NATIONAL TELECOMMUNICATIONS COOPERATIVE ASSOCIATION
The Voice of Rural Telecommunications
www.ntca.org

June 17, 2010

Ms. Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, D.C. 20554

***Ex Parte* Notice**

In the Matter of Connect America Fund; A National Broadband Plan for Our Future; High-Cost Universal Service Support, WC Docket Nos. 10-90, 05-337; GN Docket No. 09-51;

In the Matter of Jurisdictional Separations and Referral to the Federal-State Joint Board; NTCA Petition for Expedited Clarification and/or Limited Waiver of the Commission's Part 36 Rules, CC Docket No. 80-286.

Dear Ms. Dortch:

On Wednesday, June 16, 2010, Angela Kronenberg, Acting Legal Advisor, Wireline, for FCC Commissioner Mignon Clyburn, and FCC Intern Liz Ruiz, met with National Telecommunications Cooperative Association (NTCA) staff and members during an NTCA Industry and Wireless Joint Summer Committee meeting at NTCA headquarters in Arlington, Virginia. A list of those present is included in this filing.

NTCA members discussed rural telco funding impacts under the National Broadband Plan (NBP) and the FCC's April 21, 2010 Connect America Fund (CAF) Notice of Inquiry (NOI) and Notice of Proposed Rulemaking (NPRM). The participants informed Ms. Kronenberg of the threat to comparable, affordable voice and broadband service in rural areas that will result by limiting federal universal service fund (USF) and CAF support to fund just 4 Mbps download, 1 Mbps upload broadband speeds in rural areas while promoting 100 Mpbs download speeds in urban areas. This danger will be compounded by capping the high-cost portion of the USF to current 2010 funding levels when the USF is transitioned into the CAF, as proposed in the NPRM.

NTCA members noted their concerns about the data inputs and assumptions in the proposed NBP Model described in the NOI. They discussed the ambiguities of defining "competitive areas" in rural service territories and expressed the need for adequate support to meet state and lender carrier of last resort (COLR) obligations. The members also discussed the procedures

envisioned under the NOI and NPRM and endorsed the immediate consideration of expanding the USF contribution methodology to include all broadband service providers.

NTCA members provided Ms. Kronenberg a copy of *Providing World-Class Broadband: The Future of Wireless and Wireline Broadband Technologies*, Rural Telecom Educational Series, prepared by Vantage Point Solutions, funded by the Rural Telephone Finance Cooperative and sponsored by the Foundation for Rural Service. This paper provides valuable insight into the costs and capabilities of wireline and wireless broadband options for serving rural America. This paper also demonstrates that the 4 Mbps download and 1 Mbps upload broadband speeds proposed in the NBP will be insufficient to meet rural consumer demands for bandwidth and incapable of running many IP applications that rural consumers and businesses want and need. A copy of this white paper is attached to this filing.

The participants also referenced the recent jurisdicational separations freeze order, briefly discussed the pending status of NTCA's 2008 USAC audit expense allocations petition, and noted the Interim Proposal for jurisdictional separations reform filed by the state members of the Federal-State Joint Board on Separations.

The discussions were consistent with NTCA's positions in previously filed comments and pleadings in the above-referenced dockets.

Pursuant to Section 1.1206 of the Commission's rules, a copy of this letter is being filed via ECFS with your office. If you have any questions, please do not hesitate to contact me at (703) 351-2146.

Sincerely,

/s/ Karlen Reed
Karlen Reed
Senior Regulatory Counsel, Legal & Industry

KR: rhb
Attachments: List of attendees
White Paper, *Providing World-Class Broadband: The Future of Wireless and Wireline Broadband Technologies*

cc: Angela Kronenberg

ATTACHMENT

LIST OF ATTENDEES
JUNE 16, 2010

Daniel Mitchell, Vice President-Legal & Industry, NTCA
Jill Canfield, Senior Regulatory Counsel, NTCA
Karlen Reed, Senior Regulatory Counsel, NTCA
Rick Schadelbauer, Economist, NTCA
Kevin McGuire, Vice President-Business & Technology, NTCA
Wendy Mann, Director of Communications, NTCA
Caitlin Colligan, Public Affairs Manager, NTCA

INDUSTRY COMMITTEE MEMBERS

Janet Bathurst, General Manager, S&A Telephone Company
Richard Coit, Executive Director, South Dakota Telecommunications Association
Tom Conry, General Manager, Farmers Mutual Cooperative Telephone Company
Jason Dandridge, CEO, Palmetto Rural Telephone Cooperative
Wendy Fast, President, Consolidated Telephone Company
David Fox, VP/General Manager, Clinton County Telephone Company
Emory Graffis, General Manager, Northeast Nebraska Telephone Company
Phil Hayes, Chairman, Hancock Telecom
J. Frederick Johnson, EVP / General Manager, Farmers Telecommunications Cooperative
Levoy Knowles, CEO, Ben Lomand Telephone Cooperative
Keith Larson, General Manager, Dakota Central Telecommunications
Denny Law, General Manager, Golden West Telecommunications Cooperative
Wendel Myers, General Manager, Grand River Mutual Telephone Corporation
Andy Randol, Manager, Panora Communications Cooperative
Robert Rozell, CFO/COO, BTC Broadband
Gregory Sapp, General Manager, CEO, Citizens Telephone Cooperative
William Squires, Senior VP-General Counsel, Blackfoot Telephone Cooperative
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WIRELESS COMMITTEE MEMBERS

Mark Benton, General Manager, Midstate Communications
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Prepared by

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PROVIDING WORLD-CLASS BROADBAND:

THE FUTURE OF WIRELESS AND WIRELINE BROADBAND TECHNOLOGIES

"And we should stretch beyond 100 megabits. The U.S. should lead the world in ultra-high-speed broadband testbeds as fast, or faster, than anywhere in the world. In the global race to the top, this will help ensure that America has the infrastructure to host the boldest innovations that can be imagined."

FCC Chairman Julius Genachowski
NARUC Conference, Washington, DC
February 16, 2009

PROVIDING WORLD-CLASS BROADBAND:

THE FUTURE OF WIRELESS AND WIRELINE BROADBAND TECHNOLOGIES

I. INTRODUCTION

It has been said that "the broadband of today is the narrowband of tomorrow." Less than 10 years ago, a 56 kbps modem was the most common method for accessing the Internet. Today, consumers are demanding 10 to 20 Mbps, or higher. Many experts agree that customers will want 100 Mbps broadband access within the next five years and 1 Gbps within the next 10 to 15 years.

Both wireless and wireline broadband access networks are used by consumers predominantly to access the global Internet. Companies that have historically been known as cable television companies, telephone companies, and cellular companies are in the process of remaking themselves into broadband companies. The goal of these broadband companies is to provide their customers with the best connection possible to enable faster Internet access and advanced services—many of which have not been invented yet.

It is difficult to overestimate the importance of broadband access to the United States' future. Broadband is becoming the lifeblood of our very economy. The Economist stated:

> "In eras past, economic success depended on creating networks that could shift people, merchandise and electric power as efficiently and as widely as possible. Today's equivalent is broadband: the high-speed internet service that has become as vital a tool for producers and distributors of goods as it is for people plugging into all the social and cultural opportunities offered by the web. Easy access to cheap, fast internet services has become a facilitator of economic growth and a measure of economic performance."[1]

[1] The Economist, Broadband Access, January 17, 2008.

Technology advances have allowed broadband service providers new methods for providing broadband to their customers and provided significant improvements in broadband speeds. Both wireless and wireline broadband providers have benefited from technology advances, however the best *wireline* broadband technologies have historically been capable of broadband speeds that are 10 or 20 times faster than the best wireless broadband technologies. Rysavy Research stated it this way:

> "Given that the inherent capacity of one fiber optical link exceeds the entire available radio frequency (RF) spectrum, data flow over wireless links will never represent more than a small percentage of the total global communications traffic."[2]

Both wireless and wireline broadband services play important roles in the lives of most consumers and one will never displace the other. Most consumers will require the greater broadband speeds provided by a wireline provider when at home or work and need the mobility provided by the wireless provider, albeit at a slower speed. Rysavy Research also recognized that while wireless and wireline technologies sometimes compete, they are complementary in most cases.[3]

Deployment costs also vary greatly from one broadband technology to another. Some of the broadband access methods leverage existing infrastructures, while next generation broadband technologies often rely on the deployment of new infrastructures and significant investments by the broadband service provider.

This paper explores the most common methods for deploying broadband to customers along with each of their advantages and disadvantages. The broadband access methods discussed in the following pages include:

Wireless Broadband Options

- 4th Generation Wireless Broadband
  - WiMAX
  - LTE (Long Term Evolution)
- Satellite Broadband

Wireline Broadband Options

- DSL (Digital Subscriber Line)
- Cable Modems
- FTTP (Fiber-to-the-Premises)

It should be noted that there are other broadband technologies available, such as Broadband over Powerline (BPL), another wireline broadband option, and municipal Wi-Fi, another wireless broadband option. We have chosen not to address these technologies, since they are not widely deployed and many implementations have proved to have significant financial or technical challenges.

[2] Rysavy Research, EDGE, HSPA, and LTE Broadband Innovation, 3G Americas, pg. 5, September 2008.

[3] Ibid., pg. 5.

II. BROADBAND CAPABILITY OVERVIEW

(TABLE 1) As consumer appetite for more bandwidth increases, broadband networks will be required to deliver more bandwidth per user. More bandwidth allows for the delivery of new and exciting applications to consumers.

Most consumers will require a wireless and wireline broadband network connection to meet their broadband needs. The wireline broadband connection is required to provide adequate bandwidth for the rich multimedia experience consumers expect in their home or business and a wireless broadband connection is required to meet their bandwidth intensive mobile requirements.

There are many ways a wireless or wireline broadband provider can deliver their broadband connection to their customers. The various methods for deploying broadband differ in cost and quality. The quality of a broadband connection is determined by four basic metrics. These are:

- the connection's speed (size of the "pipe")
- the connection's latency (delay)
- the connection's jitter (variation in packet delay)
- the service reliability

In order for consumers to realize all the benefits of broadband, they must have high quality broadband connections that meet their needs today and in the future. From the service provider's perspective, it is important that the networks they deploy today can be easily scalable to meet the broadband needs of tomorrow without a significant additional investment. Deploying broadband in rural areas and areas of low customer density present its own unique challenges. It is not uncommon for the broadband infrastructure of a rural customer to cost up to 10 times more than for an urban customer. Since the replacement costs are so high in rural areas, it becomes more crucial that the infrastructure deployed be easily upgraded to meet the customer's rapidly increasing broadband needs of the future.

"Bandwidth-intensive applications could very quickly become the norm in the U.S.—even in rural areas. Technologies that cannot be upgraded easily could make Internet applications less than five years from now look like the dial-up downloads of today."[4]

TABLE 1: BROADBAND SPEEDS AND CONNECTIONS

500 kbps – 1 Mbps	Voice over IP, texting, basic e-mail, Web browsing (simple sites) streaming music (caching), low quality video (highly compressed and on a small screen)
1 Mbps – 5 Mbps	Web browsing (complex sites), e-mail (larger size attachments), remote surveillance, Standard Definition (SD) IPTV, file sharing (small/medium), telecommuting (ordinary), streaming music
5 Mbps – 10 Mbps	Telecommuting (converged services), file sharing (large), SD IPTV (multiple channels), High Definition (HD) video downloading, low definition telepresence, gaming (graphical), medical file sharing (basic), remote diagnosis (basic), remote education, building control & management
10 Mbps – 100 Mbps	Telemedicine, educational services, SD and HD IPTV, gaming (complex), telecommuting (high quality video), high quality telepresence, HD surveillance, smart/intelligent building control
100 Mbps – 1 Gbps	HD telemedicine, multiple educational services, gaming (immersion), remote server services for telecommuting
1 Gbps – 10 Gbps	Research applications, telepresence using uncompressed HD video streams, live event digital cinema streaming, telemedicine remote control of scientific/medical instruments, interactive remote visualization and virtual reality, movement of terabyte datasets, remote supercomputing

Adapted from California Broadband Task Force, January 2008

[4] Federal Communications Commission, *Bringing Broadband to Rural America: Report on a Rural Broadband Strategy*, Michael J. Copps, Acting Chairman, May 22, 2009.

Using history as our guide, one thing is clear—the broadband of today is not adequate as the broadband of tomorrow. Over the last 10 years, consumer demand for broadband has grown even more rapidly than most experts believed it would and there is no end in sight. Even though downstream bandwidth demand is growing at a breakneck speed, upstream bandwidth is growing even faster as user-generated content becomes more widespread.

III. WIRELESS BROADBAND CAPABILITY

Wireless broadband has become a mainstream requirement for consumers. What began with simple text messaging has grown to include Web browsing, file transfer, and streaming video. There are many ways that a wireless broadband provider can deliver a broadband connection to the customer. Each method varies in cost and quality. We begin by exploring the cellular and fixed wireless methods for deploying broadband.

A. CELLULAR AND FIXED WIRELESS BROADBAND

(TABLE 2) There have historically been two distinct groups of wireless carriers. Those that are primarily focused on serving the mobile user, which we will refer to as "cellular" carriers and those that are primarily focused on serving the stationary user, which we will refer to as "fixed" wireless carriers. Normally, fixed wireless carriers can provide greater bandwidth (or throughput) to their customers at the sacrifice of mobility. As depicted in **Figure 1**, both cellular and fixed wireless technologies are converging on what is referred to as a 4th Generation (4G) network—an all-IP network having essentially the throughputs of the fixed wireless carriers along with the mobility of a cellular carrier. There are two dominant wireless technologies that fall under the 4G umbrella today—Mobile-WiMAX and Long Term Evolution (LTE).

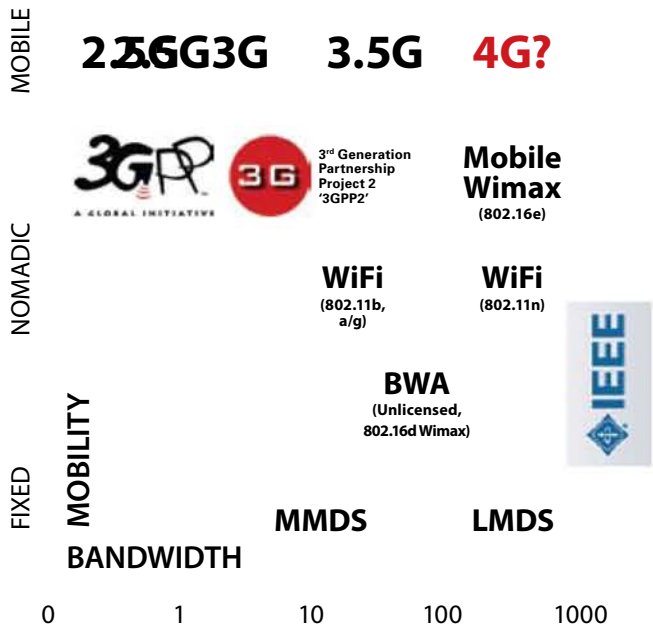

FIGURE 1: CELLULAR AND WLAN CONVERGE ON 4G

The International Telecommunication Union (ITU) has tentatively defined 4G, which it calls "IMT-Advanced," as 1Gbps capability for stationary users and 100 Mbps for mobile users—although a typical end user customer would

TABLE 2: CELLULAR AND FIXED WIRELESS BROADBAND PERFORMANCE SUMMARY

Broadband Capability	• For each wireless access point, such as a tower, the theoretical maximum is 1 Gbps for stationary users and 100 Mbps for mobile users. The bandwidth available is shared among many subscribers, and speeds are dependent upon the number of subscribers sharing the access point. Practical implementations could allow customers to burst up to 10 or 20 Mbps for short periods of time.
Latency/Delay	• Typically low latency
Other Considerations	• Since bandwidth shared among subscribers, available bandwidth per subscriber decreases as density of subscribers increases • Available bandwidth decreases as distance of subscriber from access point increases
Overall Assessment	• Bandwidth typically adequate for limited broadband access, some data, and small screen video

only realize a small fraction of this throughput. The throughput achieved by wireless technologies is dependent upon many factors, including:

- Customer distance from tower—As the distance from the tower increases, the speed of the connection decreases.
- The number of customers sharing the same connection point.
- Available spectrum bandwidth, which is normally licensed by the Federal Communications Commission (FCC)—More spectrum bandwidth means higher connection speeds.
- Frequency of spectrum—Generally, the higher the frequency the shorter the distance.
- Obstacles (trees, hills, buildings, etc.)—Obstacles attenuate wireless signals and can reduce or prohibit broadband.
- Environmental effects—Some operating frequencies are highly susceptible to attenuation due to rain, fog, or snow, which reduces the broadband speed.

Today's two "4G" technologies (Mobile-WiMAX and LTE) can achieve 2.5 bps of actual throughput per Hz of spectrum bandwidth. This means, if a carrier has 10 MHz of spectrum, they could potentially deliver 25 Mbps to their customers. However, wireless technologies share their bandwidth among many customers. For example, if 100 customers were to share 25 Mbps, each would effectively receive 250 kbps if all were using the system at the same time. New technologies are becoming available that could increase the spectral efficiency by a factor of two to four, which experts believe is the limit of spectral efficiency. 4G wireless technologies also provide DSL-like latency (on the order of one-fourth that of 3G technologies), which is also very important for making real-time IP multimedia such as gaming and interactive video possible. As these wireless throughput speeds increase, the wireless carriers increasingly rely on the high capacity fiber optic backhaul available from the wireline providers.

Wireless carriers in the United States rely on spectrum allocated by the FCC in the 700 MHz, 850 MHz (cellular), 2 GHz (PCS and AWS)[5] and 2.5 GHz (BRS/EBS) licensed bands. Many carriers have spectrum in several of these frequency bands. In order to deliver more broadband to their customers, 4G technologies will allow wireless carriers to combine the spectrum in multiple bands to effectively make them appear as a single broadband channel.

B. SATELLITE-BASED INTERNET

(TABLE 3) Satellite broadband is normally delivered to customers using geostationary satellites. Geostationary satellites orbit the earth at the same speed as the earth's rotation, so the satellites appear to be stationary above the earth. In order to do this, they are placed into orbit more than 22,000 miles above the equator. Since the wireless signal must travel so far, satellite broadband services have very high latency and typically are not suitable for the delivery of interactive multimedia services.

To decrease the latency, there have been some efforts to deploy medium and low earth orbiting satellites, where the satellites are only a few hundred miles to a few thousand miles above the earth. At these altitudes, the satellites are orbiting the earth rapidly; many satellites are required to ensure that a subscriber has a satellite in view at all times. When used for broadband delivery purposes, these

TABLE 3: GEOSTATIONARY SATELLITE BROADBAND PERFORMANCE SUMMARY

Broadband Capability	• Shared bandwidth between subscribers • Typical packages of 512kbps to 1.5Mbps for home subscribers
Latency/Delay	• High latency
Other Considerations	• Latency not suitable for interactive applications (such as voice and videoconferencing) • Can be susceptible to rain fade (outages) • Can provide data services to very remote areas that may not be feasible for wireline or other wireless technologies
Overall Assessment	• Bandwidth capacity insufficient to meet long term needs of customers • High latency limits broadband applications

[5] (PCS) Personal Communications Service and (AWS) Advanced Wireless Service – specific spectrum bands defined by the FCC

satellite systems have historically proven to be very complex and expensive to deploy and not an effective method of broadband delivery.

While advancements in satellite technology have increased the amount of bandwidth that can be delivered to customers, the bandwidth is shared among many subscribers. Like other broadband delivery systems that have a shared access network, as the number of customers increase, the available bandwidth per customer decreases.

IV. WIRELINE BROADBAND CAPABILITIES

There are several ways a wireline broadband provider can deploy a broadband connection to their customers.

A. DSL OVER TWISTED PAIR CABLE

(TABLE 4) A telephone company's core service has historically been voice service. Twisted pair copper cable was the cable of choice and telephone companies have deployed millions of miles of twisted pair copper cable in the United States since the days of Alexander Graham Bell. Digital Subscriber Line (DSL) technologies have allowed operators to deliver broadband access to their customers over the existing copper cables. Unfortunately, broadband speeds drop quickly as the length of the twisted pair copper cable is increased due to the physical characteristics of the cable. Delivering broadband over copper cable is like water in a leaky hose—as the hose gets longer, more water leaks out along the way and less water makes it to the end of the hose.

To reduce the copper cable length and increase broadband speeds, service providers have been moving their electronics closer to the customer and connecting these electronics back to the central office using fiber optic cable. **Figure 2** shows the basic network elements for a DSL deployment. As shown, DSL networks are normally divided into serving areas where the subscribers near the central office (normally within one to three miles) are served directly from the central office and the remaining subscribers are served from remote field terminals. The size of the serving area is dependent on the type of DSL technology being used and the customer bandwidth required.

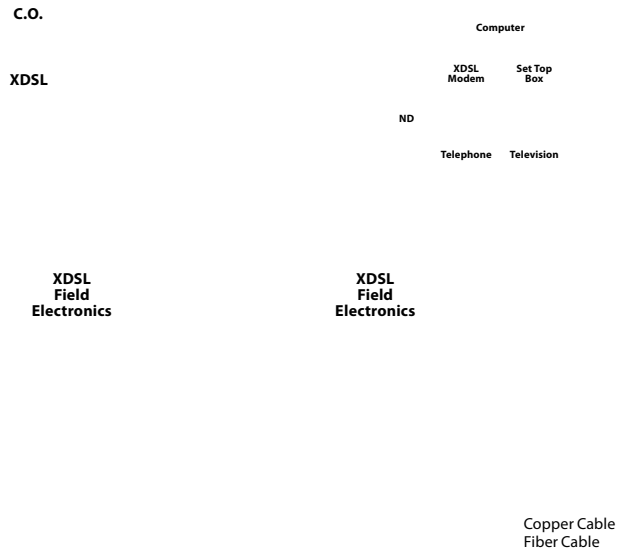

FIGURE 2: DSL NETWORK TOPOLOGY

The most common DSL technologies are Asymmetrical Digital Subscriber Line (ADSL) and Very-high-bit-rate Digital Subscriber Line (VDSL). The latest variants of these

TABLE 4: DSL OVER TWISTED PAIR BROADBAND PERFORMANCE SUMMARY

Broadband Capability	• Typically 10 to 20 Mbps for customers close to the connection point, usually more urban; could be 1 Mbps or lower for customers far from the connection point, usually more rural. • Realistic maximum: 50 Mbps over very short loops (up to 3,000 feet).
Latency/Delay	• Low latency
Other Considerations	• Attainable data rates dependent on age and quality of plant • Mature technology; few further advancements expected • Can leverage existing telco twisted pair plant • Susceptible to electrical interference
Overall Assessment	• Bandwidth capacity insufficient to meet long term customer needs

technologies are ADSL2+ and VDSL2. These technologies have been defined and standardized by the ITU-T.[6]

The latest advances in DSL have improved broadband speeds at very short copper cable lengths (less than one mile). Many rural networks are designed to have copper lengths of up to 18,000 feet. On average at these lengths, only 1 to 2 Mbps per customer is usually possible over good quality copper cable. A comparison of the data rates of the various DSL technologies is shown in **Figure 3**.

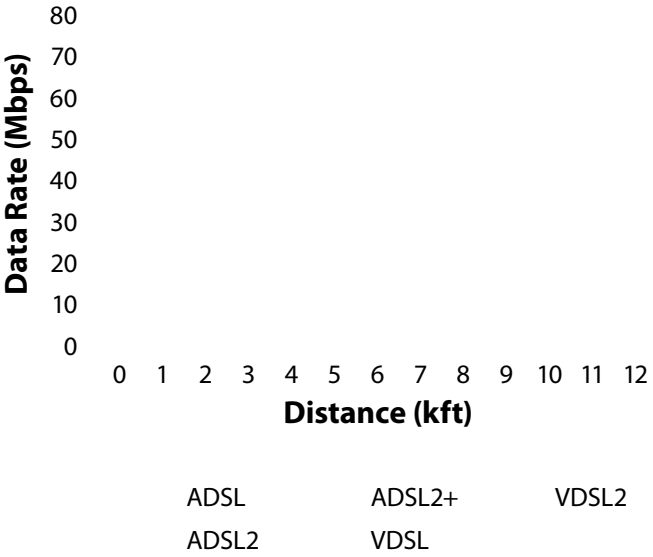

FIGURE 3: DATA RATES VS. DISTANCE

Over the past 15 years, DSL has been an effective technology for deploying broadband over existing twisted pair cable, but has been hampered by several significant limitations, such as distance, compatibility issues, the need for many field electronics, electrical interference problems, and a relatively modest broadband capability. Most service providers have realized that DSL has not been a long-term solution for broadband delivery, but it has allowed providers to deploy fiber optic cable closer to the customer and prepare for a more broadband capable network.

B. DOCSIS VIA COAX CABLE

(TABLE 5) A cable television (CATV) company's core service has historically been broadcast video. Coaxial (coax) cable was used to deliver video to their customers. The CATV industry has implemented standards called Data Over Cable Service Interface Specification (DOCSIS), which define how the coax network can be used to deliver broadband services

TABLE 5: DOCSIS OVER COAX BROADBAND PERFORMANCE SUMMARY

Broadband Capability	• Up to 160 Mbps downstream (shared among group of subscribers) with DOCSIS 3.0 • Up to 120 Mbps upstream (shared among group of subscribers) with DOCSIS 3.0
Latency/Delay	• Low latency
Other Considerations	• Increasing bandwidth requires the deployment of many fiber-fed electronics • Many systems require substantial upgrades to meet delivery requirements
Overall Assessment	• Upstream bandwidth limitations will be significant as bandwidth demands become more symmetric • Broadband capacity shared, so speeds reduce as more customers are added to the network

[6] International Telecommunication Union (ITU) – Telecommunication Standardization Sector

to customers. The capacity available on the coax cable must be allocated between video and broadband and shared by hundreds of customers that share this cable. This architecture worked well for broadcast video services, since it was a "one-to-many" service, but has limitations when delivering other services such as broadband where each customer requires a own unique connection.

DOCSIS provides the capability to give customers their own "virtual" connection across the shared coax cable by putting data on the cable at frequencies that are normally used by video channels. There are three basic methods a CATV provider can use to increase bandwidth to their customers on a coax network: 1) reduce the coax cable length to increase the available bandwidth, 2) reduce the number of customers sharing the bandwidth on each cable, and 3) implement the bonding of multiple channels together.

Figure 4 shows a modern coaxial cable system that can deliver video, high-speed data and voice services. These systems are two-way capable (downstream and upstream), and utilize fiber nodes with coax distribution to the subscriber. When used for broadcast video deployment, a fiber node can serve hundreds, or even thousands, of customers. As broadband demands increase, additional fiber nodes must be deployed closer to the customer and often serve less than 200 customers each.

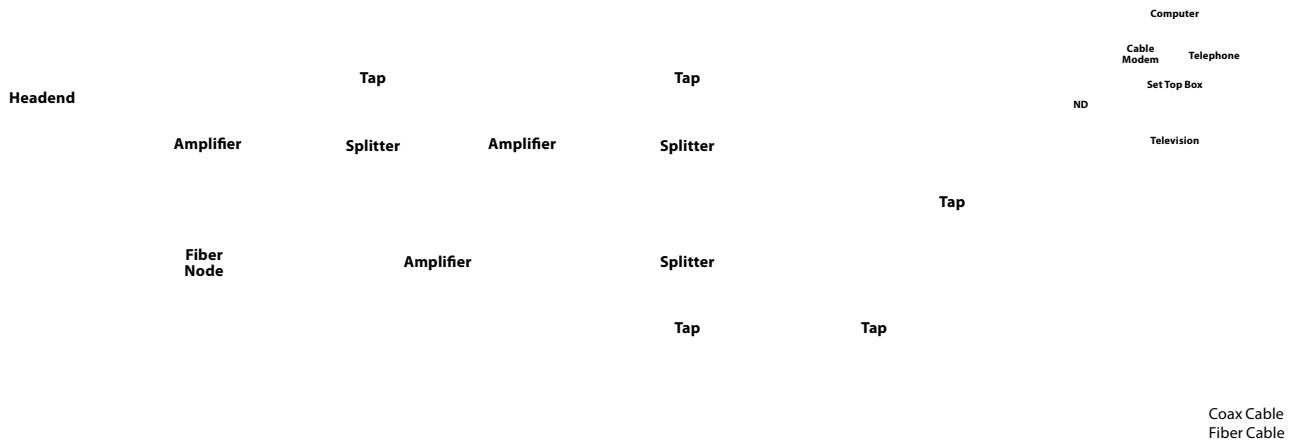

FIGURE 4: COAXIAL CABLE ACCESS NETWORK

"Building world-class broadband that connects all Americans is our generation's great infrastructure challenge."

FCC Chairman Julius Genachowski
NARUC Conference, Washington, DC
February 16, 2009

Figure 5 is a depiction of a typical coaxial cable system's channel usage. As shown, this signal on the coax cable is divided into 6 MHz segments. Analog video channels each take 6 MHz of bandwidth. As illustrated in Figure 5, a number of digital video channels can also be placed within the same bandwidth as one analog channel. The bandwidth from 0 to 54 MHz is normally reserved for upstream data (from the subscriber to the provider) and above 54 MHz is shared by video and downstream data (from the provider to the customer). It is important to note that CATV networks share bandwidth among many customers in the access network and have significant limitations in their upstream bandwidth.

FIGURE 5: CATV SPECTRUM

In a DOCSIS configuration, several hundred users share the downstream and upstream data channels. The latest version of the DOCSIS specification is version 3.0. With DOCSIS 3.0, the 6 MHz channels can be bonded together (called a bonding group) to provide up to 160Mbps downstream and 120 Mbps upstream per bonding group. All the subscribers that are assigned to that particular bonding group share this bandwidth.

C. FIBER OPTIC CABLE TO THE PREMISES

(TABLE 6) Fiber optic cable has been used by service providers for more than 30 years to build high bandwidth (high throughput) networks, primarily for long-haul transport routes. In the last decade, fiber optic cables have been used to increase bandwidth in the customer access network as well. No other technology can deliver as much bandwidth to the customer as fiber-to-the-premises (FTTP) technologies. FTTP is sometimes referred to as fiber-to-the-home (FTTH). Fiber optics has the ability to deliver greater bandwidth over a much larger distance than other technologies. In addition, the bandwidth does not decrease as the cable length increases. Each new generation of FTTP electronics allows the service provider to offer significantly more bandwidth over greater distances. There is no end in sight as to the amount of bandwidth that is possible over fiber cables. Today, there are two main competing FTTP technologies: Gigabit-capable Passive Optical Network (GPON) and Active Ethernet. Vendors are now making Wavelength Division Multiplexing Passive Optical Network (WDM-PON), which promises even greater bandwidth to the customer. Each FTTP technology will be discussed briefly below.

Most GPON implementations use optical splitters to serve up to 32 subscribers using a single fiber from the central office. GPON technology is defined by ITU standards and currently allows for 2.4 Gbps downstream and 1.2 Gbps upstream, which is shared by the 16 or 32 customers on the same PON. Under a "worst-case" scenario where all customers are

TABLE 6: FIBER BROADBAND PERFORMANCE SUMMARY

Broadband Capability	• GPON: 75 Mbps or more; 300 Mbps planned • Active Ethernet: 1 Gbps symmetrical; 10 Gbps symmetrical planned
Latency/Delay	• Low latency
Other Considerations	• Bandwidth is not limited by distance from central office • Not susceptible to electrical interference • Dramatic increases in bandwidth are possible by changing the relatively inexpensive electronics without any outside plant cable changes.
Overall Assessment	• Provides more bandwidth than other technologies; significant bandwidth increases planned

demanding maximum bandwidth, each customer could be limited to 75 Mbps downstream and 37.5 Mbps upstream—still a respectable amount of bandwidth by today's standards. Future advancements of GPON are expected to provide a four-fold increase in bandwidth (10 Gbps downstream) and be called 10GPON. A typical PON system is shown in **Figure 6**.

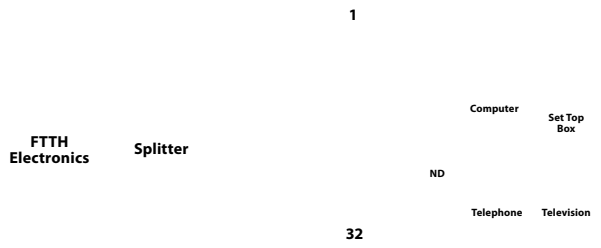

FIGURE 6: PON SYSTEM

Active Ethernet systems use a dedicated fiber between the central office and the customer, so the bandwidth consumption of one customer does not affect the amount of bandwidth available for other customers. In addition, Active Ethernet systems are symmetrical in that the downstream and upstream rates are the same. Today, most Active Ethernet systems can provide up to 1 Gbps to each subscriber—more than 10 times the bandwidth available on a GPON system. Active Ethernet has not been as widely deployed as GPON systems in the United States, since it is typically more expensive to deploy. As subscriber bandwidth demands continue to increase, Active Ethernet systems are becoming more common. A diagram showing an Active Ethernet system is shown in **Figure 7**.

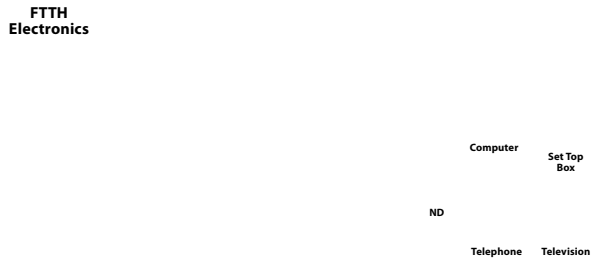

FIGURE 7: ACTIVE ETHERNET

Wavelength Division Multiplexing Passive Optical Network (WDM-PON) technologies have similarities with both GPON and Active Ethernet. Like GPON, a single fiber cable can serve multiple customers, and like Active Ethernet, each customer can have their own dedicated wavelength on the fiber. In some implementations, a small number of customers on a PON share a wavelength. Adding wavelengths on a PON network has the effect of multiplying the effective bandwidth to the customer. A WDM-PON system is depicted in **Figure 8**.

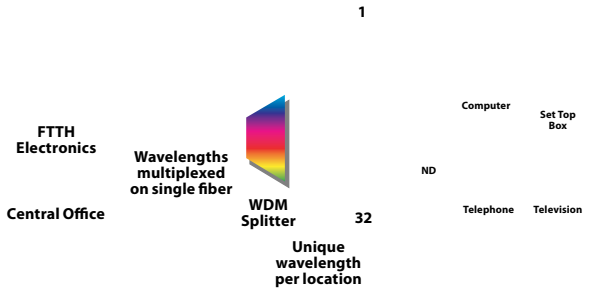

FIGURE 8: WDM-PON SYSTEM

There are currently no standards for WDM-PON. Because of the lack of standards, most vendors have not spent much time and effort in product development. Once WDM-PON is standardized and user demands increase, it may become a more popular technology for broadband deployment. WDM-PON is an example of how advancements in electronics technology can leverage an existing fiber network to provide almost limitless bandwidth potential.

V. BROADBAND DEPLOYMENT COSTS

The investment required to deploy broadband is driven by many factors. Although some of these factors are similar when comparing wireless and wireline technologies, some are very different. There are two basic measures of broadband economics:

- Broadband deployment cost per customer for a given broadband speed—This measure is useful when comparing the costs associated with different types of broadband technologies. The broadband speed assumed for the comparison is normally selected based on an established minimum broadband speed.

- Broadband deployment cost per megabit per second (Mbps) delivered to the customer—This measure is useful when determining which broadband technology is the most cost-effective to deploy. If the broadband network can easily be upgraded for more bandwidth as customer demands continue to increase, less future investment will be required.

The cost to deploy broadband can vary dramatically from one location to another. It is difficult to detail the cost of deploying broadband technology, since there are many complex factors to consider when determining the cost. We attempt to generalize the costs in the following paragraphs.

A. WIRELESS COST DRIVERS

A large portion of a wireless broadband network is the tower, tower electronics, and backhaul. Wireless broadband can be more cost effectively deployed in areas where each tower can serve a large number of customers, such as the more populated urban areas. Some of the more significant cost drivers for wireless deployments which result in increased cost include:

- Customer density
  - Low customer density—In rural areas, there are very few customers over which to spread the infrastructure costs. This results in a higher cost per customer.
  - High density—A high number of customers can overload wireless capacity and degrade service. This can be corrected through sectorization or the addition of more towers to reduce the size of the cell sites.
- Uneven terrain or obstacles—Wireless radio frequency (RF) signals used for broadband access are "line of sight." Mountains, hills, valleys, buildings, and trees interfere with the propagation of the wireless signal. These terrain issues and obstacles can mean that some customers cannot receive the broadband signal or that additional towers (and investment) are required.
- Atmospheric conditions—Temperature, time of day, humidity, and precipitation can all affect radio propagation characteristics.
- Land and right of way issues—New tower construction becomes more difficult and costly where land prices are high and where rights of way (ROW) is expensive. ROW costs increase with strict local environmental regulations, local zoning issues, protected plants or animals, or areas of historical significance.
- Frequency spectrum—Generally, more towers are required to cover an area when higher frequency bands are used. 700 MHz has a greater reach than PCS and AWS, which are located around 1,700 to 2,100 MHz. Also, the cost for spectrum acquisition can be a significant factor in the costs.

Typical material and labor costs for rural construction of a wireless infrastructure, excluding the core switching and data network, include:

- Tower (300 foot): $180K–$200K
- Land costs: $10K–$35K
- Tower electronics and antenna: $25K–$40K
- Customer premises equipment (fixed): $200–$600 per customer location

In a wireless broadband network, it is not uncommon for a tower with electronics to cost $230K to $240K. At first glance, it appears the electronics costs are small in comparison to the tower costs. However, the electronics will likely need to be replaced four or five times over a 30-year period, so with time, the electronics costs can equal or exceed the cost of the tower. In addition there are spectrum acquisition costs, backhaul costs,[7] core network costs, and interconnection costs with other carriers. Under very good conditions, a wireless broadband system may provide service up to 12 miles from the tower when using 700 MHz

[7] It should be noted that a landline fiber network will be required to provide the broadband backhaul capacity needed by the wireless network.

and normally six to eight miles when using AWS or PCS spectrum. A tower could provide service to several thousand customers in a more densely populated area, but less than 100 customers in some of the more remote rural areas.

B. WIRELINE COST DRIVERS

The largest portion of a wireline broadband network is the cable infrastructure. Wireline broadband can be more cost effectively deployed in areas where a short section of installed cable can serve a large number of customers, such as more populated urban areas. Some of the more significant cost drivers for wireline deployments, resulting in increased cost, include:

- Lower customer density—In rural areas, there are very few customers over which to spread the infrastructure costs, translating to a higher cost per customer.
- Difficult construction corridors—For buried plant, unfavorable soil conditions, such as rocks, lava flows, as well as lakes, rivers, forested areas, railroad crossings, and other challenging corridors, make construction difficult.
- Land and right of way issues—Cable construction becomes more difficult and costly where land prices are high and where ROW is expensive. ROW costs increase with strict local environmental regulations, protected plants or animals, or areas of historical significance.
- Labor and fuel costs—Cable construction is labor intensive and relies on the use and transportation of large equipment. Typically, 60%-80% of the construction costs are labor-related rather than the cable material costs.

Typical material and labor costs for rural construction of a FTTP infrastructure, excluding core network costs, include:

- Typical fiber cable construction (rural): $7k–$50k per mile or $5k–$25k per customer location
- Typical fiber cable construction (town): $10–$30 per foot or $2.5k per customer location[8]
- Central office and customer premises electronics: $500–$750 per customer location

In addition there are transport costs, switching costs, and interconnection costs with other carriers. A FTTP network is typically designed to reach customers that are up to 12 miles from the electronics, but technology exists to allow reaching customers 20 or more miles from the electronics location.

C. WIRELESS VS. WIRELINE COST OBSERVATIONS

Often, the initial capital expenditure for a wireless network is less than the capital expenditure for a FTTP network. However, it is important to note the following:

- A lion's share of the FTTP investment is the cable, which with a 30-year life, compared to the wireless infrastructure, has a greater portion of the investment associated with faster depreciating infrastructure. When replacement costs are included over a 30-year life, the cost savings for a wireless network is significantly reduced or eliminated.
- The amount of bandwidth per customer is significantly greater for a FTTP network when compared to a wireless network. Using the technologies available today, the bandwidth delivered to a customer can be more than 100 times greater than what is possible over a wireless network under similar conditions. The bandwidth advantage for FTTP will increase significantly in the coming years due to technology advances with the electronics.

[8] Town construction is normally much more expensive per foot than rural construction due to the additional expenses associated with easement and rights of way, increased labor due to placing the cable under streets and driveways, constructing around existing utilities, and the additional splicing required. Also, access to the cable is more frequent, resulting in more handholes, manholes, and pedestals.

When the costs are calculated for a 30-year period, the investment required for FTTP and a 4G wireless network are not significantly different. It should be remembered, however, that wireless and wireline broadband technologies should not be considered competing technologies as most customers will require both.

VI. CONCLUSION

(TABLE 7) World-class broadband is essential for the United States to effectively compete in the global economy. Consumers will require a landline broadband service to satisfy their high bandwidth needs, such as entertainment video, graphic intensive gaming, and cloud computing. They will also require a mobile broadband service for limited video and mobile communications including e-mail, messaging, and social networking. Because of fundamental limitations in the radio spectrum, wireless broadband has practical capacity limits and will not be able to provide enough throughput to serve the broadband needs of all consumers.

Over the next few years, the major wireless carriers will migrate their networks to 4G, at least in the more densely populated areas. One factor in determining the bandwidth available over these 4G networks is the broadband capacity of the landline carrier providing the backhaul. The 4G wireless towers require high capacity connections, typically using Ethernet delivered over a landline carrier's fiber network.

Most consumers will require both a fixed and mobile broadband connection for the unique benefits each can provide. To meet the ultra-high-speed broadband needs of their customers, landline carriers must continue to deploy fiber closer to their customers—with the ultimate goal of eliminating the copper cables from their network entirely in favor of fiber. To meet the mobile broadband needs of their customers, the wireless carriers must continue to upgrade their networks to 4G technologies. The investment on the part of the wireless and wireline carriers to achieve this will be large, but the cost of failing will be even larger.

TABLE 7: BROADBAND PERFORMANCE SUMMARY

		Twisted-Pair Copper	Coax	Fiber	4G Fixed	4G Mobile (Cellular)	Satellite
Low Speed Broadband (<1Mbps)	VoIP, basic email and simple web browsing	Excellent	Excellent	Excellent	Excellent	Excellent	Poor (latency)
Medium Speed Broadband (1Mbps to 10Mbps)	Basic telecommuting, file sharing, SD IPTV, basic interactive video, basic remote education	Very Good	Excellent	Excellent	Very Good	Good	Poor (latency and bandwidth)
High Speed Broadband (10Mbps to 100Mbps)	Telemedicine, complex remote education, high quality telecommuting, HD IPTV, advanced interactive video	Good	Good	Excellent	Poor	Poor	N/A
Ultra High Speed Broadband (> 100Mbps)	Research application, HD telepresence, virtual realities, remote supercomputing	Poor	Poor	Excellent	N/A	N/A	N/A

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