Preface

This series of reports, entitled *Strategic Technology Infrastructure for Regional Competitiveness in the Network Economy* and packaged in eleven Volumes, is the culmination of a dedicated effort of the following individuals and organizations. Each Volume can be viewed as a stand-alone publication; however, it should be noted that each Volume was written in the context of the overall project. The project utilized the Southside and Southwest Virginia regions as a model for a low-cost Geodesic Mesh network design and viable financial model that could be replicated in any region of the U.S.

Volumes

1) Rationale, Environment, and Strategic Considerations
2) Connecting the Regional Infrastructure to National and International Networks
3) A Fiber Optic Infrastructure Design for Southside and Southwest Virginia
4) Fiber Optic Infrastructure Design Guide
5) Financial Feasibility and Investment Rationale
6) Leveraging Advanced Optical and Ethernet Technologies
7) Speculative and Alternative Technologies
8) Community, Applications and Services
9) Demographics for Southside and Southwest Virginia
10) Health Information Technology and Infrastructure
11) Education in the 21st Century
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Alternative Technologies

Consumers in the U.S. pay quite a bit more for broadband than most consumers in other industrialized countries. Japan currently has almost the same broadband usage as the United States and is expected to soon surpass the U.S. This is impressive if we consider that only two years ago, the US was using broadband at 20 times the rate of the Japanese. Also, it is important to realize that broadband in the U.S. is much more expensive than in other parts of the world, even Canada. The typical U.S. broadband user pays about $40 to $50 per month while consumers in Japan and South Korea, for example, pay on the order of $28 which is low for Japan considering its high cost of living. Furthermore, a recent report indicates that 9 out of 10 businesses with more than 100 workers are within less than 1 mile from high speed networks, but do not have access. Methods to bring broadband to these businesses need to be developed.

It is already clear that dial up modems, which can carry no more than 50 kilobits per second, are inadequate for almost all on-line applications. It is also questionable whether the speeds at which DSL and cable modems operate (several hundred kilobits per second) will be sufficient for future applications, like video on demand for example. To remain competitive with the rest of the world, the US needs to make sure it continues to roll out broadband. As is evidenced by Bill Gates’ statement in 1981: “Nobody will ever need more than 640K of RAM” (in 1996, Windows 95 required at least 8000K of RAM to operate), it is difficult to predict the future. In terms of future broadband usage, it is unlikely that hundreds of kilobits per second will be sufficient. It actually is much more likely that true broadband will have to be on the order of multiple megabits to gigabits per second. In fact, the National Academy/National Research Council Committee on Optical Science and Engineering (COSE) report states: “The Terabit/s era for information technology …includes the need for cost-effective networks of virtually unlimited bandwidth with local area networks operating at tens of gigabits per second.”

This discussion is organized into two main parts. The first part discusses a number of first mile alternatives such as free space optics, data transmission over power lines and a number of wireless alternatives. The second part covers a number of unique fiber deployment methods that include fiber deployment in sewers, gas pipes and roadways.
The economic rationale for considering these fiber deployment technologies is discussed as well. The objective for both parts is not to address all the different technologies available for bridging the last mile, but rather to provide an overview of some of the technologies that are being developed.

**Last Mile Alternatives**

In this section we identify and provide a brief overview of some of the technologies that are receiving a lot of attention in the press and popular publications. Some of these technologies can be defined as “speculative” since they have not yet demonstrated the same kind of reliability, quality of service and robustness as incumbent proven technologies. Technologies that are discussed include for example free space optics, broadband over power lines and a number of wireless technologies that have shown some promise. Some of these technologies have been successfully deployed and may be suitable for certain applications. Others may have to overcome technological hurdles or may still face significant regulatory constraints.

Due to a number of factors, in the short term it is unlikely that one technology will be the dominant option and in the long run a combination of a number of technologies depending on the nature of the applications will be suitable for bringing broadband to the end user. Factors that affect which technologies get deployed include both demographic and population density aspects, physical and environmental conditions, available investment capital, and previously installed technology base. The goal of this section is not to make recommendations on which technologies are superior, but rather to make the reader aware of the kinds of options that are available. It is also not intended to cover all existing technologies but rather to highlight a number of technologies. In the case of 802.11b technology, also known as Wi-Fi, security issues as well as new developments with regard to some regulations that may impact this industry are addressed.

As this section will show, even though a number of alternative technologies exist to connect businesses and homes to the Internet, fiber optics technology is the only technology available today that is truly “future proof.”
Free Space Optics (FSO)

Free Space Optics was first used in the 1980s for secure ship-to-ship communications and for communications between ground and aircraft. Other defense type applications included ground-to-satellite and satellite-to-satellite communications. In these applications, long ranges on the order of 50 to 100 kilometers were achieved, but this required very high power lasers and highly complex tracking systems. Furthermore, the power levels required for these systems definitely were not eye-safe. It is these military uses that have led to the significant activity for developing free space optics for commercial applications. According to the Strategis Group in Washington DC, revenues from sale of FSO equipment are expected to grow from $120M in 2000 to over $2B in 2005.

FSO, basically fiber optic communications without the fiber, allows for two-way line-of-sight data transmission using infrared lasers at rates on the order of tens of megabits to several gigabits per second or more. FSO networks can significantly reduce the amount of time it takes to deploy a network, because the time required to get permits and do the actual work is minimal. Besides time savings, there may also be significant direct and indirect cost savings. The digging up of roads, which can be disruptive, unsightly, expensive, and can result in significant traffic congestion, can be avoided. Specifically, depending on the amount of construction required, FSO installations may cost 1/3 to 1/10 of the cost of deploying underground fiber.

Semiconductor lasers can be modulated at rates up to 10 Gbit/sec. Cost-effective LEDs can be modulated at data rates on the order of 100 Mbits/sec. The speed at which the FSO unit operates in part depends on the detector surface area. For faster data rates, detectors with very little surface area are required. Of course as the detector size shrinks, it becomes much more complex and expensive to obtain the required alignment. Equipment cost for FSO units is expected to decline rapidly as more cost effective laser diodes are implemented. Additionally, as modulation techniques and signal to noise ratios are improved, low power lasers, with power levels on the order of 10 to 100 mW for 100 to 500 meter distance can be implemented. To increase data rates for FSO systems even further, wavelength division multiplexing (WDM) technologies can also be used. These technologies are analogous to those used with optical fiber. Units are
currently available at costs ranging from $1000 for 10 megabits per second or $20,000 and higher for 1 gigabit per second units.

Environmental conditions do affect FSO communications. Surprisingly, however, rain and snow do not have a major impact at distances less than 500 meters. Thick fog, on the other hand, does severely affect the system’s performance. Furthermore, the signal is severely attenuated by dust particles and clouds. To determine the maximum distance that the units can be placed, it is important to determine what level of reliability is required. For businesses, for example, 99.9999% reliability may be required, whereas for residential uses, 99.9% reliability may be acceptable. To increase the effective distance or to expand on the coverage area, just as with other wireless technologies, mesh-type topologies can be implemented.

Additionally, it is important to note that when this equipment is used on tall buildings, active tracking may have to be used to compensate for building sway making the unit considerably more expensive. Still it is important to keep in mind that such active tracking units have been tested for many years for use in naval and satellite applications.

Even though much improvement has been made with FSO equipment, there still exists quite a bit of room for improvement in the design and deployment of FSO equipment. Moreover, standards need to be established for this technology. Progress on implementing standards and for bringing awareness to the public is made by the Free Space Optical Alliance.³, ⁴

Applications for FSO include last mile access initially for businesses, but eventually also for residential applications, cellular backhaul, enterprise connectivity, network deployment or service acceleration and as a backup alternative for other incumbent communication systems. An example of the implementation of a back up communication system is the installation of FSO units in New York City after the attacks on the World Trade Center in 2001. FSO units from Terabeam, operating at 1.55 micrometers and transmitting at rates up to 1 gigabit per second were used to establish new communications links between buildings.
FSO developers include well funded companies such as Airfiber, Lightpointe, Terabeam and others. A comprehensive list of companies that offer FSO products can be found on the Free Space Optical Alliance website.

Finally, a word on safety. When working with lasers, eye safety is always a concern. Most FSO systems are designed to be eye-safe or are setup to avoid the eyes. FSO systems used, for example, for building-to-building communications typically use low power lasers that are safe for the eyes or can be placed in such a way that eye exposure is avoided.

**Power Lines**

Since electric power lines are more prevalent than phone lines and even more prevalent than cable, using them for transmitting data would be ideal. Unfortunately, while quite a few companies have tried to develop products that can deliver broadband over power lines, none have been very successful. These companies include well known names like Nortel, Alcatel and Siemens. Because transmitting data over high voltage power lines has been quite problematic, Main.net Communications, an Israeli firm, transmits data over the lower voltage power lines that are closer to the end customer and are less susceptible to electrical noise and other types of noise external to the power line. The specific technology Main.net uses to transmit data is similar to a technology called code division multiple access (CDMA) modulation that is heavily used in the wireless industry. This technology even allows Main.net to avoid having to circumvent the power transformers. Main.net’s competitors at this point are not using this technology and have to circumvent the transformers. Unfortunately, just like with optical fiber networks, data transmitted over power lines needs to be “repeated” before the signal becomes too weak or too noisy (the signal is basically, captured and then retransmitted). Unlike for fiber optics, however, the distance between regenerators is rather short.

The German power grid is laid out differently from the U.S. In Germany, unlike in the U.S. where it serves only about ten homes, each transformer serves as many as 200 homes, making the regeneration of data at the transformer much more cost-effective. Also, in the US the distances to the homes are also much larger, necessitating more signal regeneration units and again making this technology more expensive. Finally, like
other broadband technologies, bandwidth will have to be shared with neighbors, which can result in much slower data rates.

Main.net Communications is currently delivering data over power lines at 500 kilobits per second to more than 10,000 homes in Europe. Service started in Mannheim, Germany in 2001 and is now also provided in Sweden and the Netherlands. Small pilot studies are also underway by AEP in Ohio, Consolidated Edison in New York and other cities. These studies, however, are still very limited to anywhere between 3 and 250 homes. It is estimated that approximately 500 homes in the US use power lines for data communications.

As was mentioned previously, the largest cost and most significant roadblock associated with data transmission over power lines lies in bypassing the transformers that down convert from a high voltage to the voltage level that is used in homes and the regeneration of the signal after it travels a certain distance. In the United States, on average each transformer serves about ten homes. There are, however, quite a few companies looking for ways of solving these problems, but it is not clear how long it will take for reliable and cost-effective data transmission over power lines. If cost issues can be resolved and data rates increased, perhaps the power industry can eventually also be a provider of video and voice.

**LMDS and 802.11b (Wi-Fi)**

A number of wireless communication systems, ranging from radio waves to traditional UHF and VHF broadcast systems, exist that can be used to transfer data. This section will discuss local multi-point distribution system (LMDS) and 802.11 b Wi-Fi wireless technologies. These wireless methods are constantly improving as companies, and in the case of Wi-Fi, users find improved ways to configure them.

**LMDS**

Local Multi-Point Distribution System (LMDS) is a wireless technology used to deliver voice or data services in the 25 GHz and higher spectrum. In the United States, 1.3 MHz of bandwidth (27.5 B 28.35 GHz, 29.1 B 29.25 GHz, 31.075 B 31.225 GHz, 31 B
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31.075 GHz, and 31.225 B 31.3 GHz) has been allocated for LMDS to deliver broadband services in a point-to-point or point-to-multipoint configuration to residential and commercial customers.7

Like FSO, LMDS is typically much faster and less expensive to deploy than wire line infrastructure. LMDS systems usually consist of a fiber optic backbone, base stations, and customer premise equipment (CPE). The base station consists of modulation and demodulation equipment, a connection to the fiber network, broadcasting and receiving equipment, and sometimes switching equipment. The CPE equipment varies widely based on the service provider. This equipment typically involves outdoor mounted microwave equipment and indoor digital equipment. The CPE may attach to the network using time-division multiple access (TDMA), frequency-division multiple access (FDMA), or code-division multiple access (CDMA) methodologies. The customer premises interfaces will run the full range from digital signal, level 0 (DS–0), plain old telephone service (POTS), 10BaseT, unstructured DS–1, structured DS–1, frame relay, ATM25, serial ATM over T1, DS–3, OC–3, and OC–1.8 When large amounts of bandwidth are required, typically FDMA is used to guarantee always-on bandwidth.

A weakness of the LMDS system is that rain can lead to depolarization of the signal resulting in signal attenuation. Additionally, just like for FSO systems, LMDS systems are line-of-sight systems capable of operating at distances anywhere from 2 to over 8 miles apart.9 Typical topologies used for LMDS as was described above are either point-to-point or point-to-multipoint. Mesh type topologies, however can be implemented to increase the coverage area.10 An additional strength for LMDS is that high symmetrical bandwidths on the order of multi-megabits per second are possible.

Wi-Fi (802.11 b)

802.11 is a family of specifications for wireless LAN’s developed by the IEEE. These standards consist of 802.11, 802.11a, 802.11b, 802.11b+, and 802.11g. Wi-Fi is a nickname for the 802.11b standard which is a short range wireless Internet technology that uses radio waves to transfer data. Wi-Fi uses an unlicensed spectrum for its transmissions. For Wi-Fi technology to work as a last mile alternative, there must be near-line-of-sight between the antenna for the network and the tower that is
broadcasting the signal from the backbone or another user. There can be a line of trees between the antenna and the tower but not much more than that.

A common way to increase coverage where line of sight is not possible or economically feasible is to use a mesh network. A mesh network uses individual computers and network antennas as node points that not only communicate directly with the tower, but also with other computers and networks. The advantages of using a mesh network are simply that a site that does not have a line of sight with a tower can still use the network by communicating with another site that does have a line of sight. The disadvantage of using a mesh type of network, however, is that the bandwidth drops as more users join a node. Instead of using a mesh type network to increase WiFi’s reach, “PacketSteering” technology was developed by Vivato that allows for narrow formed beams to send and receive information distances from many tens of meters to as far as several kilometers. A certain degree of line-of-sight is required, but alignment requirements are not as stringent as for LMDS and FSO.

Another weakness of Wi-Fi is that the 802.11 frequency spectrum is unlicensed which could lead to significant interference from other equipment operating at the same frequency, for example, some cordless telephones or other electronics operating over those frequencies. Furthermore, transmission distances, unless a beam steering technology as the one described by Vivato is used, are quite limited. The main advantage of Wi-Fi is that it is widely used, provides symmetric bandwidth, is cost-effective and easy to install. It is also fairly easy to deploy a mesh network to get around obstacles or to increase the effective coverage area, but it is important to realize that bandwidth decreases rapidly as the mesh network expands.

There are, however, limitations in this technology and the implementation of it. For starters, the distance covered by Wi-Fi is typically short range. This leads to a Wi-Fi subscriber only having access in certain hotspots or locations close enough to an access point. Furthermore, 802.11 uses the 2.4 GHz frequency to broadcast; this frequency is unlicensed. This means, as was mentioned before, that the 802.11 networks are subject to interference by other equipment. For this reason, if a wireless LAN was to be setup in a high traffic area, airport, classroom, conference, etc. 802.11a, or g would be better
choices since they have more channels and more bandwidth and fewer interfering technologies.

**Security Issues for Wi-Fi**

There are a number of security issues concerning Wi-Fi networks. The first issue is simply that wireless networks are networks that are no longer confined to cables. For a wireless network to work, it has to broadcast its presence in every direction so that authorized clients can join the network. Unfortunately, that means that anyone in the range of the broadcast now has the information they need to gain unauthorized access into the network. The second security issue facing wireless networks is the ease of implementation. Wireless access points and cards will connect right out of the box, and today’s operating systems equipped with plug and play will install and activate these devices by themselves. Furthermore the widespread adoption of wireless LAN equipment has caused the price to be very affordable. Today a wireless access point can be purchased for a mere $80 and a wireless NIC $40. These features make wireless networks extremely easy to implement. This in itself is not a security concern; it is the end users who implement them without administrative permissions or knowledge. Almost anyone can simply purchase an access point and connect it to a WLAN in many cases. This becomes a problem when either the users are not authorized to be connected to the network, or if they are authorized they simply do not know how to enforce the security policies. It has been shown that most WLANs using 802.11 technology have not enabled any of the security features. Most people have no idea about Internet security; so by implementing a “rogue” access point, they compromise the whole network. It has been shown that the majority of WLANs do not have many, if any, modifications to the default settings of the products. This means that these networks are not limiting access, and anyone with a card can simply walk into a network’s range and have access. This can lead to unauthorized users taking up much needed bandwidth, and also taking part in practices that may be illegal or against your ISP’s policy. Furthermore, theft of access is a major concern and has been for many hot spot service providers. WLANs have limited bandwidth potential, typically 11MB/s for 802.11b, and 54MB/s for 802.11a, and g. The actual realized bandwidth is usually around half that rate due to the session ID, control packets, addressing, etc. Furthermore, with the use of CSMA CA and CSMA CD as a protocol, the bandwidth is further limited. This leaves the network very susceptible to a denial of service (DOS) attack. Another very real
security risk for these networks is Media Access Control (MAC) address spoofing. A MAC address is used to identify a client on a wireless network. This same address is usually used to authenticate if that user has rights to access the network. Since, as discussed above the broadcasts between computers is easily intercepted by simple proximity these MAC addresses can be seen by unauthorized users. The unauthorized user then simply adopts the MAC address of an authorized user and has access to the network; this is called spoofing. Without some type of authentication by each user, this type of attack is a severe vulnerability. Attackers can also pretend to be an access point because nothing in 802.11 requires an access point to prove its identity. Once they accomplish faking an access point they can use a “middle man” to launch their attack.

Eavesdropping is a very real problem with WLANs and security. With some security measures in place, many packets are still sent “in the clear” for anyone within range to decipher. Some cryptographic solutions will solve this issue. Lastly, wireless networks are typically extensions of wired networks. If a hacker gets into the wireless network, it will be easy for him/her to continue into the wired network since they are connected.

Wireless networks are an option when conventional cabling is too expensive. However, using the 802.11 networks will present one with some potential obstacles as discussed above. The administrator of the network must be very security-conscious, and the network should be actively monitored for a breech. 802.11 networks can be a solution when the distances covered are not too large and the number of users per access point is kept low.

Wireless regulatory issues

The military is seeking technical restrictions on the use of some wireless technologies because it feels that some of these technologies may interfere with military radar installations. The Defense Department claims that low-power emissions could interfere with up to ten different kinds of radar systems operated by the US military. This threat is serious enough that representatives from both Intel and Microsoft met with Defense Department officials to stop this proposal. The Pentagon even went so far as to present its position at the international technology meeting in Geneva of the World Radio Conference - the international organization that oversees the allocation and standards of radio frequencies. Additionally, the military wants to stop Congress from introducing a
bill sponsored by, among others, Senator George Allen of Virginia, to expand the radio frequency spectrum available for wireless use.

What the military proposes according to some executives may require the redesign of communication systems already in operation or in final stages of development. For example, this could affect Intel’s plan to put Wi-Fi technology on all of its microprocessor chips it manufactures. This may also affect how broadcasters and cellular companies implement new technologies that more efficiently use the spectrum.

A solution to this problem could be a technology that uses frequency sharing techniques to prevent civilians from interfering with military radar systems by automatically yielding to military spectrum right of way. A system that is already successfully being used in Europe.

**Broadband over fiber**

On average, local phone companies replace three to four percent of their twisted-pair lines annually because of deterioration. Additionally, 1.5 million lines are deployed annually to newly constructed homes. The phone companies, however, are not taking advantage of the opportunity of replacing twisted-pair phone lines with optical fiber.14

Cable providers are aggressively competing for customers by first providing television service and then with cable modem service. A logical next step would be to provide voice service as well. As a final step, cable providers will also start to provide high definition television. Still, it will be a while before cable modem service will become available to rural communities. A significant opportunity exists for taking the initiative of replacing twisted-pair phone lines with fiber and to bring fiber to each new home constructed.

There are a number of reasons to consider deploying optical fiber rather than copper. Even though fiber requires a larger upfront investment, the lifetime costs for fiber are already less than for copper based systems. Attenuation (loss) for fiber is several orders of magnitude less than any other broadband technology, thereby significantly reducing the need for expensive signal regeneration equipment and/or amplifiers. Regulatory
restrictions placed on fiber optic equipment also are far less strict than regulations placed on copper based and wireless technologies. Furthermore, fiber is transparent with regard to data formats and data rates; therefore, to increase bandwidth the fiber does not have to be replaced, just the terminal equipment. Finally, the cost of terminal equipment for fiber based systems is also decreasing drastically, for example, the cost of passive optical splitters dropped from $100 per port to $25 per port in less than one year. Paul Green, Director of Optical Networking Technology at Tellabs, makes the following statement: “The future seems clear. The only questions are: how far off is it, and to whom will it belong?”

There are a number of fiber installation methods available. For example, fiber can be rapidly installed in the pavement after machines cut narrow grooves in pavement. Specialty trenching machines can install conduit (or fiber directly) one to two feet underground. Additionally, remotely controlled robots can extend the path of conduit or fiber under driveways, highways, and in one case 2km under the Hudson River. Fiber is not usually deployed immediately, but later blown through conduits using compressed air. This allows for the possibility of adding more fiber without the need for digging new trenches. The next section discusses a number of fiber deployment methods that can be considered when making fiber to the home or curb (FTTH or FTTC) a reality.

**Fiber Deployment Methods**

All wireline technologies have costs associated with access to rights of way and costs related to labor. The last mile, the section that connects the end-user’s premise to the overall broadband network, typically requires extensive construction and can include having to dig up roads resulting in traffic jams and roads that appear damaged. While terminal equipment costs are dropping rapidly as a function of production volumes and significant improvements in their performance, the deployment cost of the actual fiber typically is still very high. Opportunities do exist for reducing the cost of fiber deployment, particularly in the case of optical fiber cable that can be blown through conduit at a later time. The purpose of this section is to identify a number of unique fiber deployment methods that can be considered. This section will first discuss the economics of deploying optical fiber including time for construction, as well as the cost
for laying fiber as a percentage of the total cost of deploying the network and lighting of the network.

Morgan Stanley released an industry review report on next generation networks that provides an excellent overview of the economics of deploying an optical fiber network. The report discusses the time it takes to build a network from acquisition through actual construction, the cost of deploying the optical fiber for the network and finally the cost of lighting the network. In this section, we highlight some of their findings and will use those findings to point out some interesting fiber deployment strategies. Since the report is more than a year old, we will not discuss the dollar figures for deploying the fiber network, but will instead illustrate network deployment cost as a percentage of overall cost, i.e. all costs including lighting the network.

Rights of Way (ROW) play a very important part in determining how long it takes to get network construction underway. Having ROW issues resolved early greatly reduces the amount of time it takes to get started with network construction and can also greatly affect how much it will cost to deploy the network. Carriers that already have ROW issues resolved can save six to nine months over competitors who have to negotiate individually with each agency to build their network. This can be a tremendous advantage, and some of the opportunities on collocating fiber cable with other utilities or in some cases to deploy cable inside, for example, sewer or gas pipes may be significant.

Fiber can be deployed above ground using aerial stranding or underground via pipeline, trench digging, via directional boring or in sewers. While aerial stranding may be more cost-effective from an installation perspective, the maintenance costs will be much more significant than other methods. This is mainly due to its exposure to the environment and to the more stringent utility maintenance regulations.

Carriers typically deploy conduit and later blow or “jet” fiber cable through the conduit. Typically, depending on the application, one of three kinds of conduit are used; single, multiple or micro conduit. Unless high fiber counts are deployed, it is usually best to deploy multiple conduits so that it is easier to increase the number of deployed fibers at a future date. Carriers like MetroMedia Fiber Networks laid single conduits in metro
regions but the conduits contained 800-plus fiber counts. Other carriers such as Qwest are deploying three or more conduits – using one initially and reserving the others for future use. The multiple conduit approach provides for the greatest flexibility. Additionally, since the cost to deploy more conduits is relatively small compared to the overall deployment cost, it makes sense to deploy additional conduits especially when it is difficult to predict future demand. Instead of being forced to use coarse or dense wavelength division multiplexing (WDM) technology, the financial trade off of deploying more fiber can then be made.

Instead of blowing fiber cable, groups of fiber can be propelled in groups of 2, 4, 8 or 12 fiber strands through smaller tubes in special conduit. Instead of the typical conduit mentioned above, a conduit containing small tubes is deployed. Fiber strand bundles are subsequently jetted through the tubes at distances up to 3 km. The advantages to this method are the ability to defer the cost of adding additional fibers until they are really needed; as well as to blow out damaged fiber to replace it with new. This method is ideal for deploying fiber pairs for first mile applications. This technology, by Emtelle in Scotland, was recently selected for use in the LENOWISCO Rural Area Network in Southwest Virginia.

Sewers and gas pipe lines can have very low ROW costs for fiber deployment, but both methods are not yet fully standardized by the industry. Collocating next to highways can be cost-effective, and road availability is extensive and is especially beneficial since roadways are plentiful and provide good coverage throughout a region. Disruption of traffic, however, can be a big concern for some localities. The following several discussions consider fiber deployment opportunities in sewers, gas pipes and directly in the road. Of course, as was mentioned previously, fiber does not have to be deployed immediately, but can be pulled or blown at a later date.

**Sewers**

In Japan, optical fiber was originally deployed in sewers to create advanced sewer management systems. The excess fibers were then leased to telecom providers which created excellent revenue generating opportunities for the municipalities and a cost-effective installation method for the telecom companies. Significant additional
deployments of fiber in sewers have been done in Europe and Asia. In the U.S. with more than 2,000,000 kilometers of underground sewers, opportunities for deploying fiber in sewer lines are significant.

To deploy optical fiber in a sewer system, computer driven cylindrical robots equipped with cameras deploy steel rings and steel conduit that is used to keep the fiber cable in place. These robots can be as small as 6 inches in diameter or smaller. Conventional optical fiber cables are jetted into the conduits from the street level using air pressure, although the cable can also be deployed using the pulling method. The robot can be used to map the sewer system too, so no maps need to be available for this to work. Fiber can be deployed in sewers by either drilling a hole in the top of the sewer and installing the cable using an anchor or via an adhesive bond system, or via stainless steel rings that are used to clamp and hold the fiber cable in place. Additionally, cables also can be deployed in sewer liners, an approach that is also referred to as the pipe-in-pipe approach that permanently seals the fiber optic cables (or the conduit) in place along the sewer wall.\textsuperscript{18} The fiber cable can be made to be rodent and chemically-resistant and will typically work under any type of sewer condition. Cables with fiber counts on the order of one thousand can be deployed in sewers as well as storm drains.

The following are a few of the companies that provide robotic and other types of technology that can be used to deploy optical fiber cables in sewer pipes: Cablerunner; Ka-Te; Nippon Hume; Robotics Cabling GmbH Kabelverlegung (RCC); CA-Botics; Alcatel, France; and Stream Intelligent Networks Corp. (STAR). The speed at which fiber can be deployed in sewers can also be quite significant. For example, the STAR system being used in Canada can lay 800 meters of fiber cable per day compared with about 100 meters of using conventional methods.

\textbf{Gas Pipelines}

In the U.S. more than 50\% of the houses use utility gas as heating fuel. In fact, over one million kilometers of gas lines have been deployed in the U.S.. Electricity, oil and bottled gas respectively account for 30, 9 and 6.5\% of home heating fuel. Natural gas as a fuel source has grown steadily since World War II with the building of an extensive pipeline infrastructure. By 1960 it was already the leading fuel source for homes, mostly
because of its many uses. It can be used to power a number of appliances such as stoves, ovens, washers, dryers, etc. Furthermore, gas has the added benefit that it is less price sensitive than oil on international shortages and war because most of the supply originates from the United States or Canada. It is expected that both natural gas and electricity will continue to dominate the home heating market for the next two decades.\footnote{17}

Fiber is deployed in gas lines by “tapping” the line with a special fitting. This fitting is then welded to the main line. The conduit is deployed in the gas line and typically takes up approximately 10% of the pipe’s cross-sectional area. Once the conduit is in place, the fiber can be deployed very quickly. Specifically, up to 1500 feet of cable with as many as 472 individual strands of fiber or more can be blown at a time.

Currently, in the Dallas, Ft. Worth area, Sempra Fiber Links is working with the gas utilities to deploy optical fiber. Current estimates indicate that the cost of deploying fiber in gas lines is significantly less than conventional systems. Other companies have equipment that allows for the deployment of fiber in gas pipe lines, including Alcatel. Just like the deployment of optical fiber in sewers, installing fiber cable in gas pipes does not require additional trenching or cutting of roads or sidewalks.

It makes sense to consider leasing space in these gas lines or sewers for the deployment of optical fiber cables. Owners of the utilities can generate another revenue stream and telecommunication providers can save significantly on fiber deployment costs. There is, however, a need to ensure that effective standards are developed.\footnote{18} Issues with regard to standards are being addressed by ASTM and excellent articles dealing with the deployment of optical fibers are written by Dr. Jey Jeyapalan.\footnote{18} For example, Jeyapalan points out that if proper standards of care are not practiced, the fees received by the utility companies will not be enough to offset the cost of repairing the sewer. The concerns expressed by the committee members are provided in his article.

**Embedded in roads**

Technologies developed by Coming allow for the direct deployment of optical fiber cable in the road by cutting the surface and immediately embedding the fiber cable. Relatively
large fiber counts (several hundred) are possible and the speed of deployment is quite fast. Alcatel for example also has equipment that allows fiber to be buried in the road and is able to lay fiber at 2000 meters per hour. At these rates of deployment there is very little disruption to traffic. A moving worksite is about 300 meters long and about 2 meters wide. According to some figures, fiber can be deployed in the road at a cost savings of up to 75% over conventional fiber deployment. Significant savings are possible also because some ROW issues can be avoided. Corning has successfully deployed fiber using this method in Germany and other countries in Europe. Even if the concern for fiber breakage is high, if the network has sufficient redundancy, network outages can be significantly minimized or avoided.

**Collocation of fiber**

Finally, fiber can also be deployed next to highways, gas and water pipe lines, sewers and power lines etc. Significant opportunities exist in being ready to co-locate conduit when new utilities are deployed. Not only is money saved on trenching, but ROW costs are also significantly reduced.
Quick Reference to Frequently Asked Questions

1) Why is it difficult for an established telecommunications company to make this investment? (Volume 1, Volume 5)

2) There is already too much fiber in the ground. Why not use what’s there? (Volume 1, Volume 2, Volume 6)

3) The principal design criterion driving the development of this infrastructure is that every user has the potential to be a “producer” in the network economy. Is this the same as “broadband”, as it is currently hyped in the industry? (Volume 1)

4) Can we quantify the potential jobs that will be created if a region invests in building advanced telecommunications infrastructure? (Volume 1)

5) What should be the Tobacco Commission’s role in the deployment of first mile technologies? (Volume 1, Volume 3, Volume 5, Volume 7, Volume 8)

6) How can localities ensure that they get early access to the network? (Volume 1, Volume 5, Volume 8)

7) What kind of success have other regions had with the development of network infrastructure for economic development? (Volume 1)

8) What regulatory factors should be considered when investing in wireless technologies? (Volume 1, Volume 7)

9) Why do we need to connect to network points outside of the tobacco regions? (Volume 2)

10) Once the network is in place, what do we do with it? (Volume 2, Volume 8)

11) Since the business model for inter-regional and inter-county infrastructure did not include the use of conduit facilitating blown fiber strands, what are the circumstances in which this technology is appropriate and financially feasible? (Volume 3, Volume 7)

12) How do existing community networks fit into the overall design? (Volume 3, Volume 5, Volume 6)

13) What are some examples for deployment in the first/last mile? (Volume 3, Volume 7)

14) What type of fiber is recommended? (Volume 3)

15) What would a network design for my county look like? (Volume 3)
16) How much would all this cost? (Volume 3, Volume 5)

17) What is the appropriate organization model for managing and sustaining the Tobacco Commission’s investment in critical technology infrastructure? (Volume 5)

18) Tobacco region communities are underserved because the private sector does not see a profitable business case. What makes this feasible from a business perspective? (Volume 5)

19) If the traditional investment model for developing critical technology infrastructure has failed, what is the alternative? (Volume 5)

20) How much would it cost for consumers in the region to use the network? (Volume 5)

21) What technologies enable use of the fiber? (Volume 6)

22) How does the choice of technology to light the fiber impact the cost? (Volume 6)

23) How do wireless technologies fit into this framework? (Volume 7)

24) What is meant by the term “open access”? (Volume 8)

25) What is the difference between the broadband hype and the “next generation” networks? (Volume 8)

26) What are some next generation Internet (NGI) applications? (Volume 8)
References


3 http://www.wcai.com/fsoalliance/


7 http://www.iec.org/online/tutorials/lmds

8 http://www.iec.org/online/tutorials/lmds/topic01.html?Next.x=40&Next.y=19

9 http://www.iec.org/online/tutorials/lmds/topic06.html?Next.x=34&Next.y=21

10 http://currentissue.telephonyonline.com/ar/telecom_lmds_gets_mesh/

11 http://www.mywisecounty.com/pdf_files/Wi-Fi3.PDF

12 http://www.businesswire.com/cgi-bin/f_headline.cgi?bw.121602/223500131


