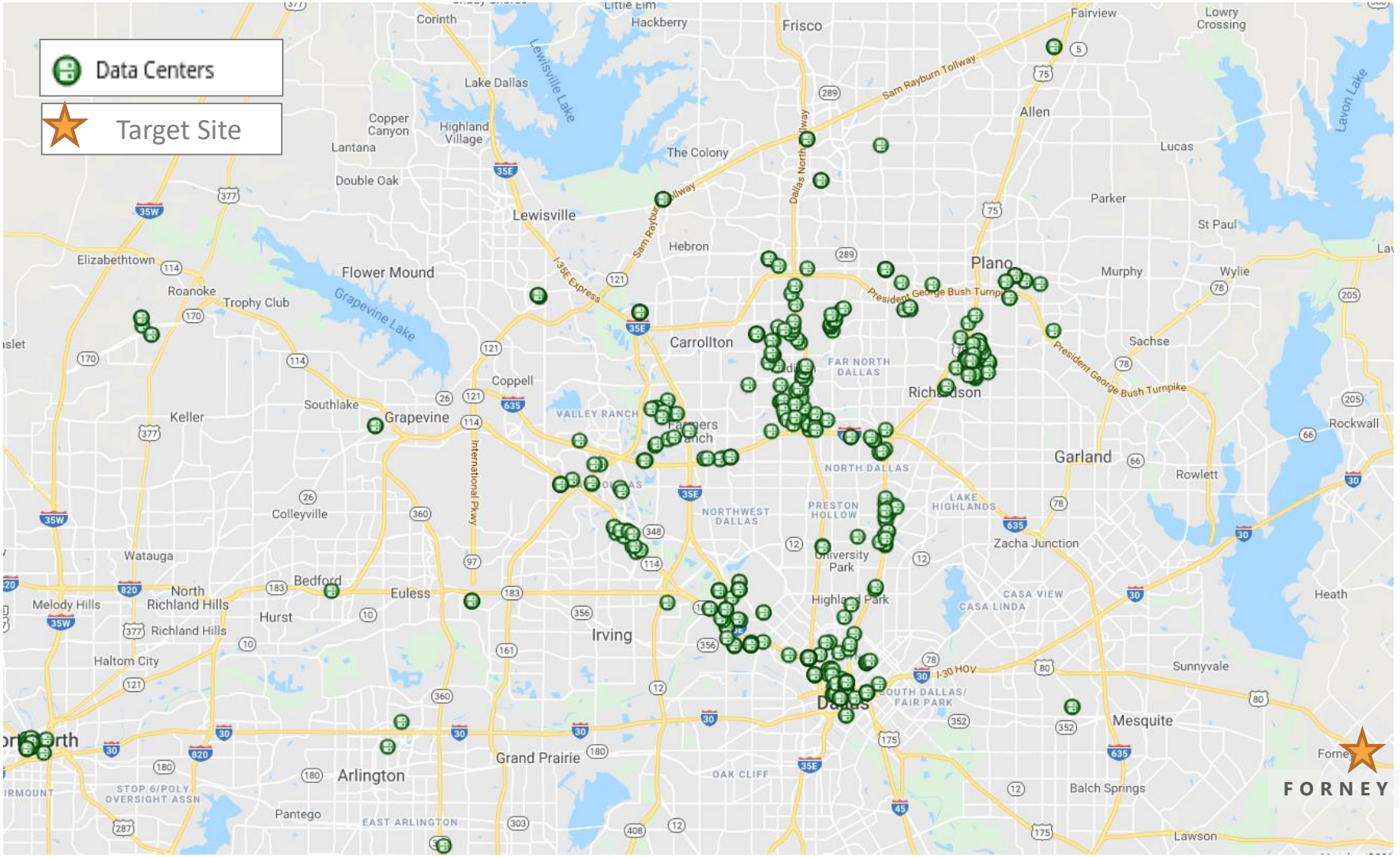
There are a number of additional facilities in the region that are ***carrier-neutral,*** meaning they allow interconnection between multiple carriers. There are more than 100 data centers within a 50-mile radius of the Target Area. Included within the list are several Tier 3 facilities. The data center tier rating system measures the level of resiliency, with tier 4 being the highest. Click here for more info about data center ratings. Most of the data centers in the world are rated or operating at Tier 3 and below. A typical hyperscaler would be operating at a Tier 2 level.

Below is a sample of data centers in the DFW MSA :

1232 Alma – Digital Realty
3500 E Plano Pkwy – Flexential
1950 Stemmons – Equinix
2440 Marsh Lane – Digital Realty
900 Quality Way – Digital Realty
Dominion Pkwy – Stream Datacenters
801 Industrial Blvd – Rackspace
400 S Akard – Cogent
1649 Frankfort Rd – CyrusOne
820 Allen Commerce Pkwy – Tierpoint

* There are more than 100 data centers within 50 miles of the target area. This is a representative list of the area.

Data Center Map – Surrounding Area

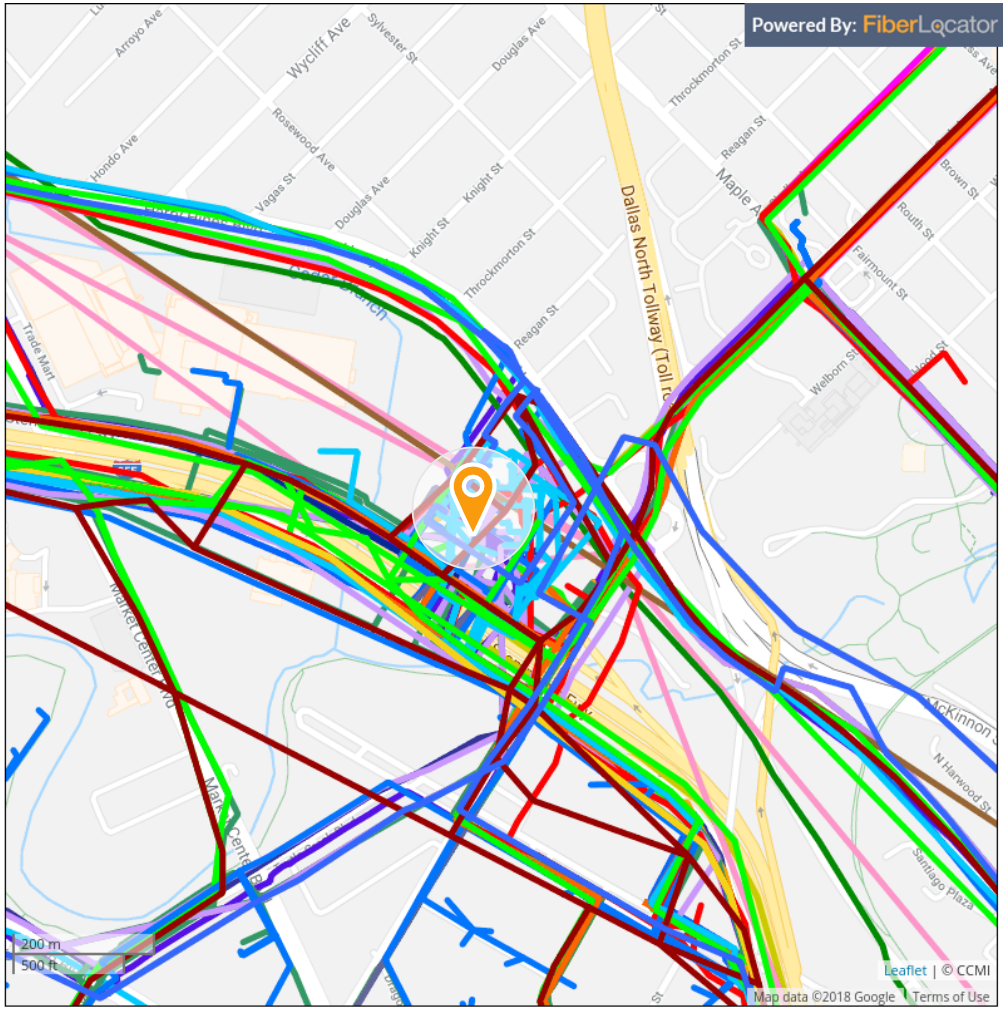


POP/Carrier Hotel – Fiber Map

Equinix's Dallas Infomart ™ | 1950 Stemmons Fwy, Dallas, TX 75207

Metro Networks
- CenturyLink Metro
- CenturyLink Metro Leased
- Consolidated Communications
- Fiberlight
- ICTX WaveMedia
- InnerCity FiberNet (ICFN)
- LOGIX Fiber Networks
- Level3 Metro
- Rail America (ROW)
- TPx Communications
- Texas Lone Star Network
- Transtelco
- Unite Private Network
- Unite Private Network - Proposed
- Windstream
- Zayo Metro
- Zayo Planned Routes

Long Haul Networks
- AT&T Long Haul
- Alpheus Long Haul
- FiberLight Long Haul
- Hilliary Communications
- Hudson Fiber LH Leased
- Level 3 Long Haul
- Sprint Long Haul
- Telia Carrier
- Windstream Long Haul
- Zayo Long Haul



5th most **interconnected carrier hotel** in the U.S.

+ 50 tenants including networks, colocation providers and office tenants

1.6 million sq. ft.

The iconic glass building located northwest of downtown is approximately 60 percent data center space and 40 percent office space. More than 40 providers have a physical presence in the building.

Connectivity Overview: Metro Fiber

Metro Fiber Infrastructure

Metro networks are typically designed to extend from a carrier hotel, data center or carrier point of presence (POP) to service the local market, business districts and/or individual properties. The construction of metro networks is largely driven by customer demand. Many metro networks are built in a protected ring fashion, while others are built in a linear fashion to provide services to a single building.

Adjacent Metro Fiber Infrastructure

The DFW MSA has more than twenty physically different metropolitan fiber systems, comprised of marquee and local names such as: AT&T, CenturyLink, Verizon, Zayo, Spectrum and Fiberlight. There are dozens of international and national service providers in addition to these local names that also operate in the market. Many of the providers simply lease, buy or barter access from the main providers' routes. Every national and many international service providers have presence in metropolitan Dallas due to the metroplex's importance as a global tech hub.

The fiber networks that support the City of Forney are interconnected to the DFW core infrastructure. Even large ILECs such as AT&T who own and operate their own large central office facilities are connected to the carrier hotels and interchange traffic. Although Dallas has an incredibly abundant quantity of providers, many of their network footprints don't extend to the surrounding suburbs.

The Target Area has four (4) metro networks that are immediately available and easy to access.

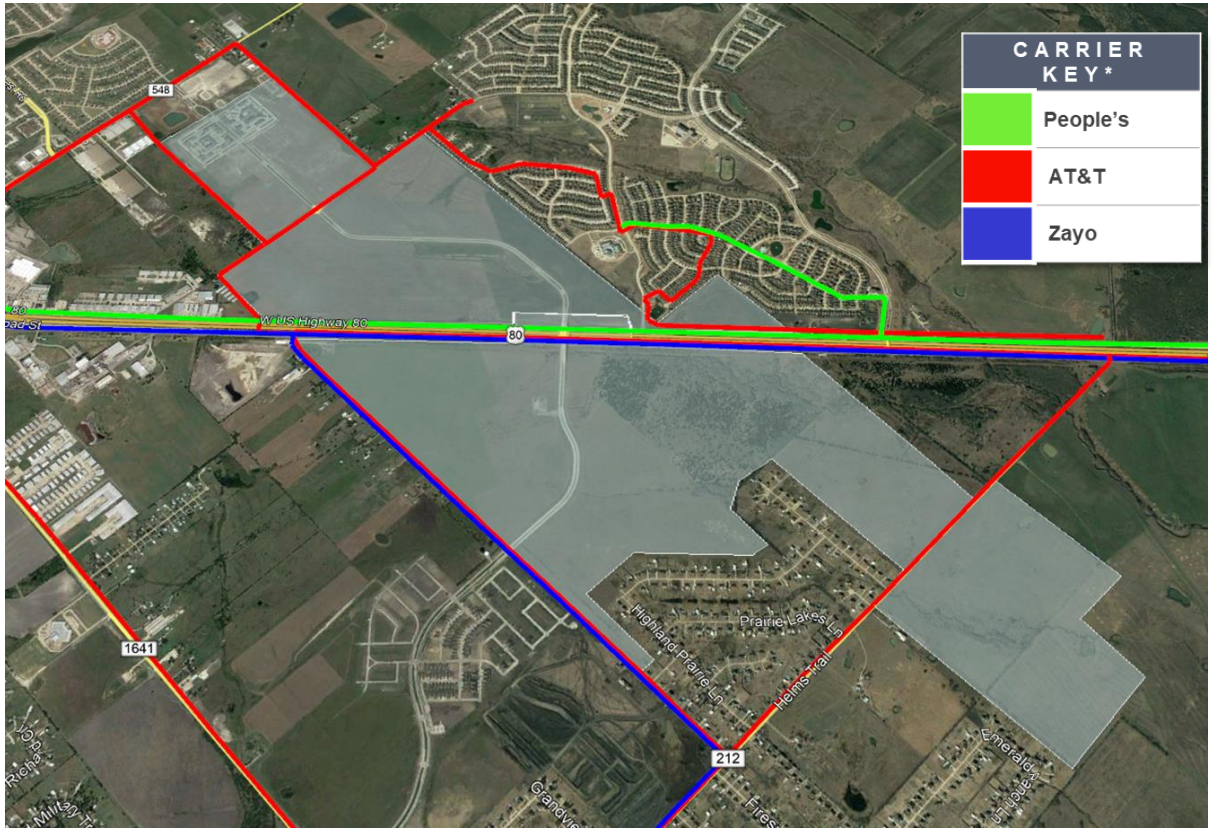
Connectivity Overview: Metro Providers

Metro Fiber Infrastructure *(does not include long-haul)*

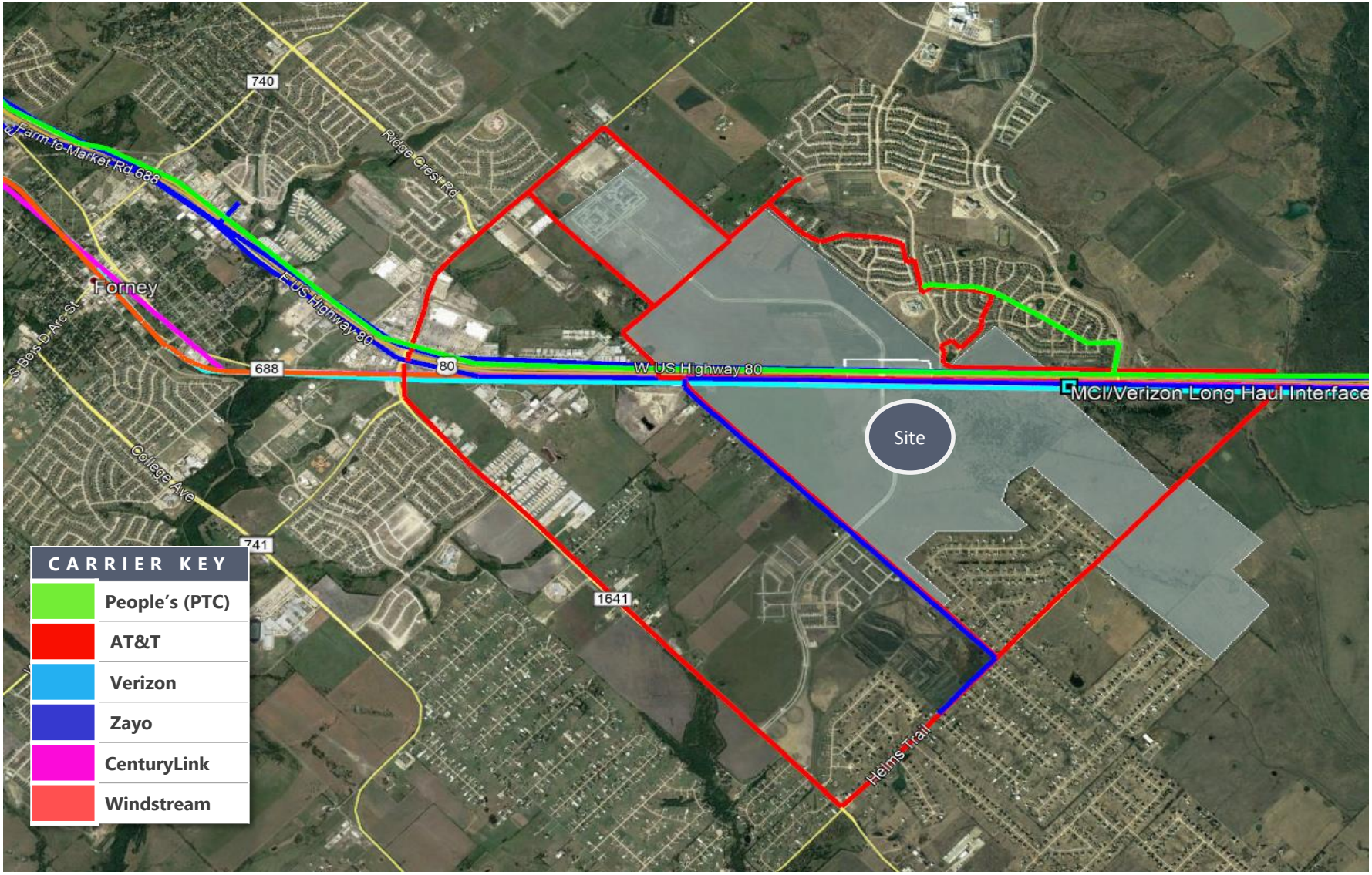
In the Target Area the Local Exchange Carrier is AT&T and the Local Cable MSO is Suddenlink.

AT&T	ILEC
suddenlink	MSO*
zayo	CLEC
PEOPLES	CLEC

**Suddenlink fiber was not mapped for this project.*



Connectivity Overview: Custom Fiber Map

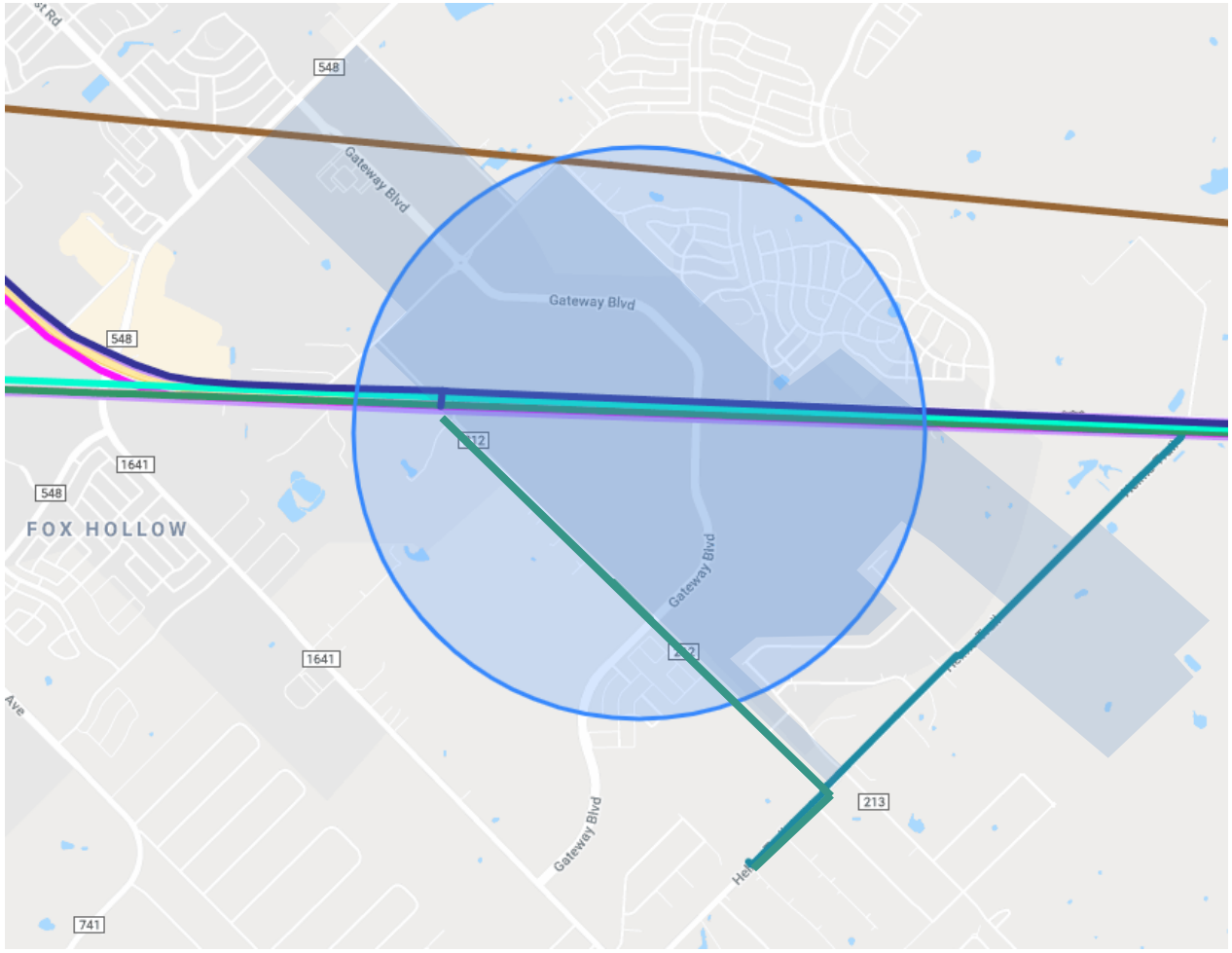


Connectivity Overview: Area Providers

Area Connectivity: **1 Mile** Radius

Metro Networks
- Texas Lone Star Network
- Uniti Fiber
- Windstream
- Zayo Metro
- Zayo Planned Routes

Long Haul Networks
- Level 3 Long Haul
- Windstream Long Haul
- Zayo Long Haul
- redIT

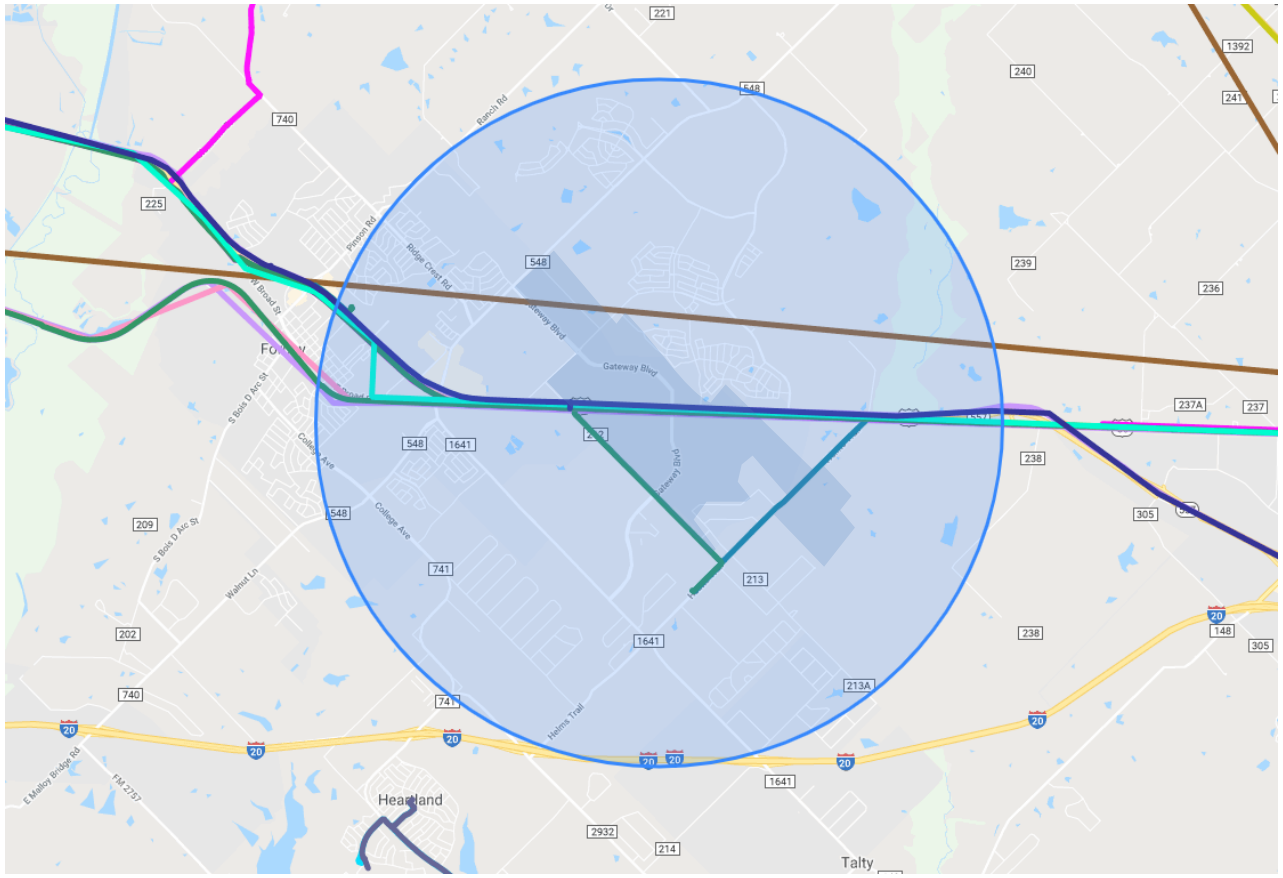


Connectivity Overview: Area Providers

Area Connectivity: **3 Mile** Radius

Metro Networks
- Texas Lone Star Network
- Uniti Fiber
- Windstream
- Zayo Metro
- Zayo Planned Routes

Long Haul Networks
- Level 3 Long Haul
- Windstream Long Haul
- Zayo Long Haul
- redIT



Connectivity Overview: IXPs

Internet Exchange Points

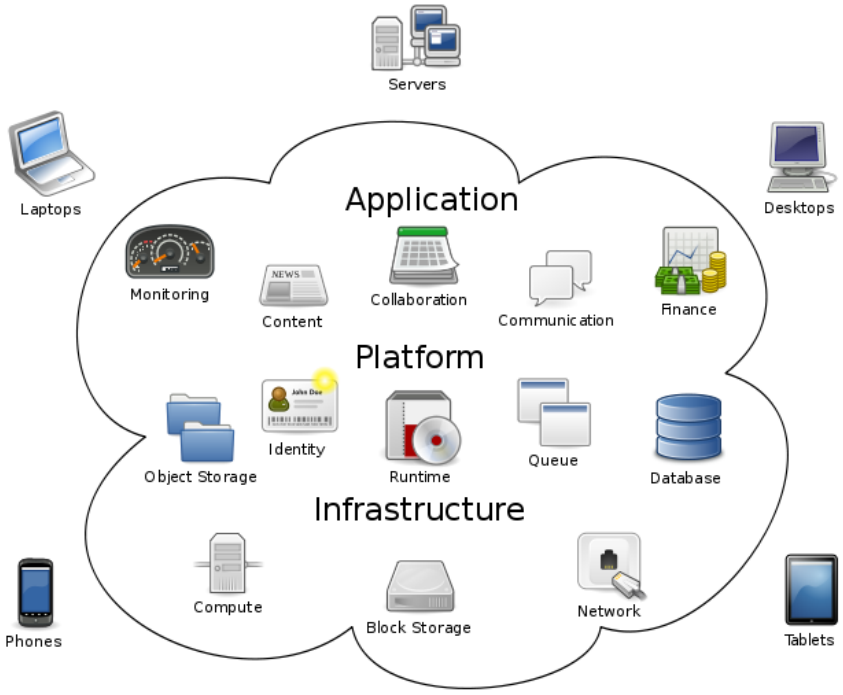
An Internet exchange point (IX or IXP) is a physical infrastructure through which Internet service providers (ISPs) and content delivery networks (CDNs) exchange Internet traffic between their networks. The Region acts as one of the USA's main interconnection hubs for the Internet. The area's data centers attract a variety of communications, cloud and digital media companies for colocation and interconnection services.

The nearest IXP is located in downtown Dallas
(Map pictured on following page)

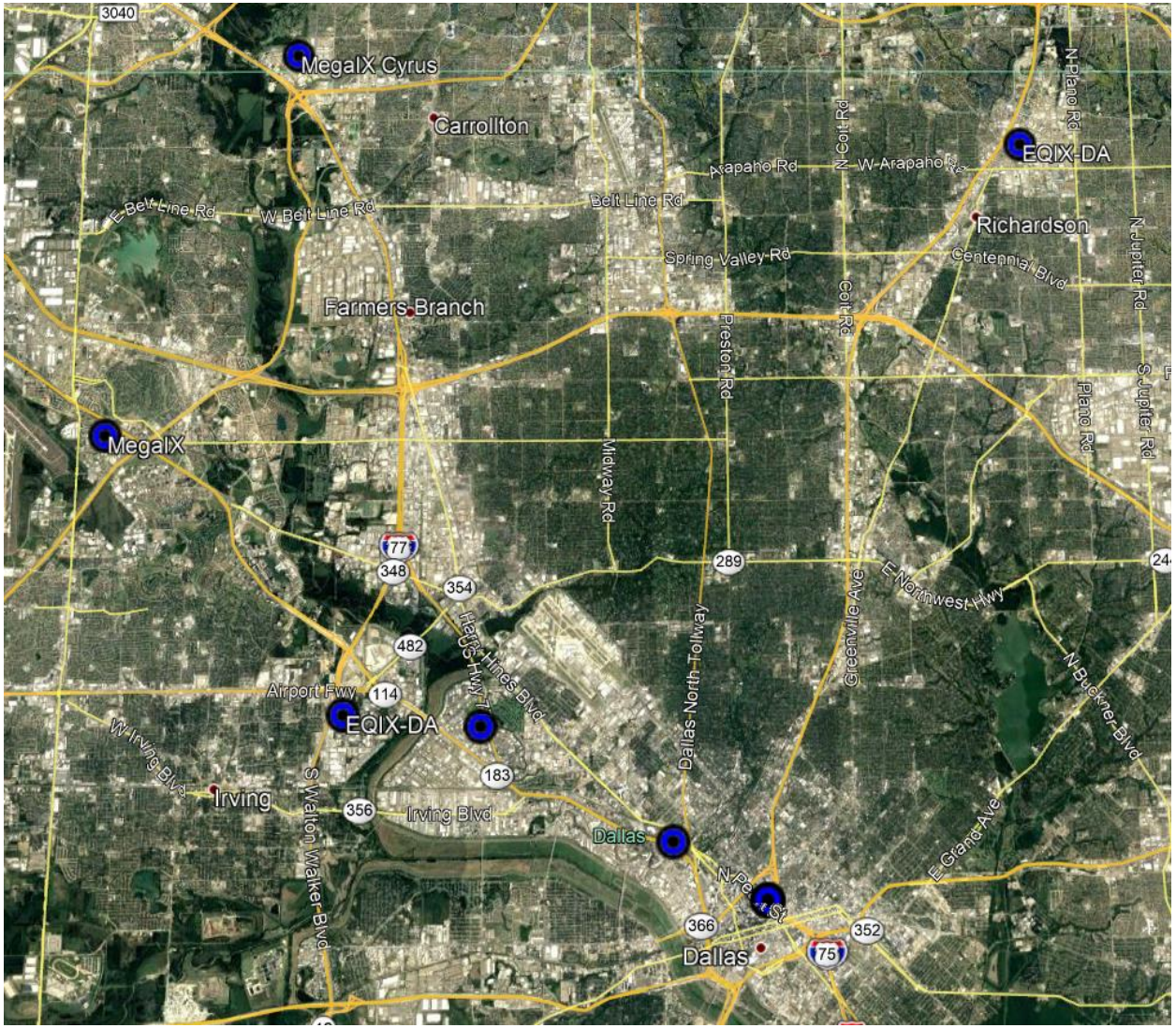
Cloud Computing

Cloud computing is an information technology (IT) paradigm that enables ubiquitous access to shared pools of configurable system resources and higher-level services that can be rapidly provisioned with minimal management effort, often over the Internet. Cloud computing relies on sharing of resources to achieve consistency and economies of scale, similar to a public utility.

The majority of the cloud-based systems are in downtown Dallas – a fraction of a second away!



Connectivity Overview: Internet Exchange Map (IXP)

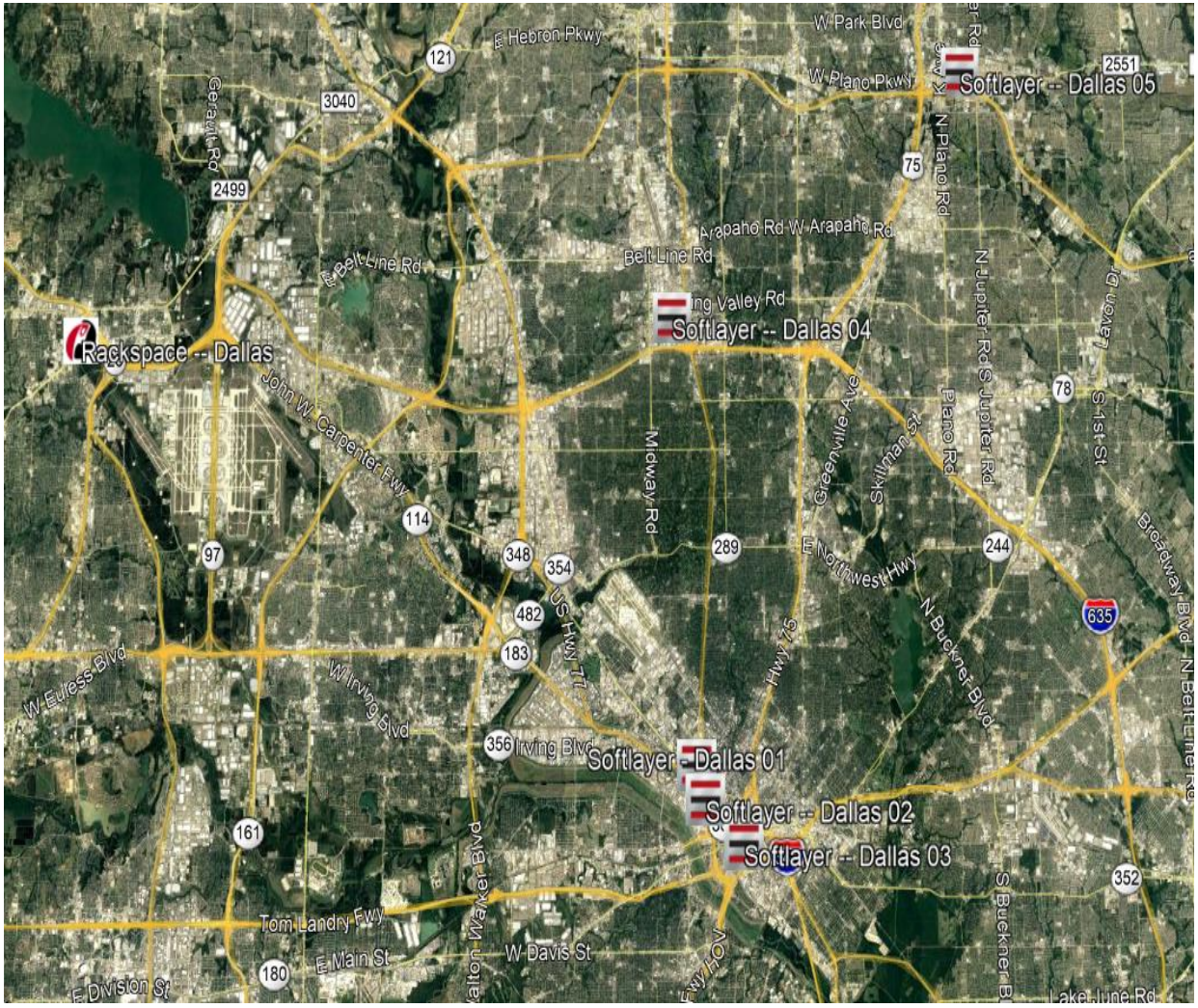


Internet Exchange Points

- EQIX-DA -- Dallas
- DECIX – Dallas
- TIE – Dallas
- MegaIX - Dallas

* A variety of data centers located in the DFW MSA have connection points that will enable the IXP.

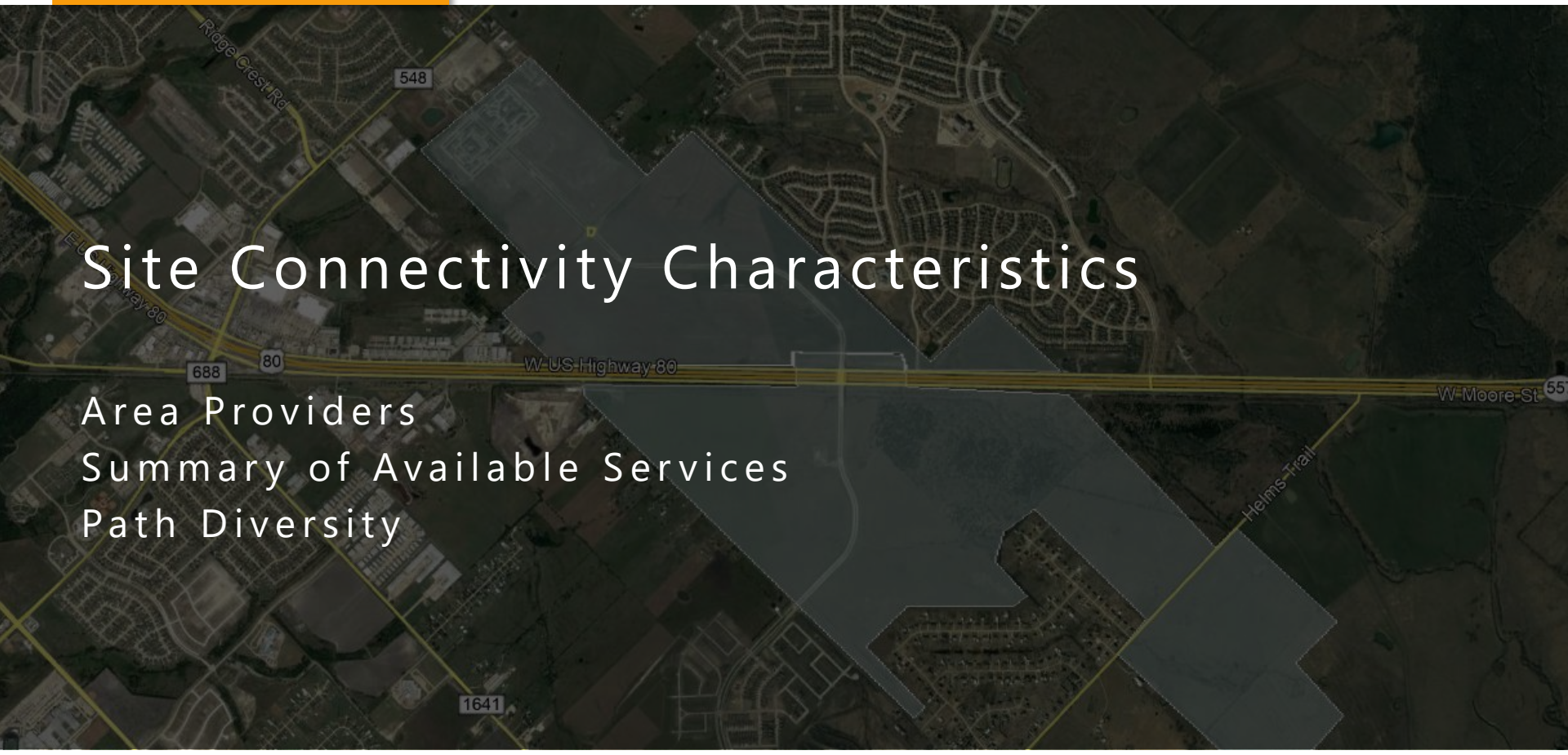
Connectivity Overview: Cloud System Map



Cloud Interconnections

- Amazon Web Service (AWS)
- Azure Cloud
- Google Cloud
- SoftLayer
- Rackspace
- Oracle

*Many of these services are available at the same datacenters. All cloud services are available at the main carrier hotels or large datacenters.



Site Connectivity Characteristics

Area Providers
Summary of Available Services
Path Diversity

Connectivity Characteristics: Target Area Service Providers

The Target Area is the Gateway Master Planned Development, located in Forney, Texas approximately 30 fiber route miles due east of downtown Dallas. From a telecommunications standpoint, the site is considered rural. This classification means that there are fewer service providers available and the network/fiber systems are less dense as compared to urban areas.

The majority of fiber networks in the general area have been deployed underground, although there are exceptions in which aerial deployment is present. Underground construction is considered more desirable by many clients.

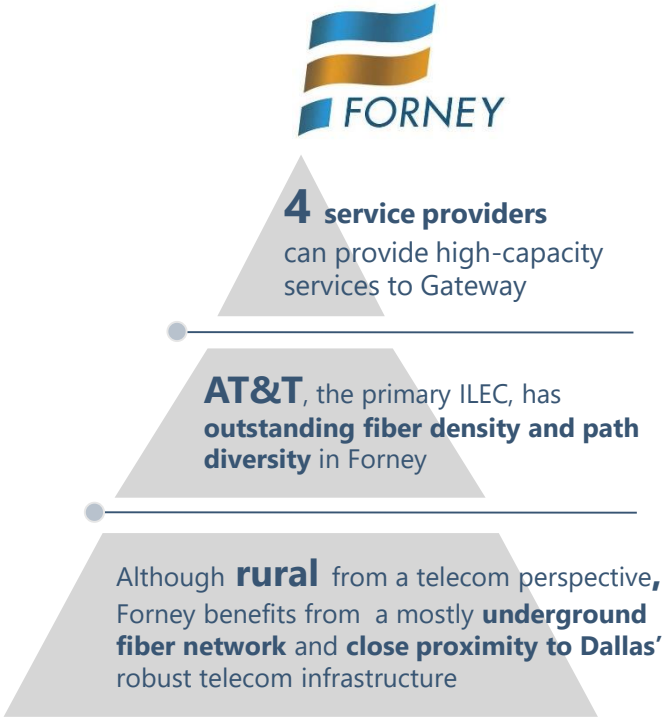
The two (2) primary service providers in the Target Area are the incumbent telephone company and cable TV company, AT&T and Suddenlink, respectively.

AT&T's network is a fiber-based system that has been upgraded, augmented and developed into an excellent service infrastructure. In comparison to many other areas where AT&T is also the primary ILEC (incumbent local exchange carrier), the fiber density and path diversity around the City of Forney is top notch.

Suddenlink is operating on an older hybrid-fiber-coax (HFC) system, with a portion of new pure-fiber segments and augmentations where needed. Suddenlink provides some of their services via aerial infrastructure, but it is primarily in support of their residential services.

In addition to these two (2) primary networks, there are two (2) additional fiber-based systems located in the Target Area; 1) Zayo and 2) People's Telephone Cooperative (PTC). Both Zayo and PTC operate independent networks and have access points along their respective paths that will allow for interconnection. Additionally, Zayo and PTC can interconnect into the Dallas core infrastructure. Zayo can also provide dark fiber, which is of benefit to various high-tech firms and data center operators.

All four (4) providers have indicated that they can provide unlimited high capacity services, the costs and timeline of which would be governed by the specific requirements.



Connectivity Characteristics: Target Area Providers

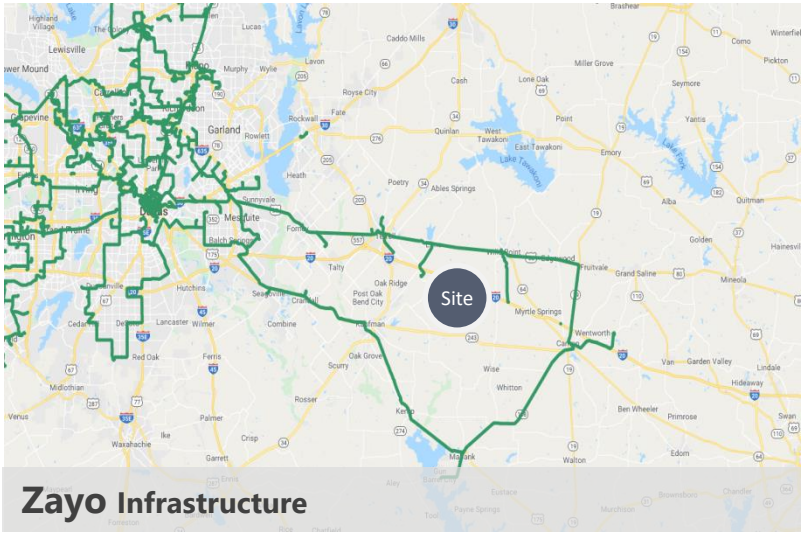
AT&T

AT&T is the incumbent telephone company; AT&T also has the largest network infrastructure footprint within the Target Area. While AT&T would not provide dedicated maps, NEF used project and construction maps of the site, as well as mark-outs to determine that AT&T is in close proximity to Gateway. The fiber footprint AT&T owns and operates throughout the City of Forney is exceptional. AT&T can provide a complete suite of services with path diversity. AT&T services are immediately available.

AT&T Infrastructure

zayo

Zayo is one of the largest CLECs in the nation and has a growing international presence as well. Zayo can provide dark fiber and many other services, such as Cloud Connect, Internet and 100G level connections. Zayo has a single-path fiber infrastructure that passes through the immediate area but can provide diverse paths with some construction by utilizing their southern "loop" back into the DFW Core. Zayo's services are immediately available .

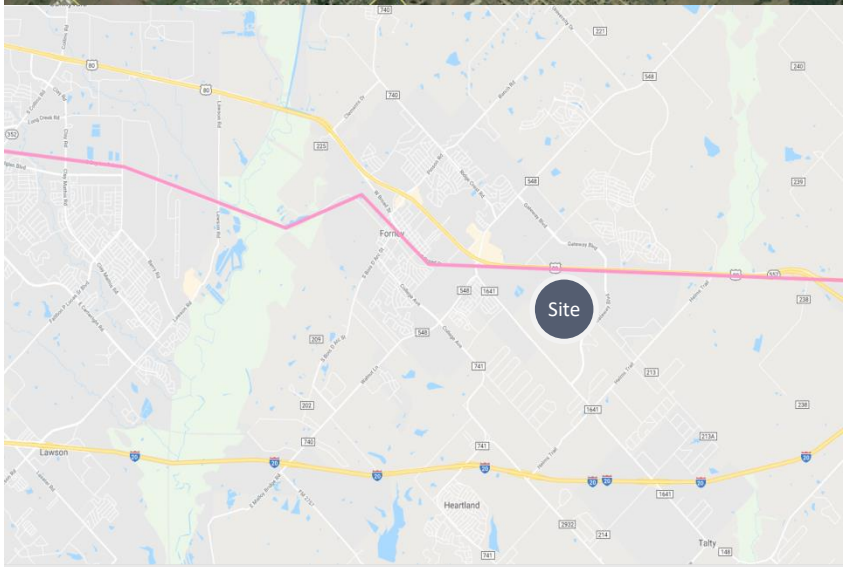


Zayo Infrastructure

Connectivity Characteristics: Target Area Providers

Suddenlink is the incumbent cable company, owned by Altice. Suddenlink has a unique infrastructure, but is primarily focused around servicing residential customers. Suddenlink has infrastructure in and around the Gateway Master Development; however, the bulk of this system is Hybrid Fiber Coax – a system designed to support cable TV operations. No maps are available at this time. Suddenlink can provide some services immediately.

CenturyLink is one of the largest CLECs in the United States and has an international presence as well. CenturyLink can potentially provide virtually every type of network or telecommunications service. CenturyLink's fiber system is a legacy long-haul system that runs along the Union Pacific railroad tracks. It might be possible to "break-out" of this system and drop services. CenturyLink has done this type of break-out for similar situations in the past.

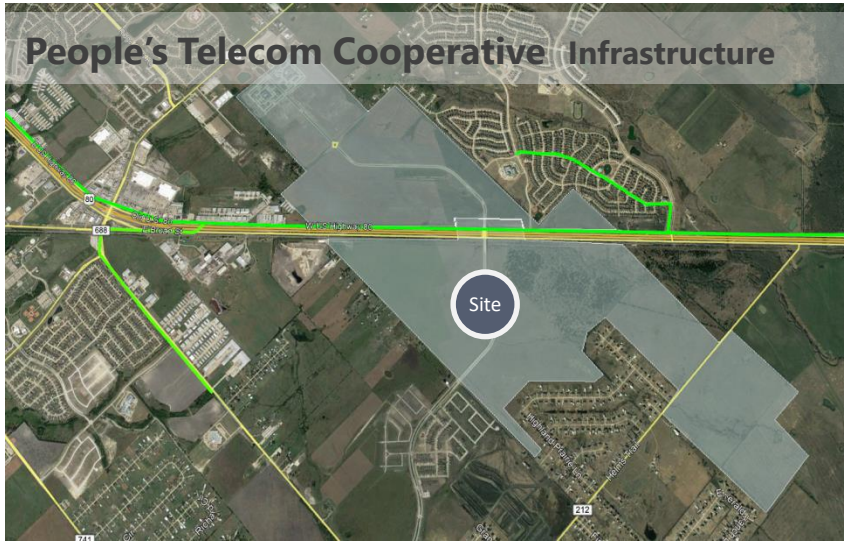


CenturyLink (legacy long-haul)

Connectivity Characteristics: Target Area Providers

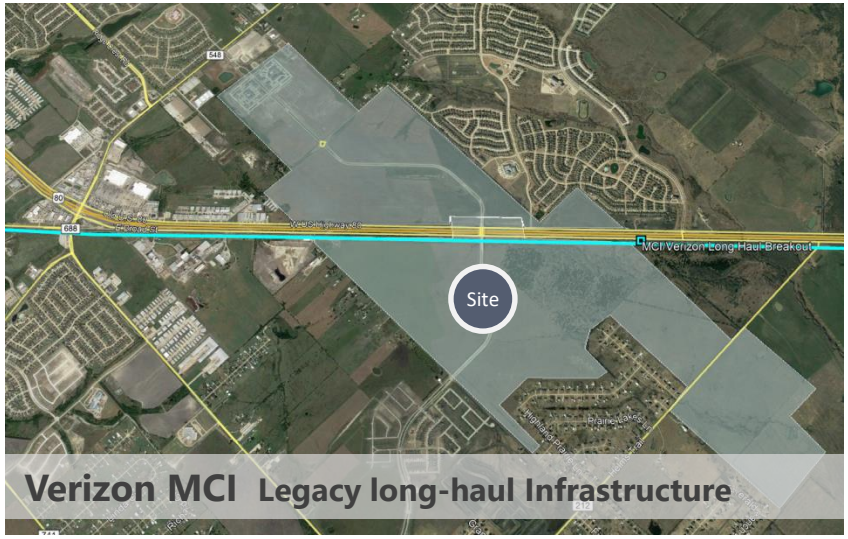
PEOPLES **(PTC)**

PTC is an old cooperative that was put in place to provide rural telephone services where they didn't exist. Over time, PTC has expanded and built new fiber while retaining its original mission. PTC has fiber that runs through the Target Area, providing services to various customers along its path. PTC can provide most standard services and has the ability to provide higher capacity transport (10G) and Internet. Services are immediately available.



verizon

Verizon is the second largest ILEC in the United States and can provide virtually any type of network or telecommunications service. Verizon has developed some very unique long-haul systems throughout the U.S. One of these long-haul routes transitions through the Target Area on one side of the Union Pacific rail tracks. There is a network breakout in close proximity to the plat, which means Verizon could potentially provide services.



Connectivity Characteristics: *Adjacent Area Providers*

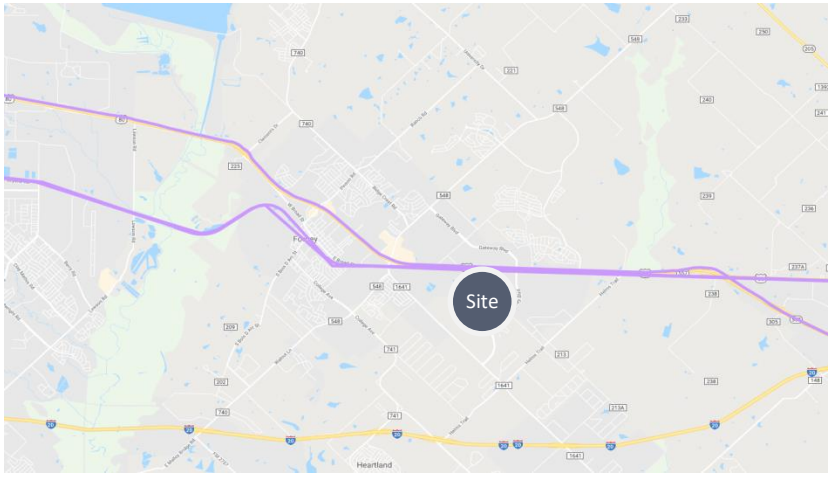
windstream

In addition to the four (4) aforementioned service providers, Windstream is also available in the area. Windstream is a large CLEC in the U.S. and can provide services such as such as Cloud Connect, Internet high-capacity transport services and voice.

Windstream has a large network in the DFW MSA, however, **they use the same network paths as Zayo, CenturyLink and PTC.**

The majority of Windstream's infrastructure that traverses through the area is long-haul that is either shared or leased from other providers. This often limits the ability to "break-out" a service locally. However, Windstream may be able to provide some level of services to the Target Area using portions of their network components.

Windstream Infrastructure



Connectivity Characteristics: Target Area Providers

The Target Area has enough available telecommunication providers and fiber pathways to ensure diverse carriers and services are delivered in a reasonable and cost effective manner.

The fiber routes are adjacent or pass through the key center of the Gateway Master Planned Development, which ensures that the entire area can get services quickly.

Given the amount of fiber, and the quality of the available providers, all potential telecommunication services are available, including dark fiber.

The long-haul systems can provide an additional dimension of diversity and services, if they can be successfully accessed.

The latency to the DFW MSA Core infrastructure is under .5 milliseconds, which is excellent.

Service Delivery & Construction Cost Matrix

PROVIDER	DIA	DARK	TRANSPORT	VOICE	TV	COSTS
AT&T	✓	✓	✓	✓		Low
suddenlink business | by altice	✓			✓	✓	Low
CenturyLink	✓	✓	✓	✓		Moderate
verizon	✓	✓	✓	✓		Moderate
zayo	✓	✓	✓			Low
windstream	✓	✓	✓	✓		Moderate
PEOPLES	✓		✓	✓		Low

In the table above, ***costs equates to the construction*** *or* ***extension of services****, not the actual services themselves.*

PRICING SCALE

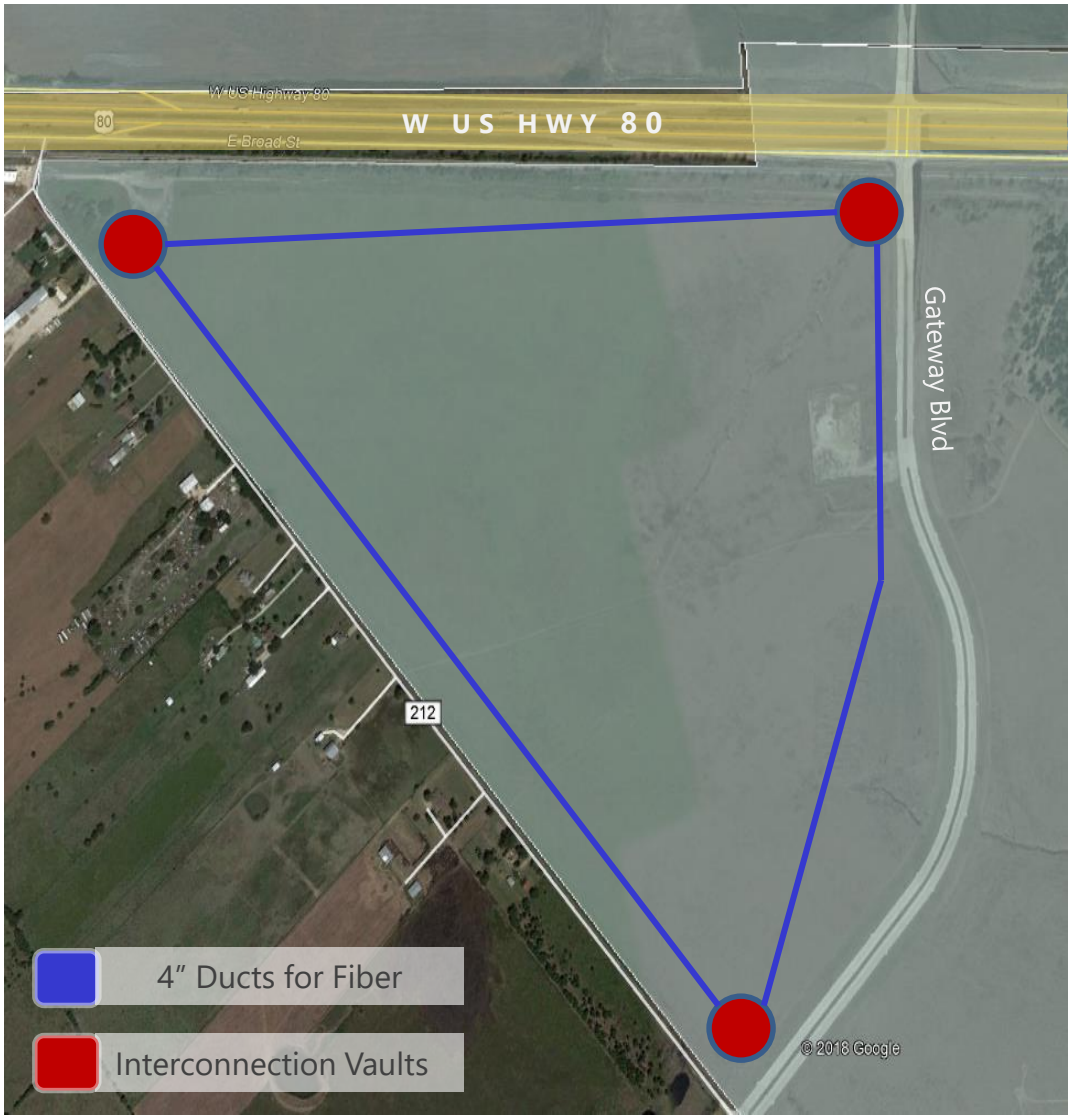
Low *Moderate* *High*

Ingress/Egress – Target Area

The design of path diversity, or ingress/egress, is a key component in data center site selection and evaluation. Because network reliability is critical for data centers, facilities are designed with diverse fiber network paths entering and exiting the building, and in many cases, equipped with diverse service providers.

This same concept can be applied on a larger scale when thinking about the planning of telecommunications infrastructure providing services to a community. When designing the roadway, it is beneficial to plan how the fiber optic network will enter and exit and ultimately service the site. Typically, network reliability is enhanced when roadways are engineered and constructed in a way to ensure as many paths as possible can be created from the public right-of-way to the future facility.

In the illustration to the right, an example ingress/egress design is shown for a portion of the Gateway Development.



Summary of Connectivity Characteristics

Forney, Texas | Gateway

Key Features
Immediate availability of fiber from several of the premiere providers operating within the U.S.
Potential interfaces to **adjacent long-haul** fiber systems
Low latency to key Dallas data centers and carrier hotels, with less than .5 millisecond RTD latency
Easily established **carrier and fiber path diversity**
Access to **Cloud and IXP connection points**
Low costs to establish services

Available Telecommunication Services
✓ Virtually unlimited high-capacity services
✓ International transport services
✓ Standard voice services
✓ Internet and cable television
✓ Dark fiber available

APPENDICES | Gateway Development - Forney Texas

I. Additional Network Maps
II. Latency Background & Area Specific Calculations
III. Fiber Optic Infrastructure Deployment
IV. Dark Fiber / Other

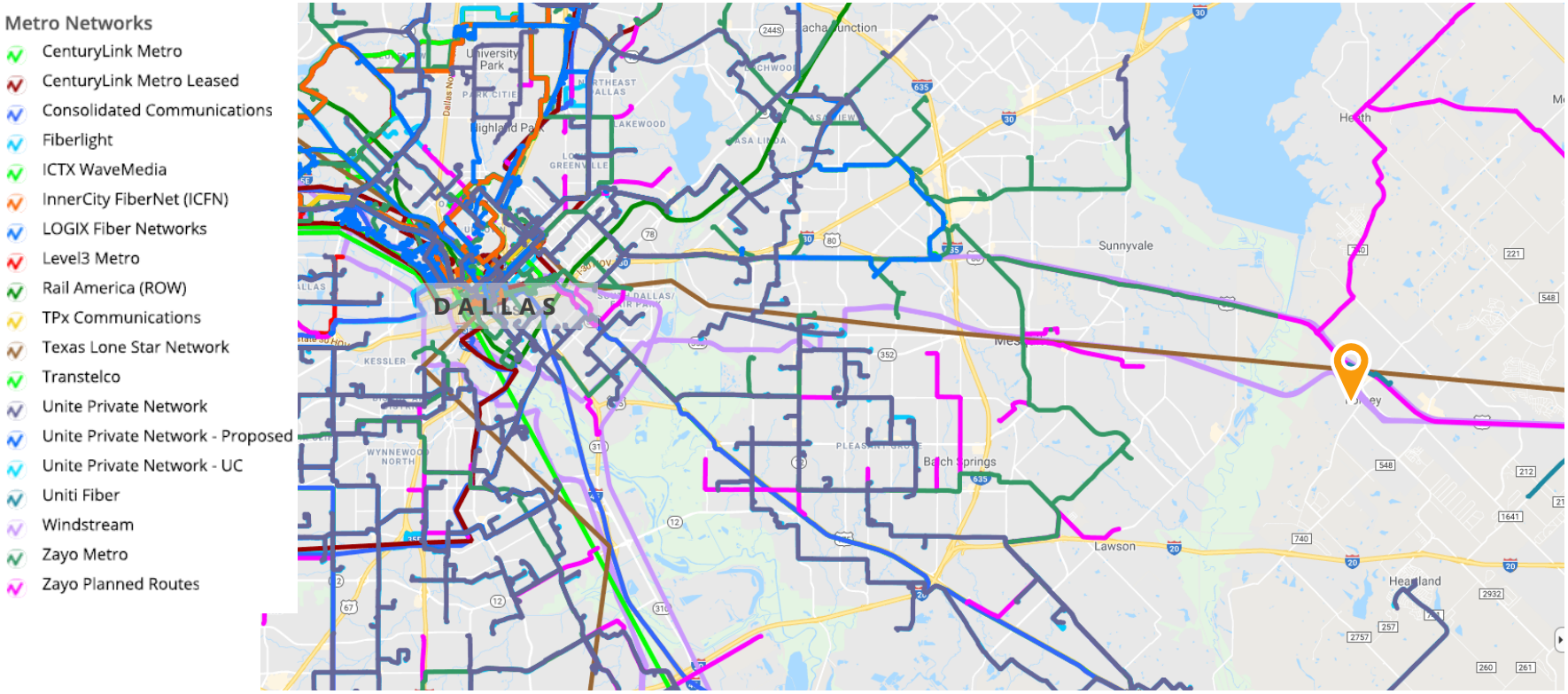
ADDITIONAL AREA MAPS

Dallas Area Metro Fiber Maps

25, 50 and 100 Mile Radius

Additional Maps: Dallas Area Providers

Dallas Area Connectivity: **25 Mile** Radius - *Metro*

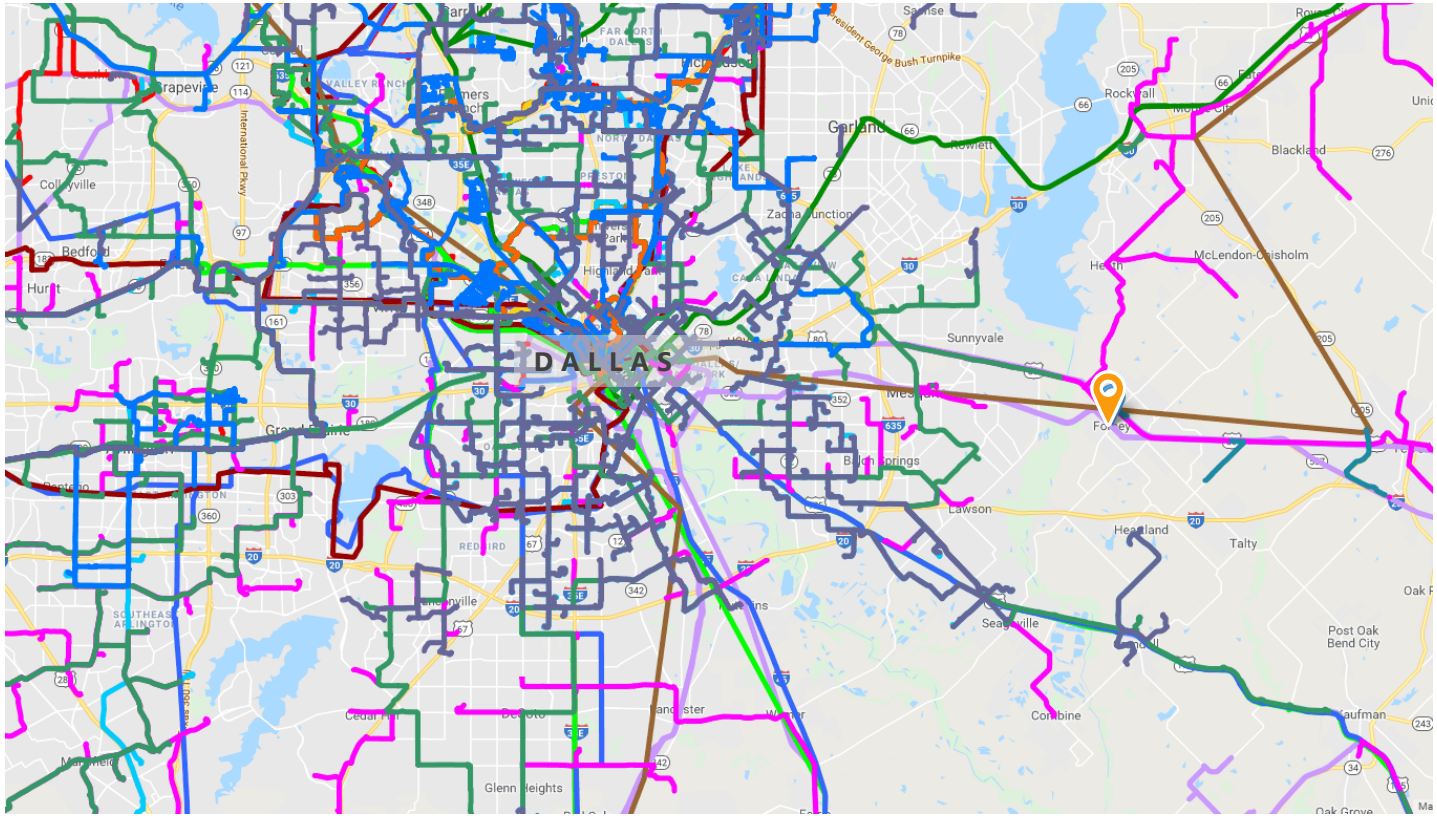


Additional Maps: Dallas Area Providers

Dallas Area Connectivity: **50 Mile** Radius - *Metro*

Metro Networks

- CenturyLink Metro
- CenturyLink Metro Leased
- Consolidated Communications
- Fiberlight
- Grande
- ICTX WaveMedia
- InnerCity FiberNet (ICFN)
- LOGIX Fiber Networks
- Level3 Metro
- Rail America (ROW)
- TPx Communications
- Texas Lone Star Network
- Transtelco
- Unite Private Network
- Unite Private Network - Proposed
- Unite Private Network - UC
- Uniti Fiber
- Windstream
- Zayo Metro
- Zayo Planned Routes

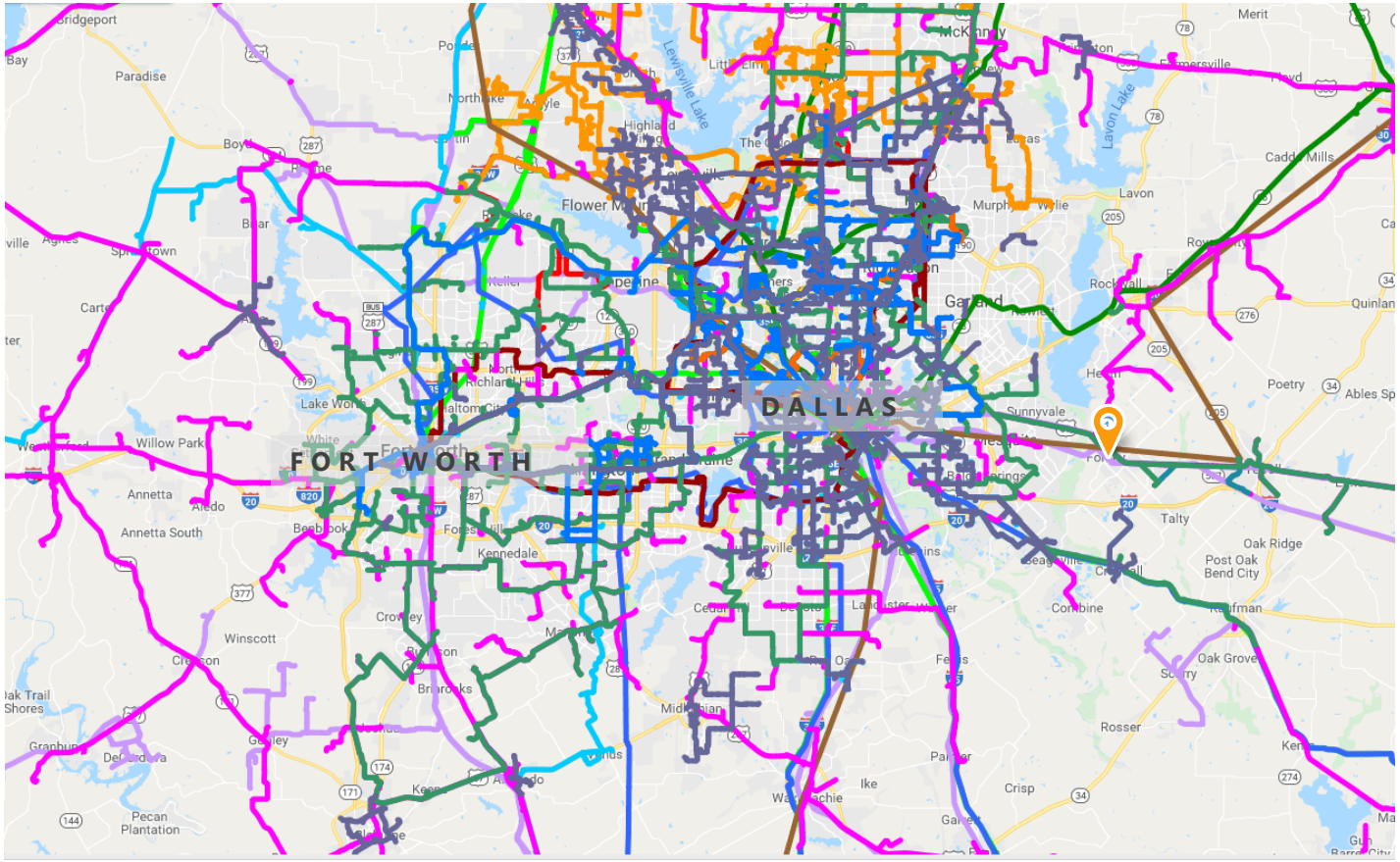


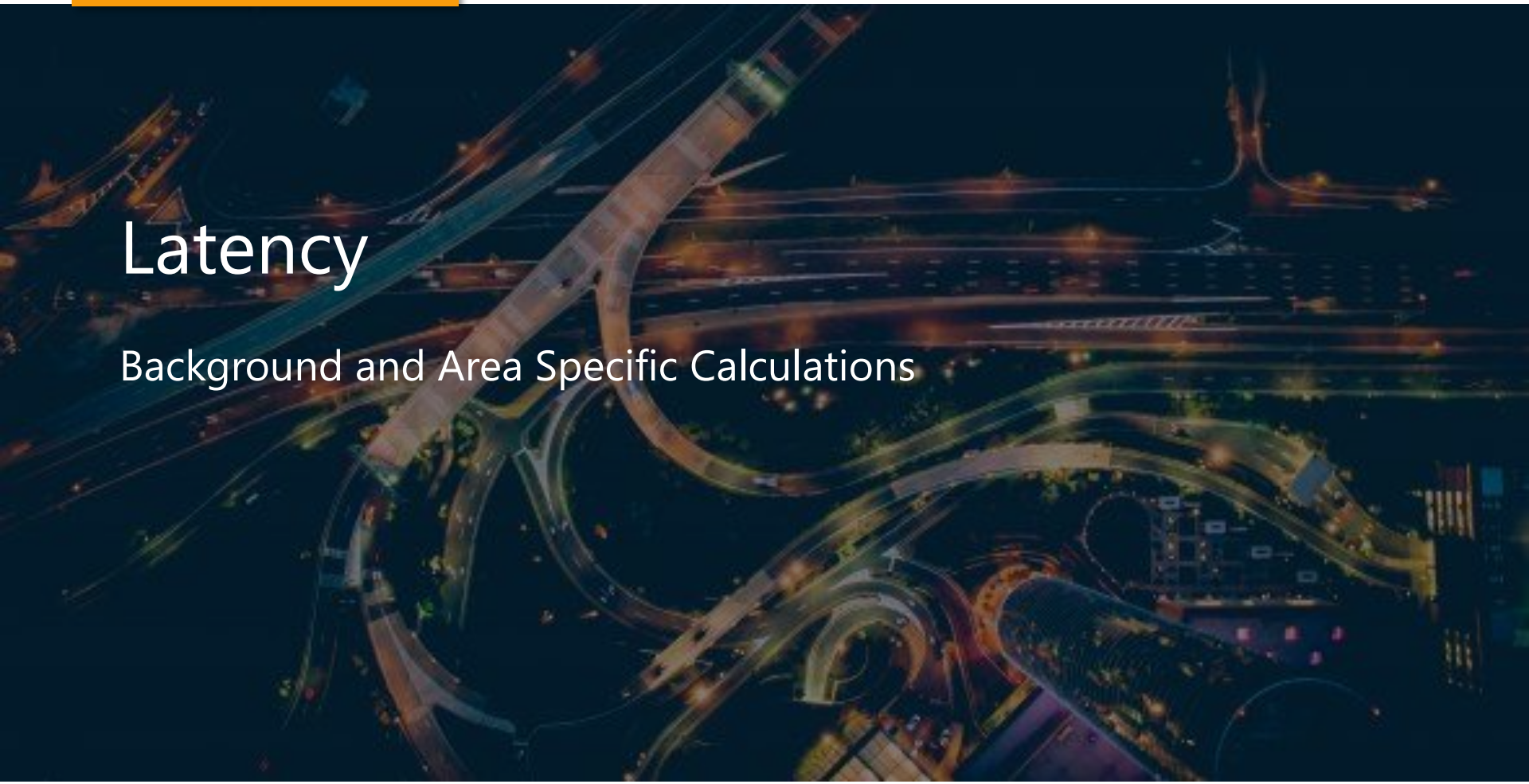
Additional Maps: Dallas Area Providers

Dallas Area Connectivity: **100 Mile** Radius - *Metro*

Metro Networks

- CenturyLink Metro
- CenturyLink Metro Leased
- Consolidated Communications
- Fiberlight
- Grande
- ICTX WaveMedia
- InnerCity FiberNet (ICFN)
- LOGIX Fiber Networks
- Level3 Metro
- Rail America (ROW)
- Sudden Link
- TPx Communications
- Texas Lone Star Network
- Transtelco
- Unite Private Network
- Unite Private Network - Proposed
- Unite Private Network - UC
- Uniti Fiber
- Windstream
- Zayo Metro
- Zayo Planned Routes





Latency

Background and Area Specific Calculations

Latency | What is latency and what factors impact it?

Latency *is defined as the time it takes for data to be transmitted from one point to another, across a network platform. Normally, this is expressed as* **Round-Trip Delay (RTD)** *as data is sent and an acknowledgement of that data being received must be returned to the sender to ensure validity is maintained.*

In telecom networks, "latency" is the term used to describe the amount of time it takes for data to travel round-trip from a point to a destination and back. Extrinsic factors businesses face such as competition, compliance or software applications drive the need for latency sensitive networks. For some businesses, latency is a critical requirement in their IT infrastructure planning and for others a "nice to have" element of their network. Still others may not have any need for a lower latency network solution. It has become an important enough element of network design that companies should at least be aware of latency and how it affects their IT infrastructure and related applications that drive their business.

Multiple factors affect latency such as:

- *Physical distance*
- *Natural and man-made obstructions*
- *Equipment and data processing*

Fiber optic technology is based on light as a medium, and the speed of light travels at approximately 186,000 miles per second, which equates to 700 million miles per hour (299,792,458 meters per second). However, current technology has not completely harnessed nature's capabilities, so even with fiber optics, which is a transmission media capable of bending and controlling light-waves, only 80-85% of the speed of light can be achieved with today's equipment.

Latency | Background and Modern Day Application

Companies with a business model based on speed of data transmission are constantly seeking a faster network alternative, and in turn fiber providers have sought to create solutions that address that demand. In some cases, these "ultra" low latency networks use a microwave transmission design because such a design is considered "line of sight" which delivers the shortest possible distance between two points. Deploying this technology has its drawbacks, but for some applications it is the best fit.

The majority of latency sensitive networks are centered on similar locations or hubs, and thus several providers have optimized fibers along a specific path in order to create low latency routes between two points. The optimization focuses on the two key factors of physical path distance and the latest advancements in equipment. These routes are typically owned by larger providers including AT&T, Verizon, Zayo, Windstream and Level 3; however, there are some smaller, niche providers that focus their business entirely around offering the lowest latency services available. Their networks are designed, deployed and optimized solely for the purpose of being faster than the next.

Historical Perspective of Latency

Latency has always been an issue in one form or another in communications. From postal mail a few centuries ago to today's cutting-edge global communications networks, transmitting information faster from one point to another has always been the goal. When voice calls had to be manually patched through by an operator, it was annoying enough that an undertaker named Almon Strowger invented a switch to replace the manual operator patch panels. More recently, the wireless telecommunications and internet revolution created latency issues that had to be addressed by innovation. Many can recall the early days of AOL and other destination web-based services that were wrought with inefficiencies and slow delivery.

There have been many advances in equipment, networks and the respective applications all focused on negating or limiting the effects of latency. However, because latency is a factor in voice, video, storage, transactional and a variety of other applications or services, companies should be mindful when selecting facilities to ensure that required services can be delivered.

Latency is reported in **milliseconds** of **Round Trip Delay Time (RTD)** and calculates the expected delay between two points.

LOWER = **FASTER**
Latency = Speed

DISTANCE

Increases Latency

Latency | Calculating Latency and RTD

While traveling through fiber-optic cable, signals travel slower than they would traveling in a vacuum. How much slower? Depending on the specific equipment used, signals travel roughly 122,000 miles per second as compared to 186,000 miles per second at the speed of light. The general rule of thumb for calculating latency is using 8.2 microseconds per mile, or .82 milliseconds per 100 miles for a fiber-based solution with newer equipment designs.

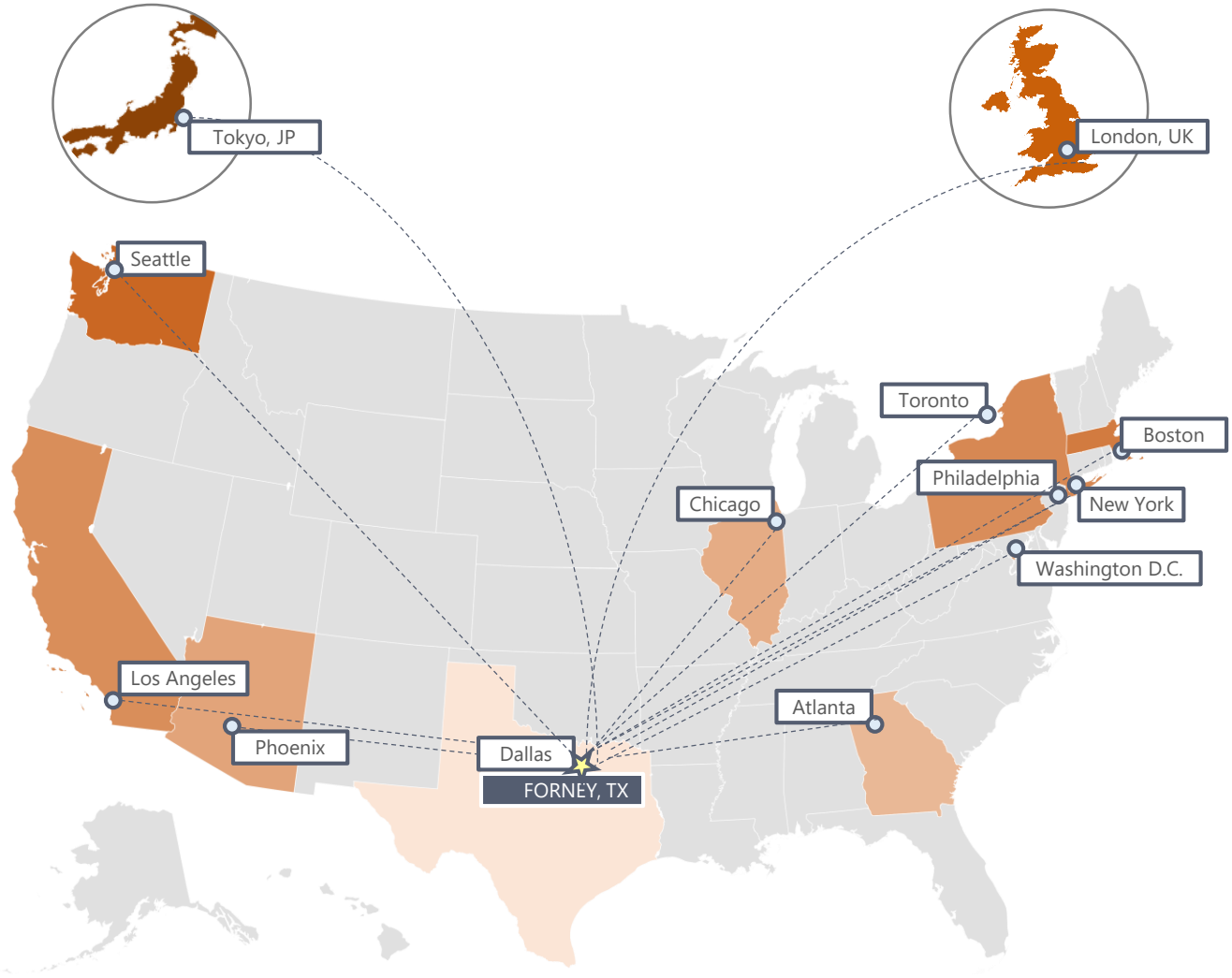
The latency of a terrestrial network is based on two (2) main factors: 1) **fiber route length** (most important factor) and 2) **equipment optimization.** Because the actual length of the fiber route is the overriding element in calculating latency, long-haul fiber has the greatest impact on the speed of a network. In calculating long-haul latency, the metro network latency must be factored in to the measurement along with the long-haul paths themselves. Because metro networks are typically built over shorter distances, their effect on the overall latency is relatively minimal. However, there are cases where the metro network design and equipment are not optimized to support latency-sensitive services.

Compounding the inefficiencies of human-created media and technology, deployed fiber optic networks rarely follow a straight and direct line. Instead, networks have followed the railways, highways and transportation corridors which are never straight due to geological obstacles and right-of-way disputes. Most of the networks that are currently available are not "as the crow flies" routes. However, many providers have optimized their routes to create shorter connects between two points.

Route	Distance	Time, light in vacuum	Round-Trip Delay Time (RTD) in fiber
New York to San Francisco	4,148 km	14 ms	42 ms
New York to London	5,585 km	19 ms	56 ms
New York to Sydney	15,993 km	53 ms	160 ms
Equatorial circumference	40,075 km	133.7 ms	200 m

Area-Specific Latency

Latency to Key Locations from Forney, TX



City	State	Ctry.	RTD (ms)
Dallas	TX	USA	0.5
Atlanta	GA	USA	15.2
Chicago	IL	USA	19.2
Phoenix	AZ	USA	21.6
Washington	DC	USA	26.3
Los Angeles	CA	USA	29.1
Philadelphia	PA	CA	29.1
New York City	NY	USA	30.7
Boston	MA	USA	35.1
Seattle	WA	USA	41.8
Toronto	ON	USA	45.9
London		UK	95.4
Tokyo		JP	129.2

Latency calculated using 10Gigabit Layer 1 Transport Services. The most interconnected point or data center in each market was used.

Fiber-Optic Infrastructure

Aerial versus Underground

Outside Plant Fiber Optic Infrastructure

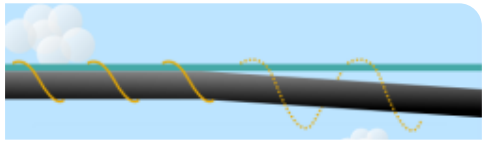
Today a single fiber pair is capable of supporting at least eight (8) terabytes of traffic. For the sake of illustration, a terabyte equates to the amount of information contained in 1,000 copies of the Encyclopedia Britannica. Ten (10) terabytes would roughly equal every printed document in the Library of Congress. (These statistics were calculated for a fiber pair utilizing equipment that is currently available.)

A great deal of science and creative genius went into the development of our incredibly robust fiber optic networks. To make the technology a reality, the laws of physics had to be harnessed and fundamentals of light manipulated.

Most of modern science is focused on equipment, solving questions such as how to cram more data onto the same two fibers or how to extend the range of the transmissions. However, the largest piece of a fiber optic network requires less science. This piece of the puzzle is often the costliest and tends to act like a drag parachute on a race car, slowing the speediest vehicle to a crawl. This all-important piece is the Outside Plant Infrastructure and acts as the fiber backbone - the laterals and splices that interconnect the fiber optic science in such a way that it can be called a network.

These cables are comparable to the roads on which we drive, interconnecting towns, cities and countries. Just as there are multiple roads to get from one place to another, there are multiple methods of deploying fiber from one place to another. The two primary methods include aerial and underground construction.

Aerial
Fiber Cable Systems



VS

Underground
Fiber Cable Systems

Aerial Fiber Cable Systems

Aerial fiber construction is the process by which fiber optic cable is installed on utility poles. These are often the same wooden or metal poles that provide pathways for the electrical grid. In placing aerial cable, a supporting wire (previously referred to as messenger wire) is needed in addition to the cable. Some aerial fibers are pre-lashed to a support strand, streamlining the process.

Lashing is the process of securing the fiber cable to the support strand via lashing wire. When placing cable on a pole, the required spacing distance varies depending on the type of cable or equipment. These requirements are often set by local, state and national standards such as the National Electric Code.

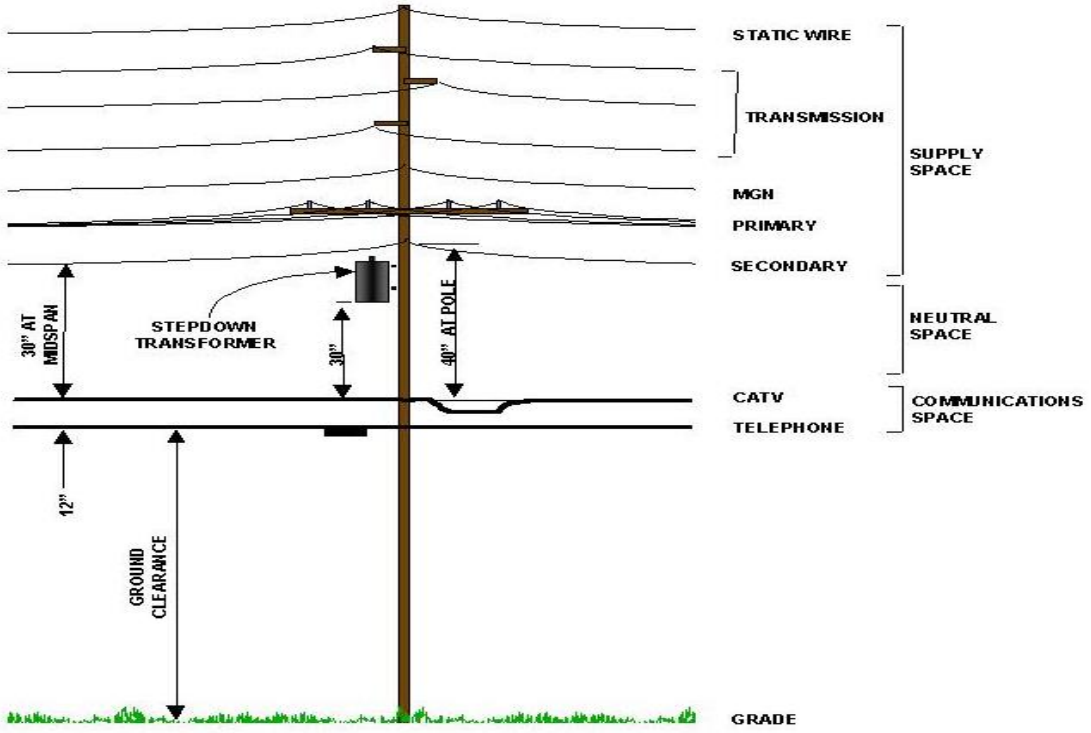
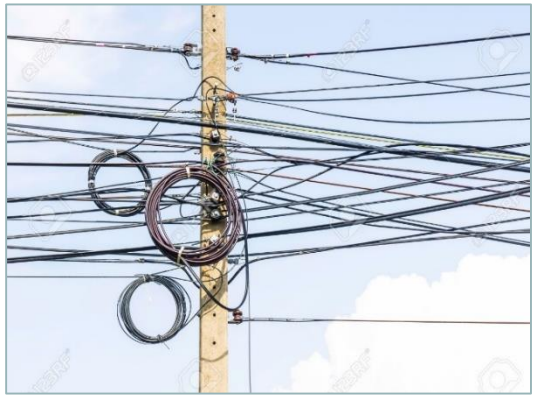


figure 9

Aerial Fiber Cable Systems

If you took a cross-country road trip and looked closely at installations, you'd see a marked difference in types of deployments as you move from town to town.

The "Good"



The "Bad"

The "Ugly"

The variations in these installations is due to many factors, including a lack of enforced standards, utility pole ownership mismanagement, layers of byzantine rules and the aforementioned skill levels involved in the physical deployment of these cables.

Aerial fiber makes up the majority of deployments for three main reasons:

1. COST
2. PROCESS
3. TIMELINE

Aerial Fiber is King

More than **80%** of all **deployments** ongoing in the U.S. are placed on **utility poles.**

Underground Fiber Cable Systems

Underground fiber construction is the process where fiber optic cable is installed under the ground in pipes or conduits. Unlike aerial, there are a variety of different methods for installing this type of fiber infrastructure. Some methods include plowing, open-trenching, horizontal drilling/boring and micro-trenching. Robots have even been used to place fiber cable in sewers and other existing pipe structures. The aforementioned methods continue to develop and advance, primarily because the costs of underground construction are significantly more than aerial.

In city environments providers risk hefty construction costs. For example, if a provider has to restore a granite sidewalk or replace pavement to meet DOT standards, the costs for new underground construction could run over $1,000 per foot. While this is rare, it is not unusual to see $500 per foot construction expenses. The median construction cost in a city core hovers near $125 per foot, with most of this cost being attributed to things other than the actual construction! Countless variables are involved in underground construction in a city, which contributes to the high expenses. Most of the fiber deployed in crowded metros is done through the old-fashioned street-cut and trench method. There is no safe way to drill in a city utility easement filled with steam pipes, water systems and Jimmy Hoffa's remains.

Despite the challenges, tens of thousands of miles of underground fiber and conduit systems have been deployed across the U.S. Many of these miles of underground fiber have cost less than $20 per foot, averaging around $35 per foot. Normally, the low-cost structures are achieved through plowing techniques.

MICROTRENCHING

PLOWING

A Question of Reliability – Aerial or Underground?

There is always the question of underground fiber infrastructure being infinitely more reliable and secure than aerial deployments. There is a perception of inherent reliability in something that is underground and can't be seen. However, fiber is not money in a bank vault. Fiber can only be transmitted so far before it must surface and become vulnerable to the same forces that could interrupt aerial services. In many cases, fiber networks transition from aerial to underground regularly. This transition occurs for a variety of reasons.

More importantly, not all environments are equal. Let's take New York City for instance. In the Empire City Subway system fiber is so thick in many of the manholes, the weight of it can change the transmission characteristics in the summer when it gets incredibly hot inside the vaults. Better yet, when techs decide to climb down into the vaults to get to "their" fiber, they use "your" fiber as the ladder. Oops! Aerial can also be impacted by big wind events in the south and consistent ice and snow storms in the northern and mountainous climates. Although there are risks impacting both aerial and underground fiber networks, these are examples of extremes.

One important myth to debunk is that building an underground network will be more reliable than the equivalent aerial plant.

This is simply not true. Most of the fiber cuts in the U.S. are from underground construction. In a study conducted by MCI , 60% of the fiber cuts were from dig-ups, while a Fujitsu study attributed 80% of failures to dig-ups. Dig-up issues were so bad a political lobby was created to pass legislation in all states to create the modern day "dig-safe" or "one-call" system. Furthermore, as cited in the Fujitsu report, the reliability factor for aerial fiber was over 25 times better than buried fiber. Most buried fiber networks transition along the same paths (Public Right of Ways) and so when a "dig-up" event occurs, it typically takes down more than one network. Buried fiber networks also have to surface in manholes, hand-holes or similar points to accommodate splicing. These locations are at ground level and certainly more accessible to vandalism, intentional or unintentional breaches.

A Question of Reliability *(continued)*

Of course, there are exceptions to outages involving underground as well. For example, there is a pipeline turned fiber-transport company that built a route using a large stainless-steel pipe buried 5 feet deep. To our knowledge this route has never had an outage from physical damage, which is the exception, not the rule. Most communication networks are buried from 18 to 36 inches deep and in suburban areas need to come to the surface frequently for splicing and distribution.

Most of the studies that have been conducted on fiber optic networks are relatively old, with the more recent being authored in 2001. While there has been little effort made to refresh these studies, one must ask the question if anything in the deployment methodologies or technologies has changed? We would argue that there are no substantive changes that would warrant another deep dive. The facts haven't changed, and the fiber is only getting

Another myth to debunk is that underground topologies are "better." The counter argument is that when an outage occurs in an aerial topology, the typical time to repair is much less on aerial cable for many different reasons:

1. Failure point easier to locate	**4.** No heavy equipment required for restoration
2. Power distribution systems (poles) have high priority restoration attention	**5.** Traffic impact lessened
3. Temporary restoration is easier to facilitate	**6.** Simple access

In conclusion, both underground and aerial topologies are good network topologies. Both topologies have strengths and weaknesses. The best network design would, ideally, utilize both topologies; however, in many cases the cost of the underground deployment far exceeds the "value" realized by its incorporation into the networks design.

Dark Fiber & Carrier Hotel

Dark Fiber is a service that is only offered by a few carriers/service providers. Many enterprise clients use dark fiber to interconnect their campuses or to connect to a carrier hotel. There are various reasons for selecting dark fiber as a product, but the primary reasons most companies use dark fiber is to :

1. ensure that they maintain maximum control of their costs for all services, and to
2. create an environment that is dynamic and flexible, (e.g. if they need Cloud, VOIP, storage services they can select from dozens of options)

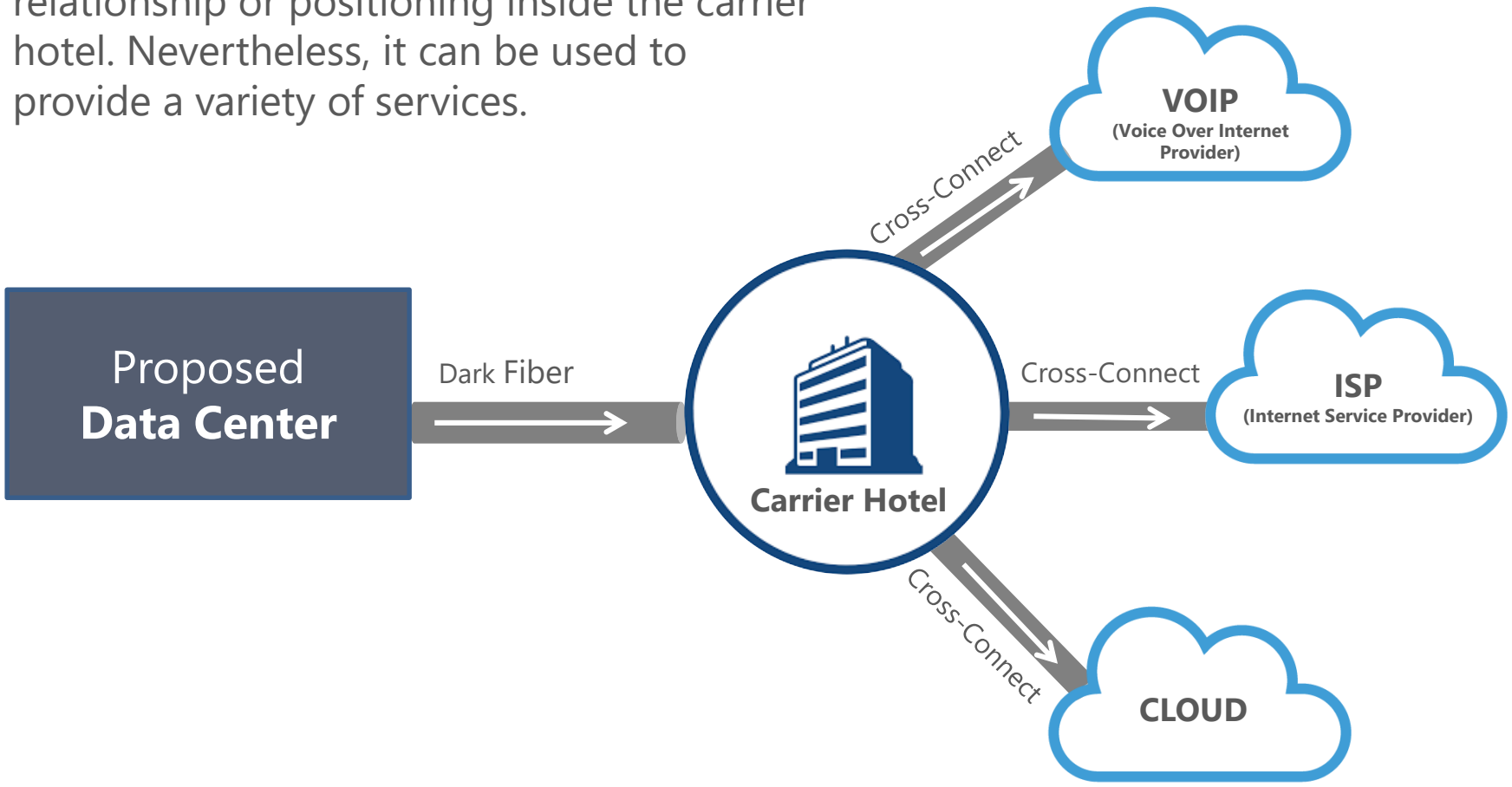
Dark Fiber can be used as easily as a cross-connect or fiber jumper. Since the distance to the carrier hotel is less than 10 km the fiber provider can interconnect to the lowest costs IP provider to save hundreds of thousands of dollars in a 5-year period.

Implementation of dark fiber can also be used to establish a point of presence at a carrier hotel, which would mean some kind of colocation facility. A simple, cost-effective device could be deployed with 10G or 100G optics (off the shelf) that could facilitate VLANs or virtual circuits in a small space at the carrier hotel, allowing a connection to multiple providers for services such as VOIP, Software As a Service, Cloud, etc. This fosters flexibility for clients and ensures the latest technologies/services are available without limiting the options to the services offered by one specific provider.

Carrier Hotels are simply data center facilities that have become the center of our interconnected world. Every provider doing business in the region is typically available at these facilities, and hundreds of applications or services are just a cross-connect jumper away. Space in these facilities can be as small as a ¼ rack or as large as dozens of racks of equipment. Connecting the carrier hotel and fiber are as simple as ordering any other services.

Dark Fiber & Carrier Hotel

Dark Fiber requires some level of relationship or positioning inside the carrier hotel. Nevertheless, it can be used to provide a variety of services.



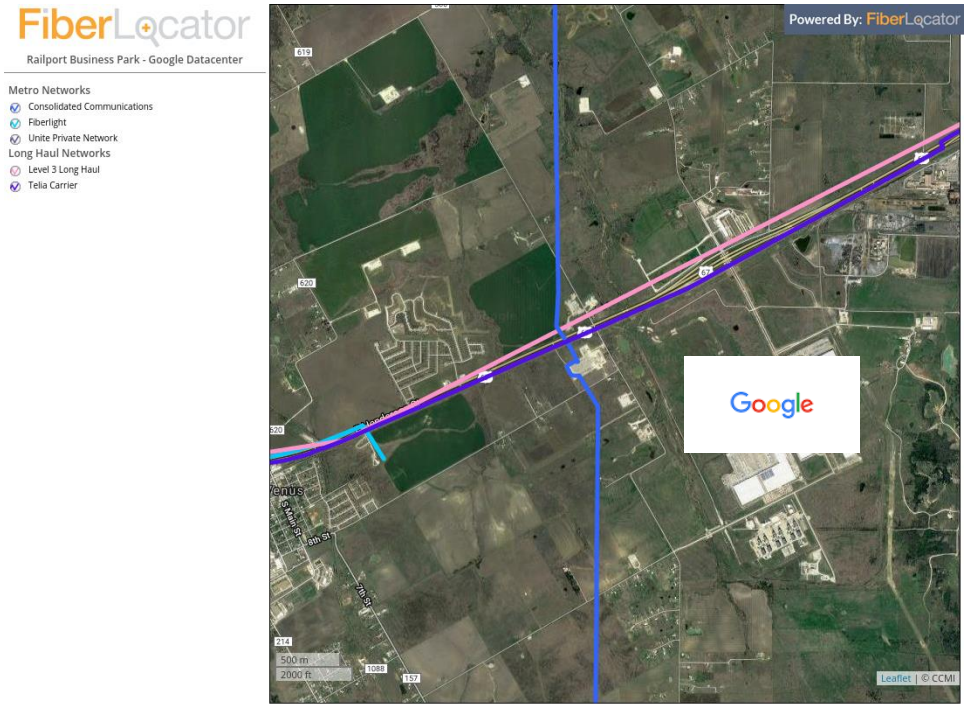
Midlothian Texas – Google's Choice for a Google Cloud Data Center

Google chose to place their regional cloud data center in Midlothian Texas, which is about the same distance to Dallas's core infrastructure as the Gateway Development.

Additionally, the fiber connectivity characteristics are similar for the metro and long-haul fiber.

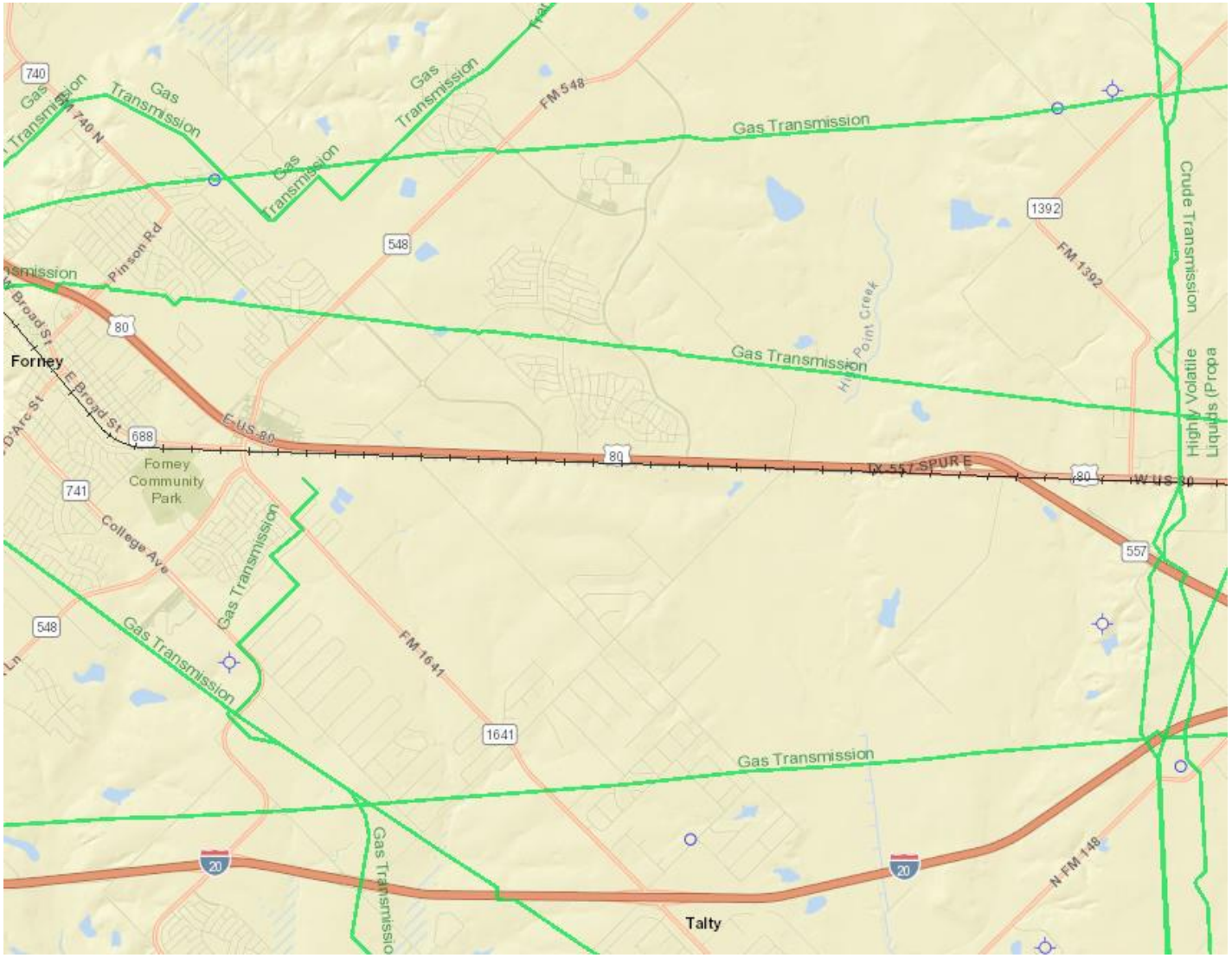
Companies such as Google focus on a great many criterion in making selections for where they will place their data centers, which are the core of Google's revenue generation. Although the site selection process can be complex, the most basic requirements are fairly straightforward. In order to maximize profits, data centers must be located in places with the following:

- Power (costs and sustainability play)
- Water
- Network availability & latency
- Environmental (natural disasters can greatly impact risk factors)
- Healthy business climate

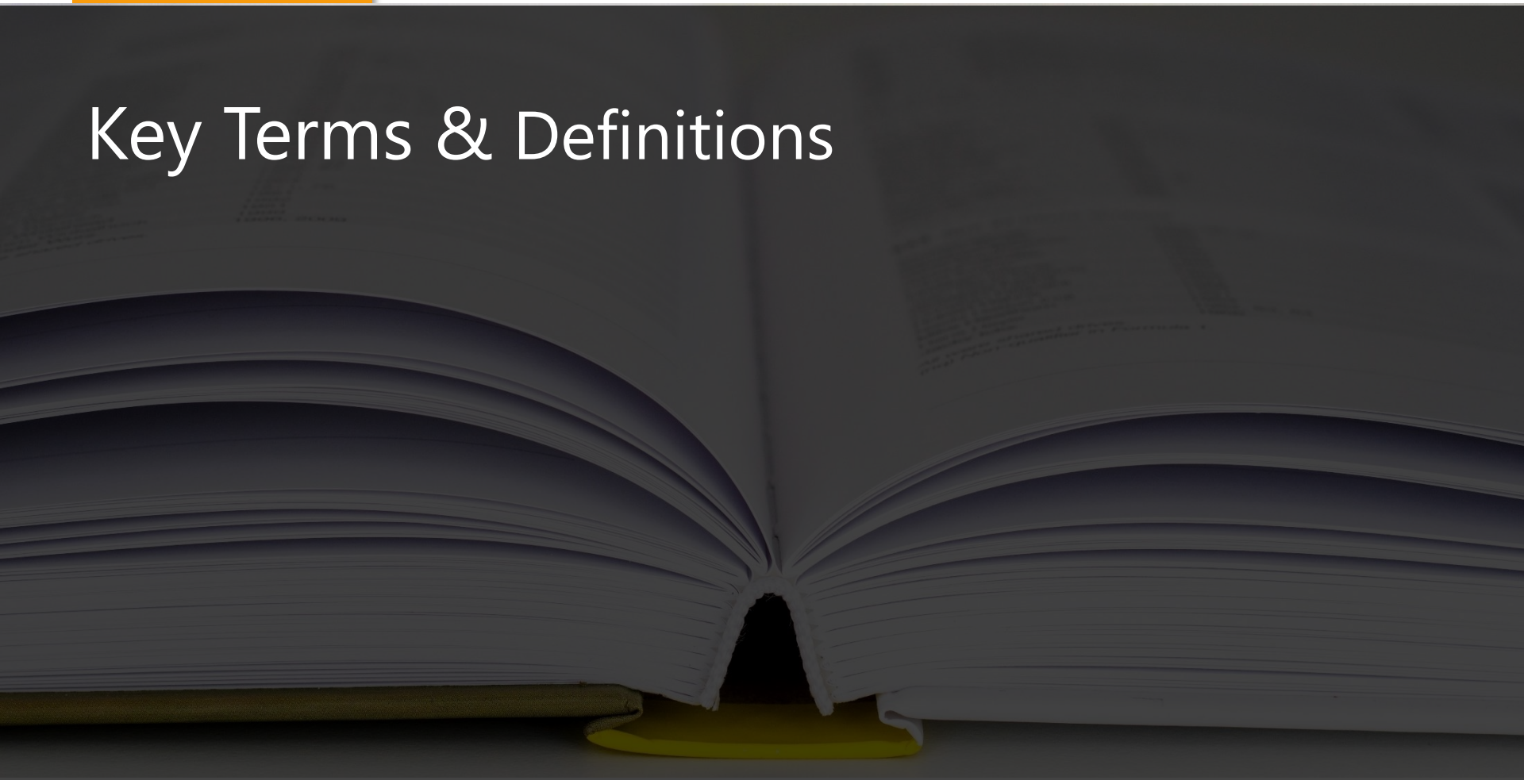


Article about why companies are moving to DFW

Area Gas Pipeline Map



Key Terms & Definitions



A

AWS
Amazon Web Services (AWS) is a cloud services platform that offers compute power, database storage and content delivery for businesses.

Azure
A cloud computing platform and infrastructure, created by Microsoft, for building, deploying and managing applications and services through a global network of Microsoft-managed data centers.

B

Backhaul
A term used for the transmission of a signal (normally video) from the ends of transmission systems such as microwave to a central point. For a satellite videoconference, a backhaul refers to a signal brought in from a secondary site to the origination site, mixed with the primary signal, and sent out over the program out satellites.

Bandwidth
Bandwidth is the capacity to transmit information across a network or medium. Bandwidth describes the data transfer rate; rates are measured in bits (bps), kilobits (kbps), megabits (Mbps), or gigabits per second (Gbps).

C

Carrier
Vendor of transmission services operating under terms defined by the FCC as a common carrier. Carriers own a transmission medium and rent, lease or sell portions for a set tariff to the public via shared circuits.

Carrier Hotel
A data center facility that is highly redundant in design and function, which acts as a place where long-haul and metropolitan networks meet. Providers within carrier hotels can efficiently interconnect their networks – a necessary function to complete services in many cases.

CDN
A Content Distribution Network (CDN) is a large distributed system of servers deployed in multiple data centers across the Internet. The goal of a CDN is to serve content to end-users with high availability and high performance. CDNs serve a large fraction of the Internet content today, including web objects (text, graphics and scripts), downloadable objects (media files, software, and documents), applications (e-commerce, portals), live streaming media, on-demand streaming media and social networks.

CLEC
A Competitive Local Exchange Carrier (CLEC) is a telephone company that competes with the already established local telephone business by providing its own network and switching.

Cloud
Cloud computing is a recently evolved term to describe the consumption of computing resources. Cloud computing involves deploying groups of remote servers and software networks that allow centralized data storage and online access to computer services or resources. Clouds can be classified as public, private or hybrid.

D

Dark Fiber
A fiber optic strand, normally used in pairs, that has no signal or equipment placed on it. It is typically used for large bandwidth (20-30Gigabit and higher) services by carriers and enterprise clients.

Data Center
A centralized repository, either physical or virtual, for the storage, management, and dissemination of data and information organized around a particular body of knowledge or pertaining to a particular business.

DWDM
Dense Wave Division Multiplexing (DWDM), is a Layer 1 physical layer of the networking world. DWDM's capabilities are similar to dark fiber, which can provide virtually unlimited bandwidth capability.

E

E-LAN
Enterprise-wide Local Area Network or E-LAN is a multipoint-to-multipoint service that connects a number of User Network Interfaces (UNI). E-LAN's are used to create multipoint VPNs and multicast networks and typically have a distance limitation of less than 50 miles.

End User
The ultimate last user of a telecommunications system whether it is a student within a school, business or a subscriber on a cable television system.

Ethernet
Baseband protocol and technology developed by Xerox and widely supported by manufacturers; a packet technology that operates at 10 Mbps over coaxial cable and allows terminals, concentrators, work stations and hosts to communicate with each other.

F

Fiber Optics
Communications medium based on a laser transmission that uses a glass or plastic fiber which carries light to transmit video, audio, or data signals. Each fiber can carry from 90 to 150 megabits of digital information per second or 1,000 voice channels. Transmission can be simplex (one-way) or duplex (two-way) voice, data, and video service.

I

Interconnect
The connection of two or more cable systems. Can also be used to describe the connection of a headend to its hubs.

IXC
Inter-Exchange Carriers (IXC) can carry inter-LATA traffic. Examples of IXCs include long distance telephone companies such as AT&T, MCI and US Sprint.

I

Interface
The link between two pieces of disparate equipment, such as a CPU and a peripheral device. Also, a method of translating data from computer to user. For Internet, the user interface is difficult for the uninitiated to use. Software programs have been written which change the look of the screen by provide pull-down menus, buttons, hierarchical files folders or hypertext to use and move around the Internet. Software program names include Mosaic, Lynx, Internet in a Box and GINA.

IP
Internet Protocol (IP) is the digital media transport system by which data is sent from one computer to another on the Internet.

ILEC
Incumbent Local Exchange Carrier (ILEC) is a telephone company that was providing local service at the time of the Telecommunications Act of 1996 was enacted. Examples include the former Bell operating companies. CLECs have since been introduced to promote competition.

J

Jitter
Jitter is the undesired deviation from true periodicity of an assumed periodic signal in electronics and telecommunications, often in relation to a reference clock source. Jitter may be observed in characteristics such as the frequency of successive pulses, the signal amplitude, or phase of periodic signals. Jitter is a significant, and usually undesired, factor in the design of almost all communications links.

L

LAN
A Local Area Network (LAN) is a private transmission network interconnecting offices within a building or group of buildings and usually designed to convey traffic; e.g., voice, data, facsimile, video. Usually associated with a computer network made up of computers, printers, and mass storage units.

LATA
A LATA is the Local Access and Transport Area of a telephone company.

Latency
The delay between the sender and the receiver decoding it, this is mainly a function of the signals travel time, and processing time at any nodes the information traverses.

LEC
Local Exchange Carrier (LEC) companies are divided into two large categories: long distance (interexchange carrier, or IXCs) and local (local exchange carrier, or LECs). This structure is a result of the 1996 divestiture of then-regulated monopoly carrier American Telephone & Telegraph. Local telephone companies at the time of the divestiture are also known as Incumbent Local Exchange Carriers (ILEC).

M

MMR
A Meet Me Room (MMR) is a designated place within a data center where networks can interconnect with one another.

MPL
Multiprotocol Label Switching (MPL) is a scalable, protocol-independent transport. In an MPLS network, data packets are assigned labels. Packet-forwarding decisions are made solely on the contents of this label, without the need to examine the packet itself.

MRC
Monthly Recurring Charges (MRC) are charges that are seen on every monthly bill, opposed to one-time expenses.

N

NAP
A Network Access Point (NAP) is a public network exchange facility where Internet service providers (ISPs) are connected with one another in peering arrangements.

N + 1
Created by the FCC, this formula serves as the basis by which the FCC regulates expansion of channel capacity for non-broadcast use. The FCC requires that if the government, education, public access, and leased channels are in use at least 80 percent of the Monday-through-Friday period for at least 80 percent of the time during any three-hour period for six consecutive weeks, then within six months the system's channel capacity must be expanded by the operator.

NRC
A Non-Recurring Charge (NRC) is a one-time charge for services that can occur on an invoice from a provider.

P

Peering
Peering is the interconnection of multiple carriers across a single physical port. Peering is a voluntary interconnection of administratively separate Internet networks for the purpose of exchanging traffic between the users of each network. The pure definition of peering is settlement-free, "bill-and-keep," or "sender keeps all," meaning that neither party pays the other in association with the exchange of traffic; instead, each derives and retains revenue from its own customers.

POP
On the Internet a Point-of-Presence (POP) is an access point from one place to the rest of the Internet.

S

SaaS

A Software as a Service (SaaS) is a software licensing and delivery model in which software is licensed on a subscription basis and is centrally hosted typically in a cloud environment. It is sometimes referred to as "on-demand software".

SONET

A SONET or Synchronous Optical Network will offer dedicated point-to-point lines via fiber, with bandwidths ranging from 51.84 Mbps to over 2gbps. SONET defines optical interfaces for high speed digital transmission - ranging from 51.84 Mbps to more than 2 Gbps in multiples of 51.84 Mbps. The purpose of the SONET standard is to guarantee that fiber, and fiber terminating equipment (e.g. digital loop carrier systems) from different central office vendors, can all interface with each other. While many trials are currently under way to test the SONET central office standards, all new fiber deployment is expected to be compliant with this standard.

T

Tier Level

Data center tier levels describe the availability of data from the hardware at a location. The higher the tier, the greater the availability (uptime) and resiliency.

V

VLAN

Virtual Local Area Network (VLAN) is a local area network that maps on a basis other than geographic location, for example by department or type of user.