ASSOCIATION OF COMMUNICATIONS ENGINEERS

# Good Engineering Practices
# Relative to Broadband Deployment in Rural Areas

## Introduction

With the American Recovery and Reinvestment Act of 2009 (ARRA), Congress mandated that the FCC develop a National Broadband Plan "to ensure that all people of the United States have access to broadband capability." Keys to meeting this mandate in the most efficient and economical manner include maintaining the existing broadband infrastructure and deploying new broadband infrastructure in currently unserved areas. The National Broadband Plan prepared by the FCC falls short of meeting this mandate because its recommendations for accomplishing the broadband build out to unserved areas do not employ good engineering practices.

The Association of Communications Engineers (ACE) is made up of individual firms employing professional engineers dedicated to the improvement and advancement of telecommunications technologies throughout the United States. ACE member firms provide services related to telecommunications and other advanced technologies including planning, design, project management, economic analysis and construction management. For over 50 years, ACE engineers have helped companies deploy new technologies, extend services into rural areas, and provide cost effective solutions to complex problems. ACE has prepared this paper to highlight concerns about the FCC's National Broadband Plan.

## Background

Good engineering practices applicable to the deployment of telecommunications systems require sound planning and careful consideration of the overall project or system objectives, alternatives, user requirements, proposed system capabilities, available resources, restrictions or limitations, economic life cycles, public health & safety and other social impacts. This paper outlines high level engineering considerations applicable to broadband telecommunications systems, especially as they relate to the derivation of Universal Service Funds for Broadband in the United States.

1. Broadband services are becoming essential services for citizens throughout the country; especially for citizens in rural areas that do not have easy access to retailers or consumers. Reliance upon these systems is increasing, and user demand continues to expand in terms of penetration and broadband speed.

2. Broadband delivery systems must be capable of providing the needed performance (speed), quality of service, availability and reliability and must accommodate future demands.

3. "One size" does not fit all; broadband system designs must accommodate the specific needs and restrictions of the area in which they are deployed. A national financial model

is unlikely to reasonably represent the many factors that must be considered with the engineering design.

4. Technology designs should produce the best possible long term value and usefulness, avoiding foreseeable obsolescence.

Scoping

Engineering tasks take place in several steps beginning with the development of an initial idea for a product, system or activity. Engineering typically focuses on the technical aspects, as shaped by the business (financial) and marketing (user) objectives. Technical solutions tend to be bound by (1) technical feasibility, (2) available resources, and (3) time, all of which are interrelated. For broadband systems, a clear identification of the anticipated network capacity and functionality is required to support customer use over the life of the investments. Both long term and short term networking needs must be considered in the engineering plan.

The initial tasks of the engineer are to establish a set of requirements, identify possible solutions, estimate the cost and time necessary to implement the solutions, then determine if the available funding can reasonably support the technical solution and deliver the desired results within the allotted schedule. Once the fundamental requirements are established, the engineer develops the project details, addresses technical challenges, and prepares documentation necessary to implement the system.

Network designs must take into consideration current and projected network reliability and capacity requirements to meet consumer demand over the useful life of the construction project.

The Broadband Assessment Model (BAM) proposed by the FCC does not account for the iterative process essential to responsible engineering practices.

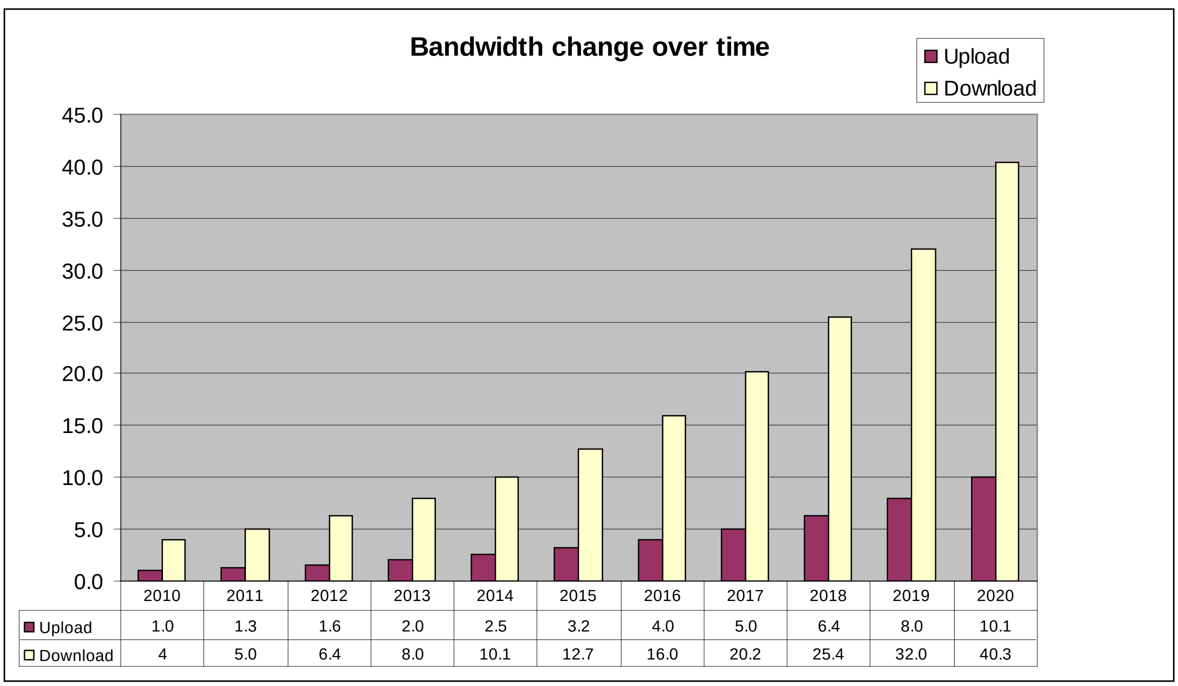
Determination of Broadband Requirements

The concept of “broadband” is relatively new. In 1999 the FCC first defined broadband as a data service with speeds of 200 Kbps in the last mile. In 2008 the definition of broadband was expanded, with a minimum downstream speed set to 768 Kbps. Round one of the broadband programs associated with the American Recovery and Reinvestment Act of 2009 (ARRA) retained this 768 Kbps downstream threshold as well as defining the upstream threshold at 200 Kbps. In the Notice of Funding Availability for Round two of the Broadband Initiatives Program, the Rural Utilities Service “… determined that rural areas without service at 5 Mbps (upstream and downstream combined) lack high speed broadband service sufficient to facilitate rural economic development as required by the Recovery Act.” Whether the service is called “broadband” or “high speed”, Americans are creating, transmitting and receiving data in increasingly large volumes, and are demanding that these data be transmitted very quickly. According to the Omnibus Broadband Initiative (OBI) Technical Paper No.1 (the OBI Report), bandwidth projections are found to be “doubling every three years”.

During the planning and design process, the engineer must anticipate user demand and ultimate system capacity. The Golden Gate Bridge carried an average of 9,000 vehicles per day when it was opened in 1937. Today an average of 120,000 vehicles make the crossing each day. The comparison is far from perfect, however the concept is clear: Systems must be planned and designed to accommodate growth.

During 2010, common engineering practices anticipate that residential end user demand will exceed download speeds of 20 Mbps, with projections reaching beyond 100 Mbps. A base calculation will include 100 – 200 Kbps for voice, 3-4 Mbps for basic internet applications, and a minimum of 8 Mbps for a single high definition broadcast video stream, resulting in a minimum 12 Mbps of download requirement. The OBI notes that other applications may include 3 Mbps for streamed standard definition classroom lecture video, or 6 Mbps for 2-way video teleconference. The National Broadband Plan notes that Smart Grid applications are expected to require between 100 Kbps and 500 Kbps. The FCC has long held that video transmission is a fundamental component of “Advanced Services”. Typical IPTV systems are designed to accommodate a minimum of 20 Mbps today, and are projected to require at least 40 Mbps with the advent and adoption of 3D TV and continued use of high-definition (HD) programming.

The National Broadband Plan notes that currently the average actual download speed in American households is 4 Mbps, and that bandwidth usage is doubling every three years, or about 25% per year. This rate of growth is charted in Figure 1, and shows that the average American home is expected to require download rates significantly higher than 4 Mbps as soon as next year. Some estimates, such as the Cisco’s Visual Networking Index, predict faster growth in the next two years, with the rate of growth slowing after 2013.




| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Upload | 1.0 | 1.3 | 1.6 | 2.0 | 2.5 | 3.2 | 4.0 | 5.0 | 6.4 | 8.0 | 10.1 |
| Download | 4 | 5.0 | 6.4 | 8.0 | 10.1 | 12.7 | 16.0 | 20.2 | 25.4 | 32.0 | 40.3 |

Figure 1: Bandwidth Growth based on “doubling every 3 years”

When considering the overall system requirements, the engineer will consider the needs of the users and the anticipated demand. If there are significant differences in user requirements from one area to another, the engineering criteria may be customized to local needs. As an example, broadband users in rural settings may have greater need for higher speeds as compared to their urban counterparts. For rural America, the economics of daily living and business include a higher cost for fuel and transportation, which translates to time and money. As examples, Telemedicine/Home Telecare, Distance Learning, public safety and remote security may have a greater impact in rural areas.

The above examples focus on residential uses. Every broadband delivery system must also serve other end-users, including businesses, schools and colleges, hospitals and medical facilities, cell sites, public safety entities, government facilities and other anchor institutions. These end-users have a wide variety of specific needs that are often greater than the typical home use. The National Broadband Plan recognized these needs by setting a goal 1 Gbps for all anchor institutions.

The National Broadband Plan specifically addresses the shortcomings of bandwidth to medical facilities, noting that a significant number of physician's offices do not have access to 4 Mbps broadband, and that this problem is seven times worse in rural areas compared to urban settings. Proper engineering practices will include identification of critical communications gaps such as Health Information Technology and will seek solutions to close these gaps.

The FCC has noted that high cost funding sources are to be used to extend broadband to "unserved" areas, defined as housing units that do not currently have access to 4 Mbps data services. For a successful program, it is essential that all parties agree on the geographic extent and details of these unserved areas. Detailed maps showing the boundaries of these unserved areas are essential to the development of a broadband system capable of serving the target areas. In the absence of official maps or reliable data, the engineer may need to conduct field research and validate available data to identify unserved areas.

Unserved areas may be very small geographic areas that have little or no usable existing infrastructure. These areas may also include difficult construction conditions resulting in high costs per subscriber. Low housing densities and/or poor economic conditions may also factor into the overall evaluation of a system to provide service in a particular area. The design of a technology solution to serve multiple small unserved pockets may be influenced by the presence of nearby systems that might be expanded to cover the unserved area. Even at a high cost per user, the extension of an existing system of any technology may be more practical and more cost effective overall than attempting to establish a small pocket of a new technology. To evaluate technology alternatives network planners must take into consideration capabilities of existing network assets e.g. fiber sub loop, use and location of existing remote terminals, availability of existing conduit, pole attachments, and location of commercial power supplies. Good planning and thorough engineering will consider all existing infrastructure and synergistic opportunities.

In summary, good engineering practices will ensure that broadband systems are designed to support future data speed requirements. Failure to anticipate these requirements may result in the construction of a system that is almost immediately obsolete, and which will require significant upgrades or possibly a complete replacement to meet these future needs.

The 4 Mbps download and 1 Mbps upload speeds proposed by the FCC for universal service fall short of reasonable network design criteria and do not align with responsible long term planning.

Technology Selection

The selection of a particular technology or delivery system may or may not be strictly driven by technical requirements. Factors that might influence this choice include existing infrastructure, interconnection with other broadband networks, local factors such as customer density and usage characteristics, local economic expansion or contraction, expertise, time to market, anticipated trends in technology development and operational costs.

Broadband delivery systems available today include a variety of wireless and wireline distribution techniques. The OBI Report describes several systems currently considered potential candidates for the provision of broadband services. The most prominent technologies described by the OBI are 4G wireless (Long Term Evolution, or LTE) and 12 kft Digital Subscriber Line (DSL). Other technologies have capabilities that may also be considered, including Fiber to the Premises (FTTP), WiMAX (wireless) and hybrid fiber-coaxial cable system (HFC).

Wireless

A major benefit to wireless distribution systems is the potential to accommodate mobility and portability. When moving from one location to another within coverage of the system, the user can access and deliver information with ease. In the case of medical care, an ambulance may be remotely connected to a hospital or trauma center and transmit critical patient information with the hospital or specialists at the scene of an accident and while in transit. As part of the technology selection, the engineer must identify which wireless systems support mobility, and which do not. As an example, a system designed for fixed wireless access may not support mobility.

Good engineering practices will consider the ultimate capacity of a wireless system in a real-world environment. Wireless technology will have a different value proposition, and may not be a good long term solution compared to fiber or fiber and copper based on bandwidth projections and rural engineering economics.

Wireless signals are limited by a variety of factors, such as the signal-to-noise ratio (SNR) available at the receiver. Depending on the frequency used, a line-of-sight or near-line-of-sight path may be required on a wireless link. Terrain, foliage and buildings are three significant obstacles for any wireless system to overcome. For short distances at low frequencies, 700 MHz will have the greatest success in non-line-of-sight applications. The OBI describes such 4G systems as operating at 700 MHz with cell radius distances of 2, 3, 5 or 8 miles, depending on terrain.

In a typical cellular network configuration, multiple sectors provide coverage in different directions from the base station. Depending on the system design, the same frequency may be used by adjacent sectors or by adjacent cells. An operator may need to implement one or more techniques to minimize interference between sectors and cells. Interference is a major contributor to the "noise" factor described above. When neighboring cells are operated by different companies, the options to control interference may be limited.

In any implementation, low signal to noise ratios will first degrade the throughput, lowering the speed ("bandwidth") available to the end user, and if the SNR drops below a certain threshold, the link will become unusable. For LTE, sophisticated modeling and operations management are necessary to predict and adapt to these conditions.

Small cell radii, such as the 2 to 8 mile distances noted above, are necessary to deliver an adequate SNR to the area subscribers. At greater distances, potential users are unable to obtain the desired upload and download speeds. A radio signal at 700 MHz, even though unusable (as designed), will propagate for many miles beyond the defined cell radius. It is common for faint 700 MHz signals to extend well beyond 35 miles from their point of origin. Signals reaching beyond the desired cell radius are considered noise in the analysis and operation of a system, and may significantly degrade the performance of neighboring systems.

Every wireless system experiences a decrease of signal strength with greater distances from the cell site, and an increase in noise. The result is a decrease of SNR, and a corresponding decrease in effective throughput. For example, CDMA systems capable of delivering more than 2 Mbps near the cell site are found to commonly deliver user speeds of only 300 to 800 Kbps.

The actual usable bandwidth capabilities of wireless systems are dependent on many factors, including the signal to noise ratio described above. Estimates of usable bandwidths at speeds of 10, 20 or even 80 Mbps have not been supported in real-world deployments. Practical download speeds with wireless systems appear to be in the 8-10 Mbps range for close proximity to the cell site. A system designed for a throughput of 4 Mbps at the edge of the cell will have limited ability to meet the expanding demands of the typical consumer. High bandwidth internet applications such as medical imaging and file transfer will strain the network. In addition, a single stream of standard definition video will strain the network and a single high-definition video stream will exhaust this 4 Mbps capacity. As the speed requirements for many existing and new applications continue to increase, key data components of the wireless network would require great leaps in technology. Wireless might be an attractive choice compared to fiber or fiber/copper if capacity or consumer use in a local area is not expected to scale quickly or increase by any significant amount over time.

Realities of real world terrain conditions and natural and manmade obstructions vary greatly with the earth's geological features. Good engineering practices require the use of propagation prediction studies and detailed analysis of predicted signal strengths as well as interference from both internal sources (self-interference) and external sources (neighbors). Frequency coordination is a mandatory function of wireless design and deployment.

Another challenge with some wireless solutions is the lack of "real world" testing. For example, LTE systems are in the very early stages of deployment. As a result, there is not a sufficient bank of data available to validate its modeling or speed projections. As a result, techniques needed to optimize the performance of the LTE systems are still being developed by the operators and the users. While a few large carriers are able to invest in large scale systems, smaller operators have limited options to purchase, test and deploy LTE base station equipment.

There are few, if any LTE user devices such as hand held computers or plug-in adapters available for purchase in the US market. Only after commercial deployments by major operators are completed will concerns about the technical viability of these systems be answered by real world test data and urban end-user experiences. While manufacturers will eventually make equipment available to smaller operators, actual cost of the infrastructure and user devices in a rural setting can only be estimated. Today equipment pricing can only be based on the pricing leverage and economies of scale enjoyed by large operators.

WiMAX base stations and CPE are commercially available, and represent a viable short-term technology choice for some operators. Engineers and planners should be aware that the capabilities of this technology may quickly be overshadowed and possibly rendered obsolete by the predicted wide scale use of LTE

Another significant concern is the lack of available spectrum. The OBI Report accurately notes that "no U.S. service provider currently has more than 2x10MHz of contiguous spectrum in the 700MHz band.", while acknowledging that Verizon Wireless and AT&T have significant spectrum holdings. The high costs and lack of access to spectrum is a major hindrance to rural operators who might otherwise consider the use of 4G wireless technologies. Even if new spectrum is released in the near future, the lag time between release of spectrum and availability of low-cost, mass produced equipment will delay usability of such spectrum for many years to come.

Technology changes or upgrades for wireless systems are often forced upon the provider with the incremental technology developments in data speed, coupled with the consumer's move to the fastest speeds available with each new handset replacement. A responsible engineer will anticipate significant advancements beyond the initial technology.

The FCC's Omnibus Broadband Initiative and the Broadband Assessment Model oversimplify the challenges of deploying a stable, reliable and effective wireless system, and make significant assumptions about the as-yet unproven LTE technology.

<u>Wireline</u>

The "value proposition" for wireline systems is the potential to deliver large amounts of bandwidth to a specific location. Wireline systems include all technologies based on the placement of a physical cable between the operators' central location and the customer's premises. This section focuses on 12 kft DSL and Fiber-To-The-Premises (FTTP). Other technologies such as hybrid-fiber-coax may have comparable capabilities, and may be the best choice for specific operators.

12 kft DSL is described by the OBI as Asynchronous Digital Subscriber Line "2+" (ADSL 2+) deployed with a maximum loop lengths of 12,000 ft. ADSL 2+ technology, based on the International Telecommunications Union (ITU) G.992.5 Standard is mature and widely deployed, although typically with l8,000 ft. or longer loops. To convert a system from an 18 kft design to a 12 kft design, the engineer must re-evaluate the size and location of all copper cables in the serving area, and identify new locations for the remote electronic equipment. In a theoretical wire center with the central office at the center of an 18 kft circle, a minimum of 4

new remote cabinets, each with a reach of 12 kft, would be required to replace the original electronics. Each of these remotes would need a high capacity circuit back to the central office. This high capacity link might be accomplished with bonded copper pairs, but most likely would require the construction of new fiber cable to each remote cabinet. Most exchanges have non-ideal geometries, and the number of new remote cabinets would need to be designed for each existing DSL serving area based on these unique local conditions.

The engineer should carefully consider future bandwidth expansion requirements before deploying a 12 kft DSL system, as a requirement to increase system capacity from 4 Mbps to 6 Mbps or 8 Mbps would require another complete redesign effort, purchase of new remote cabinets, and the construction of additional fiber.

FTTP designs currently encompass two major architecture design concepts: Gigabit Passive Optic Networks (GPON) and Active Optic networks. With GPON system, the optical signal is passively split between many users, usually with a maximum ratio of 64:1. In order to maximize each subscriber's bandwidth, many operators do not exceed a 32:1 split. GPON can deliver speeds of 2.4 Gbps on the downlink and 1.2 Gbps on the uplink to be shared by either 32 or 64 subscribers at distances of at least 12 miles, depending on the splitters used. Next Generation XPON networks are expected to increase the available bandwidth to 280 Mbps per user. Compared to active systems, GPON systems require lower fiber counts, and may require fewer miles of new construction in a particular serving area. With an active solution, each user has a direct fiber connection, which enables a much higher ultimate bandwidth capability than GPON. Speeds in excess of 1 Gbps are possible with active networks today. With careful design, OSP facilities may be flexible enough to accommodate either an active solution or a PON solution, or to be migrated from PON to active in the future. Standard engineering practices will consider the fact that the fiber investment will likely be a 20 to 30 year investment while the electronics are a 5-7 year investment.

The engineer should be mindful that demand for copper cable had decreased, and the costs of manufacturing copper cable have increased. As a result, installation of fiber cable is generally a less expensive option compared to copper cable.

The FCC underestimates or ignores the new construction that will be necessary to convert to or deploy a 12 kft Digital Subscriber Loop solution, and does not consider the short economic life span of this bandwidth limited technology.

## Backhaul

For any broadband distribution system, the overall planning and design must include consideration of backhaul, or the "second mile" between the distribution electronics and the central facility. All of the distribution systems described above (12 kft DSL, LTE or WiMAX, FTTH) require a high capacity link in this second mile. The two most common techniques include construction of fiber or microwave links.

Fiber construction for the second mile involves the same techniques, challenges and risks of a FTTP system. Fiber systems can be implemented as "protected" with an appropriate choice of electronics for failover switching. The capacity of a fiber backhaul is usually limited only by the capabilities of the terminal electronics.

Microwave backhaul systems may utilize licensed or unlicensed frequencies, and may or may not be protected. Often a protected terminal includes all of the components of a non-protected terminal, resulting in twice the cost. In congested areas it may be difficult or impossible to obtain licensed spectrum, and the unlicensed spectrum may be affected by interference. More rural areas will have fewer challenges related to spectrum. Microwave antennas may require significant loading capabilities for the tower or support structure, depending on the size and quantity of antennas proposed at a location. Each microwave backhaul link must be individually engineered to ensure that the line of sight is clear and to make sure the system will perform properly in all seasons and all weather conditions. Systems operating on longer links at higher frequencies (18 and 23 GHz and higher) may be significantly affected by weather.

Microwave backhaul is more common with wireless systems as the same tower that is used for the LTE (or WiMAX) antennas might be used for the microwave dish. However, with the backhaul bandwidth requirements required by LTE systems (requiring up to Gigabit bandwidths), fiber backhaul is often the optimal choice. Microwave is less commonly used for FTTP and DSL systems due to the fact that it is more likely that new towers may be required for the microwave antennas.

Interconnections and interoperability with neighboring networks or transiting systems must also be considered when planning network routes and capacity requirements.

The FCC’s model does not allow for the multiple real-world challenges of designing efficient and reliable backhaul systems.

<u>Restrictions and Limitation Considerations</u>

As part of the planning and implementation of a broadband system, the engineer must account for “real-world” restrictions and limitation of all types. For wireline systems, these include varying soil conditions, local depth requirements, significant physical or geographic barriers (rivers, railroads, interstates), local planning & zoning restrictions, considerations of planned growth, access to easements or rights of way (or lack thereof), etc.

Good engineering practices include the consideration of alternatives, which may include the use of various routes, techniques or technologies. For example, railroad and interstate crossings tend to be very expensive due to the extra safety precautions and other unique requirements that must be considered. The use of aerial construction along some wireline routes may be a more economical choice compared to buried techniques in areas where buried cables have tight corridors or are expensive to construct. A more expensive choice of utilizing flexible duct as opposed to directly burying a cable may be prudent in congested areas where dig-ins are likely, or where multiple buried utilities are present. Similarly, a longer route may be preferable to a shorter route along busy highways or interstates, to avoid a greater risk to workers and passing drivers both during construction and subsequent maintenance.

Construction costs in rural areas differ greatly and conditions could vary widely within the same serving territory. In some areas, rural construction is relatively inexpensive (cable plow with minimal directional boring). In others, it is expensive (rocky areas requiring rock saw or congested corridors). There is no "ubiquitous" set of rural construction costs that apply to every situation.

During the design of a wireless system, local Planning and Zoning requirements may be imposed, including height restrictions, masking or hiding antennas, landscaping, etc. These types of special accommodations often result in delays and significantly increased costs. Often existing towers are found to be inadequate due to limitation of structure loading, ground space, height, or specific location. The owner of an existing tower is not obligated to lease space, and may withhold permission either for competitive reasons or in an effort to obtain higher rental fees. Terrain conditions and natural and manmade obstructions vary greatly from location to location, often changing significantly over a distance of just a few hundred feet. Two towers in close proximity may yield very different coverage characteristics.

When considering the implementation of a fixed wireless system, the engineer will consider the challenges of using directional antennas for customer locations. These types of antennas are often used where an indoor unit is not capable of receiving a usable signal. Typically a directional antenna will be installed on the outside of a building or on a pole or tower, usually by the service provider. Costs for installing a fixed wireless system at the customer premises are often greater than the cost of the electronics, and may significantly affect the economic viability of a network deployment.

The Broadband Assessment Model proposed by the FCC cannot anticipate and resolve the multiple challenges and complications faced by operators and engineers on a daily basis, let alone track these challenges as they evolve over time.

<u>Example Technology Comparison - FTTP vs. 12K DSL or LTE</u>

Engineers should test assumptions when considering a technology choice. As an example, a 12 kft DSL system may be more expensive than a FTTP design in thinly populated rural areas along roads that radiate away from a population center. With loaded copper plant, the loops may extend out to 20 miles or more. Consider a road, 20 miles in length, leaving a community and generally following the bottom of a river valley. For such a case, the road is not straight but instead follows the twists and turns of the valley. It is common for farms and ranches to be located along the road and in the valley, with a few located in the higher ground on spurs from the main road. To generalize the design parameters, assume that the node electronics for both 12 kft DSL and LTE are spaced 4 miles apart to allow a reach of 2 miles in each direction.

The minimum number of nodes necessary to serve this area is 5, with the first located 2 miles out of town, and the others at 6, 10, 14 and 18 miles respectively. The "second mile" fiber necessary to support all five nodes will require 18 miles of fiber construction. The incremental cost to extend fiber to each home along the roadway is minimal as the fiber drop needs only be extended from the nearest point on the road to the home. Homes located on the higher ground, off "spur" roads will require varying amounts of construction, depending on the exact geography. In a carefully designed system, it may be possible to provide broadband to these "spur" homes with DSL technologies, however there is no known wireless implementation that will economically extend from a backbone to serve one or two homes. Costs to serve these homes are clearly higher than a comparable number of homes located in a densely populated area such as a town.

The cost to serve this same area with a 12 kft DSL design would presumably be lower due to re-use of existing copper drop cables; however the DSL network would have a limited bandwidth expansion capability.

The cost to serve this same area with an LTE design would presumably be lower if the cost of installing fiber drop cables exceeded the cost of installing Fixed Wireless Access CPE equipment. In many real-world examples, towers will not exist at the necessary strategic locations, and even if they did, intervening terrain will likely affect the coverage capability of the towers.

The broad assumptions included in the FCC's Broadband Assessment Module do not allow for local conditions or special considerations which may drive up the cost for all possible solutions.

## Engineering Economics

Proper engineering practices require the engineer to ensure that engineering economic principals are considered and reviewed with the finance, operations and marketing resources for any project. Each component of the system will have a different economic life expectancy. Most electronic systems have an economic life of about 7 years. Some highly evolving products, such as personal computers and wireless handsets, have a turn-over of 2-3 years. Other, more stable technologies may reasonably be expected to function for 10 to 13 years, depending on the useful life of the equipment. The assets with the longest economic lives are cable plant and towers, which may be useful for 30 years or longer. It is reasonable to assume a lifespan of over 20 years for fiber and towers. If an economic study is to consider the value of a system over a 20 year period, a good economic model will account for the replacement of electronics at least twice during this period (once every 7 years). Mobile wireless systems have experienced a particularly robust evolution, moving from analog cell phones to "2$^{nd}$ generation" digital in 1996, 2-1/2 G (text messaging and e-mail) in 2000, 3 G (web browsing and picture messaging) in 2005 and 4G in 2009. With roughly four years between generational advances and no end in sight, it is reasonable to anticipate that the emerging 4G LTE systems will be replaced within 7 years.

Ideally the design of broadband systems could be simplified to a pre-defined process, even modeled by a set of standardized equations to identify least cost solutions. Preliminary estimates of a project cost may be based on relatively simple mathematics, as an example. The practicing engineer recognizes that such an approach can only be applied to an accurate, consistent and repeatable data set. During the design process, the engineer will consider the whole set of unique requirements and limitations applicable to a specific service area. As more variables are introduced to a model, the likelihood and magnitude of an error increases dramatically. The National Broadband Plan refers to a highly sophisticated and complex analytical model for estimating construction and operating costs for broadband systems, to be applied across the nation. Application of a generic financial model may result in a project budget that limits the ability of the engineer to implement a system capable of delivering the desired broadband services to the targeted service area. In addition, the application of a generic financial model may result in a more expensive solution because the modeled solution was under-designed and reached the end of its useful life before reaching the end of its economic life.

## Environmental Considerations

Rural network constructions must consider the cost and delays associated with special studies required to secure construction permits to address issues with all types of systems. In particular, the National Environmental Protection Act criteria must be addressed. These include a site-specific examination of the potential impact to endangered species, culturally sensitive areas, historic impacts, wetlands, state or federal ownership, tribal or Native American needs, and social impacts of construction activities. As part of the engineering process, the engineer will incorporate the requirements for these entities into the overall project analysis.

## Conclusion

The application of good engineering practices result in the best long term use of available capital, provide the operator with the maximum opportunity to accomplish the intended goals, and target the available technologies to the specific needs of the customer base and/or general public. The examples cited in this paper illustrate the difficulty of applying a single set of criteria nationwide, and emphasize the evaluation of local user needs, local restrictions and limitations as well as the alternatives available with the various technology options. The Broadband Assessment Model cannot anticipate or predict the real world deployment challenges faced by engineers and service providers in the provision of broadband services to all the people of the United States. As a whole, the National Broadband Plan underestimates the bandwidth needed in rural areas, and overlooks the realities and complexities of creating sound designs and sustainable, usable broadband systems.

Respectfully Submitted;

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