The Pipe Is There:
Using Existing Infrastructure To Speed FTTH Deployment

North American water, gas, sewer and electric utilities should be getting into the fiber network business, as they are in Europe. Here's why.

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The very governmental, commercial, and residential end users who are craving true broadband already have sanitary sewers, storm drains, drinking water pipes, and natural gas lines reaching their premises. They also have roads and electrical conduits. Fiber can be housed in these utilities, after forming creative business partnerships among optical fiber owners, service providers, utility pipe owners, and vendors. These underground pipes start in the vicinity of the current local fiber POPs (points of presence) in existing metro loops or backbones and finish inside the very buildings where the users are.

Fiber could also be installed in micro road cuts and microducts. Municipalities and energy companies could even take the lead from "pure" telecommunications companies, given that they already own and manage most of these underground assets for the public.

It makes all the sense in the world to locate the first mile of fiber in these existing rights of way. There are a number of FTTH projects underway nationwide and additional communities have undertaken feasibility studies on FTTH deployments. Many of the techniques reported in this paper could be used to lower the overall cost of FTTH deployments while cutting the construction time substantially.

This article details the potential and shows the way to get the job done.

Advantages for Traditional Utilities

Kennedy[1] asserts that the traditional, non-communications utilities are better positioned to solve the first mile problem than any other players due to the fact that they have the ability and incentive to invest in a high-capital cost, low-return access network.

In fact, there are numerous challenges for anyone other than local utilities or incumbent carriers to build the first mile:

- Local municipalities control access to much-needed rights of way.
- They charge franchise fees, make the permit process really difficult, and pass numerous ordinances to discourage open-cut construction of fiber and even impose network build moratoriums.
- Some even demand free fiber, where the network provider will lose even its existing revenue from the very municipalities, while requiring that the network builder pass on to them a portion of the gross revenue from the remaining fiber.

Often, the areas where municipalities are willing to let fiber construction proceed are not where demand is and even in these, municipalities enforce strict time limits. The ILECs already have backbone fiber infrastructure in place in most locations and only fiber laterals, easy using existing utility corridors, are needed to bridge the first mile anyway.

Building owners also erect hurdles such as entrance fees and connection

Type	Miles	Km
Sanitary sewers	800,000	1,280,000
Storm drains	450,000	720,000
Combined sewers	100,000	160,000
Potable water lines	850,000	1,360,000
Natural gas lines	1,125,000	1,800,000
Petroleum pipelines	300,000	480,000
Irrigation pipelines	200,000	320,000
Industrial waste lines	550,000	880,000
Total	**4,375,000**	**7,000,000**

Table 1. Underground utilities in America; there are lots of opportunities to run fiber.

fees. The overall regulatory environment has not given competitive local exchange carriers (CLECs) the legal teeth they need to compete more aggressively in the marketplace against the ILECs. The result is a mere 10 percent penetration by CLECs in the local access market even after a decade operating in the aftermath of the Telecom Act of 1996.

Also, first mile conduit design and installation has been in the hands of mostly telecom personnel, with little or no input from civil engineers, resulting mostly in expensive and laborious implementation. If adequate civil engineering talent were involved in approaching the municipalities for access for rights of way on behalf of fiber installers, given that so many municipal public works departments are managed by civil engineers, matters would have preceded much faster.

Other countries have similar underground pipe networks.

Using them for fiber also would afford us an opportunity to monitor the security of these underground lifelines. It would also provide us an opportunity to operate treatment plants, compressors, pumps, and other equipment unmanned from remote unknown locations, for better homeland security measures. Additional details on the win-win solutions from the business plans involving optical fiber deployment in existing sewers and gas pipes have been discussed in more detail in many of my articles.[2]

There are a number of cities around the world that have used existing utility pipes for building their broadband networks while serving their originally intended functions. Table 2 provides a partial list.

It appears the needs of FTTH, renovation of aging pipeline infrastructure, and improved sensing and surveillance could all be accomplished by municipalities taking the lead to build the first mile with suitable partners in existing pipeline infrastructure.[3]

Possible Business Plans

Using existing pipe networks for deploying first mile fiber could be done with any of the following business plans:

Plan 1: The fiber builder will either purchase or lease existing retired pipelines that are no longer in active service, in exchange for either an upfront payment or an annuity-like payment to the owner of this strategic asset. Pacific Gas and Electric, KeySpan Energy, Con Edison, Atlanta Gas, and Peco Energy are examples of utilities using this business model.

Plan 2: The fiber builder will make the pipe owner a business partner, where reserve capacity in the existing pipe network could be used by the fiber builder for installing first mile fiber in exchange for a negotiated percentage of the gross revenue. The cities of Albuquerque and Indianapolis are examples this business model.

Plan 3: The owner of the existing pipeline network will take network providers, content providers, and vendors as partners to install fiber in their pipes and operate this network. Other than the few strands needed by the pipe owner for its needs, the rest would be leased to any number of the above partners for additional revenue to the pipe owner, where the cost of the fiber buildout will be borne primarily by the pipe owner. The city of Berlin is an example of this.

Plan 4: In this plan, some elements of the above three plans will be combined toward optimum results for all parties concerned. The author is aware of several entities in the middle of active negotiations to reach many forms of business partnerships to deploy first mile or FTTH fiber and the results will be reported at a later time.

Plan 5: In this plan, the pipe owner builds and owns the fiber network. Tokyo, Hamburg, Vienna, Boston, Dublin, New York, and Los Angeles are examples.

Table 2. Broadband networks already using underground utilities worldwide (sewers unless otherwise noted).

City	How Long?
Tokyo	850 km
Vienna	400 km
Taipei	400 km in gas lines
Hamburg	100 km
Berlin	50 km
Yokohama	42 km
Kawasaki	37 km
Ogaki	24 km
Sapporo	21 km
Nagoya	18 km
Kyoto	18 km
Minami	13 km
Yodogawa	11 km
Albuquerque	9 km
Osaka	6 km
Toronto	5 km
Hmeji	5 km
Akashi	5 km
Indianapolis	5 km
Hanau	5 km
Tokushima	4 km
Dublin	3 km
Munich	3 km
Amsterdam	2 km
Copenhagen	2 km
Madrid	1 km
Boston	1 km

This Idea Has Been Around Since 1983

Using existing conduits for multiple purposes is not a new concept. Early attempts were tried in Paris more than 100 years ago but poor results led to abandonment of the concept of installing multiple utilities in the same underground tunnels. There also were a number of projects in America about 80 years ago where telephone companies were permitted to lay their cables inside of drinking water supply lines.

The idea of using existing fluid conduits for additional functions not originally intended emerged again in 1983 when I worked on the design of two high pressure hydropower penstocks 2144 mm (84 inches) in diameter, to hang from the roofs of 6.4 m (21 ft) diameter outlet tunnels at the Jennings Randolph and Gathright dams in West Virginia and Virginia.[4]

The technical issues involved in using existing pipelines for housing optical cables are rather minor compared to what we coped with in 1983 and we have progressed in our civil engineering know-how on many fronts in the past 20 years. These large penstocks were designed in 304L stainless steel to survive the area's acidic water with a pH of 3 or less, flowing through the outlet tunnels.

Optical Fiber in Japanese Sewers

Shortly thereafter, the first invention for using existing sewers for installing communication cables was developed by a group of engineers from the Water Research Center (WRc) in the UK.[5]

A patent on the technology was issued by the UK in May 1984. The US patent (4,647,251) was secured in March 1987; the assignee was Cabletime Installations Limited operating out of Washington, DC.[6]

For reasons unknown even to the current employees of WRc, this patent was allowed to expire due to nonpayment of annual dues after WRc attempted to commercialize this invention for some years.

There is a good chance that … liner companies will succeed if they are able to offer value-added relining systems for an attractive incremental fee to city sewer agencies over the standard lining systems without cutting too much into the current functions of the sewers.

The Japanese assembled a robot in 1987, following an art somewhat similar to that disclosed in the UK invention, to install optical fibers initially in Tokyo sewers,[7] and the Japanese applied for European, Japanese, Korean, and US patents.

The US patent, 4,822,211, was issued in 1989 to protect the robot; Nippon Hume, Tokyo Metro Government, and Tokyo Metro Sewer Service Corporation were co-assignees.[8] The primary reason for the Japanese engineers to install optical fiber in their sewers in Tokyo in 1987 was to control sewage treatment plants remotely without having to employ live humans at each of these locations.

The Tokyo Metro Government and Tokyo Metro Sewer Service Corporation promoted this concept. Subsequently, the Japanese engineers formed the Japan Sewer Optical Fiber Technological Association and promoted this technology for additional functions. JSOFTA was instrumental in changing the Japanese public law in 1996 for the sewer owners to permit materials other than sewage in their sewer system. That paved the way for a wider deployment of fiber in the sewers. Tokyo Metro alone has more than 850 km of fiber in its sewers, with about 140 km installed by these robots, more than any other city in the world. According to Nippon Hume, the original robots could be either self-driven or operated by winches.

Given that most of the sewers in Japan are made of centrifugally cast reinforced concrete pipe, drilling into the pipe wall required a significant amount of power through the umbilical cable supplying water, air, electricity, and communication circuits to the robot. According to Nippon Hume, when the Tokyo Metro discovered that it was better to conserve power for drilling, self-driven robots were not the preferred option.

Nippon Hume began to widely promote this robot system for sewer sizes 200 to 1200 mm. Recently, the Japanese Ministry of Construction has also publicized its goal of building 100,000 km of optical fiber networks in existing sewers all over Japan by 2010 to promote the national goal of a "Multi-Media Society."

Berlin Using Nippon Hume Robots

BerliKomm, owned by Berlin Water, had an ambitious plan in 1997 to provide each customer in Berlin with a broadband connection within 30 days of asking. Berlin Water turned to three Japanese robots sold by Nippon Hume, initially by setting up a new company named Robotic Cabling GmbH Kabelverlegung (RCC) owned with Marubeni and Nippon Hume. It installed about 1500 meters of optical fibers in its own combined sewers in Berlin in the winter of 1998. The Japanese robot was steered by a control unit but was pulled using winches through the manholes.

A special drill was used to cut a hole 6 mm in diameter and 15 mm deep for the J-hook anchor of the cable. A two-part resin system hardens in the hole after activating a plunger pin deployed once the optical fiber cable is placed in the J-hook.

According to Beyer[9] and Nippon Hume[10] Berlin water returned two second-generation robots back to Nippon Hume, but kept the third unit, a first-generation model. A change from the version of the Japanese robots Berlin used is that the three units assembled in Berlin could propel themselves once inside the sewers, in a way no different from the ro-

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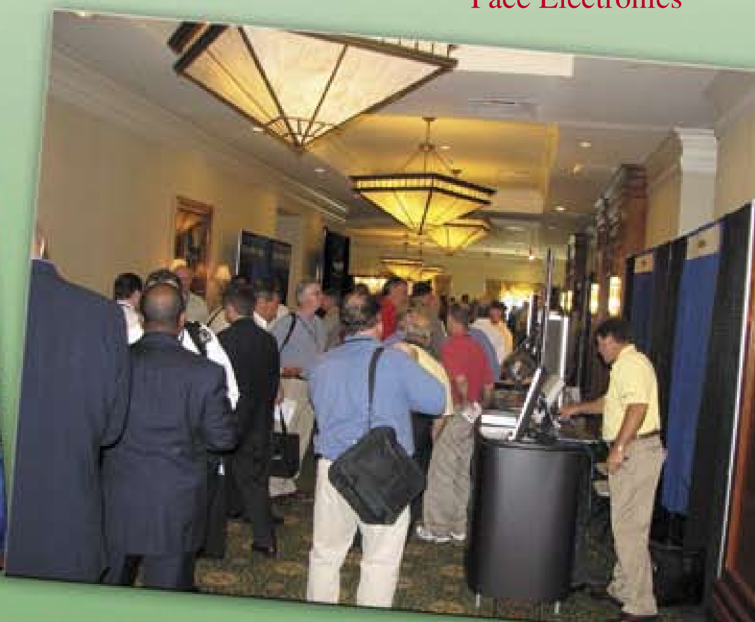

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bots Japanese had in their first generation for Tokyo Metro, installing the cable at high speeds under optimal conditions.[11]

Man-Entry Technology

Man-entry sewers are those with a diameter larger than 700 mm (28 inches). Some 90 percent of sewer lengths in North America are smaller. What's more, the larger sewers usually lie on the outskirts of major cities, where the demand for first mile fiber is rare. This implies that the market for man-entry technology is rather small in North America at this time.

Many methods could be used for putting fiber into sewers once humans can enter them. For fixing expansion anchors, a hole must be drilled into the sewer wall, which would pose no major structural problems as long as there is adequate wall thickness, as there is in sewers with larger than 800mm diameter and above. The cables can then be added in the future as demand for the fiber count increases. This technology has been in use for some years. In Tokyo alone, there is over 700 km of such fiber installations in man-entry sized sewers. And in Vienna, there is over 400 km of man-entry fiber laid using CableRunner.

More Ways for Fiber in Sewers

CableRunner uses a drill and dowel system in sewers 250 to 700 mm wide. DTI-CableCat uses either a back-reamed anchor or an adhesive bed system in sewers 200 to 1200 mm, while Nippon Hume and RCC use drill-and-dowel systems for the same sized sewers.

In addition, there are liner systems vying to do some of this as part of routine sewer maintenance programs. There is a good chance that these liner companies will succeed if they are able to offer value-added relining systems for an attractive incremental fee to city sewer agencies over the standard lining systems without cutting too much into the current functions of the sewers.

I am also aware of a number of other new technologies for building optical fiber networks in sewers. For example, see US patent No: 6,301,414 issued on October 9, 2001 to a group of optical fiber experts from Draka Comteq.[12] Nippon Hume, Consec, TMG, and TMSSC have jointly applied for new patents to protect their new C and W anchors and new modular robots, shown in Figure 1.

Figure 1. New Nippon Hume modular robot.

TMG, and Ashimori Industries' offering to use tensioning devices to span the optical fiber cable manhole-to-manhole to anchor them on the walls of the manhole are quite similar. A typical technology to build optical fiber ducts as part of relining a sewer is shown in Figure 2.

Figure 2. Optical fiber ducts built into pipe liner.

Optical Fiber in Natural Gas Pipes

Sempra Fiber Links, Draka Comteq, and Gastec are three companies offering new technologies to install optical fiber cables in natural gas pipes. Tokyo Gas and Osaka Gas also have installed cables in gas mains. In Sempra's technology, special fittings are attached after tapping the gas main at two locations to form the entry and exit points for the optical fiber.

The gas mains can be as small as 25 mm (one inch) in size. Even at that diameter, the fiber conduit will take up to no more than 10 percent of the gas flow area.

In the event a particular gas line cannot handle even a 10 percent reduction in capacity, additional pipe capacity will be added, according to Sempra literature. In my opinion, however, if the additional pipe capacity is needed, this approach offers little advantage over traditional dedicated conduit for placing the optical cable.

A small HDPE conduit is threaded through the entrance fitting until it reaches the exit fitting. A special tool is used to grab hold of the threaded conduit and pull it out through the exit fitting. Once this housing conduit is placed in the gas main, the optical fiber cable is pushed through this conduit from one fitting to the next.

The fittings and seals are designed to meet all gas pipeline safety requirements of the U.S. Department of Transportation, 49 CFR, part 192 and any local regulations such as California PUC General Order 112-E. Sempra reports that a crew of five to seven workers can install up to 600 meters of fiber per day.

In the Draka Comteq system, a balloon device is used to pull a specially designed optical fiber cable through the inlet port clear through the outlet port, using a gas pressure differential. The cable itself has a special metallic barrier, to prevent hydrogen gas migration from causing the optical fiber strands to go blind. Again, the seals and the ports are designed to meet various safety regulations. More details can be found in Leppert et al.[13]

Gastec offers a solution where a specially designed shuttle pulls a cord from an inlet attached to the gas main all the way to the exit port using a gas pressure differential. This is done by creating an overpressure of about 150 mbar at the inlet side while a negative pressure is created by flaring off gas through a venting safety valve at the outlet side. An added benefit of fiber in gas deployment is that a few strands of the fiber could be used as a leak detection system by collecting

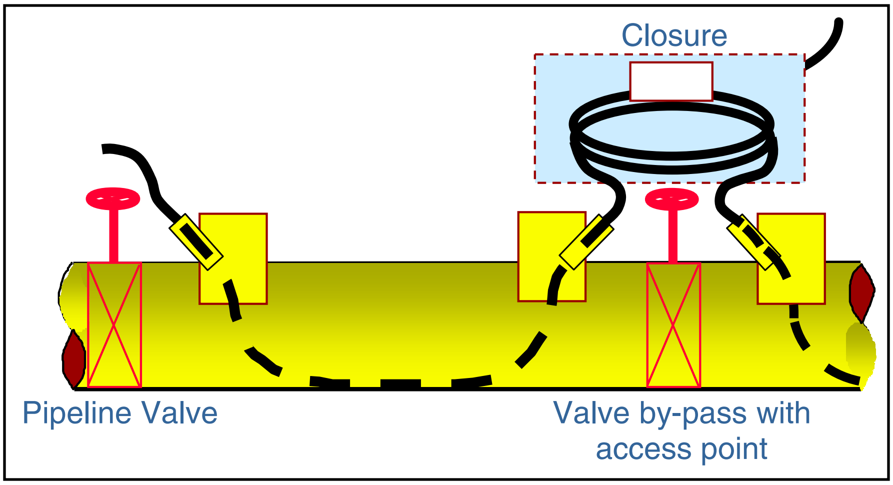

Figure 3. Draka Comteq's optical fiber cable in natural gas mains.

Removing the first mile bottleneck to generate the voice/video/data traffic needed to solve the intercity fiber glut will involve creative business partnerships with existing utility pipe owners.

spatial resolution data. The fiber-in-gas solution as introduced by Draka Comteq is shown in Figure 3.

Fiber in Drinking Water Pipes

Drinking water pipelines also enter most buildings. If you use that route, of course, all fiber cable materials must meet EPA regulations for drinking water. In typical metropolitan regions, numerous valves exist in the drinking water pipeline and are bypassed with the cable.

A cable entry point consists of a water pipe flange and a sealed cable inlet. The flange is installed on the water conduit under normal operating conditions and the water flow is interrupted only for the actual cable insertion. The cable is installed by means of a rope, which is fed into a flange and floated to the next flange as shown in Figures 4.

The cable is then attached to the rope and pulled manually into the pipe. In drinking water pipeline systems, cable-pulling sections are on the order of 250 meters in length, although some additional cable is stored in the small manhole above each valve to accommodate future fiber links. Fiber in drinking water pipes is also inexpensive and every valve is a potential customer connection point.

There have been many installations of communication networks in active or abandoned drinking water pipes going as far back as 100 years. Figure 5 details what the flange actually looks like.

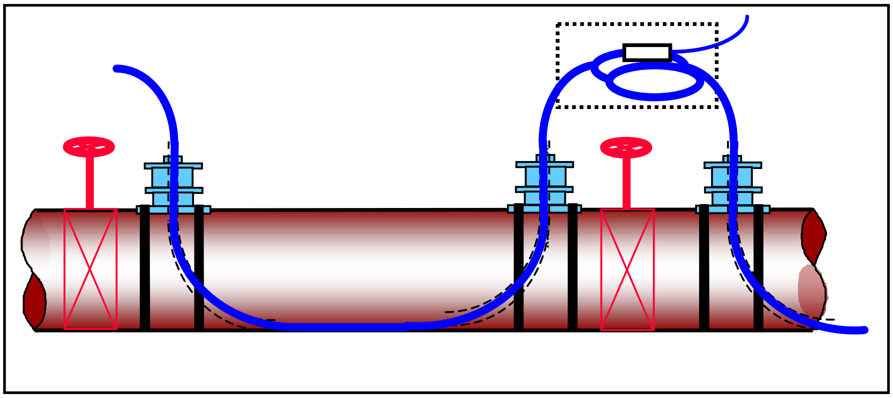

Figure 4. Draka Comteq's optical fiber cable in drinking water pipes.

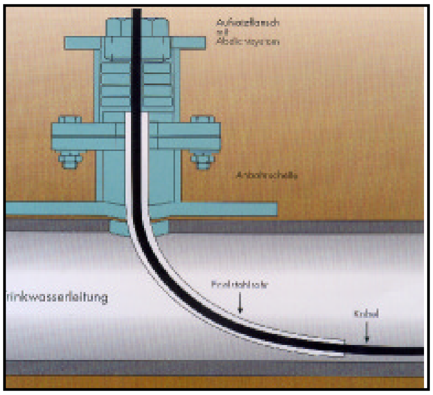

Figure 5. Flange fitting for Draka Comteq's optical fiber cable in drinking water pipes.

Other Methods of Fiber Installation

There are numerous other ways to build FTTH using micro-cuts in pavements and ducts that are either new or occupied by other cables. Draka Comteq, Ericcson, Strangeways, and others are able to deploy by making micro-cuts in pavements.

Pipe bursting could be used to install cables with pipes for other functions. In the US, Renaissance Integrated Solutions holds the patents.

Microduct blowing of fiber is done by Draka Comteq, Sumitomo, Neptco, ABF, NextGen, Emtelle and others.

Cables of fiber can be blown by Plumettaz, Lancier, Condux, Neptco, and others.

Horizontal directional drilling also can be used for cable installation. Many different forms of rehabilitation liners are also available for fiber cable inclusion during pipe renovation.

Standardization at ASTM

Over 200 stakeholders from 20 countries have joined together to form a new ASTM Committee, F36, on Technology

ASTM Standards for Technology and Underground Utilities

- F2233-03 Standard Guide for Safety, Access Rights, Construction, Liability, and Risk Management for Optical Fiber Networks in Existing Sewers
- F2303-03 Standard Practice for Selection of Gravity Sewers Suitable for Installation of Optical Fiber Cable and Conduits
- F2462-05 Standard Practice for Operation and Maintenance of Sewers with Optical Fiber Systems
- F2304-03 Standard Practice for Rehabilitation of Sewers Using Chemical Grouting
- F2414-04 Standard Practice for Sealing Sewer Manholes Using Chemical Grouting
- F2454-05 Standard Practice for Sealing Lateral Connections and lines from the mainline Sewer Systems by the Lateral Packer Method, Using Chemical Grouting
- F2550-06 Standard Practice for Locating Leaks in Sewer Pipes Using Electro-Scan—the Variation of Electric Current Flow Through the Pipe Wall
- F2349-04 Standard Practice for Operation and Maintenance of Integrated Natural Gas Pipelines and Optical Fiber Systems
- F2350-04 Standard Practice for Selection of Natural Gas Pipelines Suitable for Installation of Optical Fiber Systems

and Underground Utilities. This group has been at work developing standards for the deployment of fiber-optic cables in underground utilities, pipeline rehabilitation methods, and seismic risk assessment procedures.

Participants in the new committee include municipal authorities, building owners, robot manufacturers, pipe manufacturers, optical-fiber cable manufacturers, telcos, and construction, architectural and engineering consultants, to name just a few.

This committee usually meets in January and June. Although attendance of members is always preferred because of its value in networking, participation is still encouraged via Web forums, teleconferences, emails, and regular correspondence. See box for listing of the standards in print to date.

Conclusions

The installation of optical fiber cables inside of sewers, waterlines, and gas pipes is a major breakthrough in sharing the underground pipes so that the end-to-end optical fiber offer from the above major players could materialize faster than in dedicated fiber conduits. However, telecommunication companies need to address all the concerns associated with using existing pipes, before widespread fiber deployment could proceed.

It should be borne in mind that the inclusion of additional conduits to carry optical fiber either inside or outside of utility pipes planned in new construction projects would add minimal cost to the overall design and construction of conduits in the ground. Therefore, consideration of such utility corridors is a must in every new construction project with provisions to serve multiple functions.

AT&T, Verizon, Qwest, Level 3, and others have all promised to provide end-to-end optical networking and true broadband to the masses – at least the masses living in greenfield developments. The world is hungry for bandwidth and the established rules of many telecom companies have led to a meltdown. It's time to consider new rules and new partners to recoup the investment made in long-haul and backbone fiber.

Removing the first mile bottleneck to generate the voice/video/data traffic needed to solve the intercity fiber glut will involve creative business partnerships with existing utility pipe owners.

U.S. EPA rules require most cities to upgrade their sewers and water lines in the coming years anyway. It appears that a viable partnership could be arranged among telcos, pipe owners, service providers, and vendors, where each party has something to gain by cost sharing.

Working in the sewer, water, or gas pipe will affect the health, safety, and welfare of the people we serve and any shortsighted approach to selecting the suitable sewers or gas pipes for installing and operating optical fiber cable, would expose all those in this new industry to an enormous liability. Developing sound engineering standards to guide this new industry falls well within this obligation.

The factors that will continue to provide momentum for the market are:

- Aging underground infrastructure
- Doing more work with less funds
- Protecting the environment
- Increasing congestion in urban and suburban centers
- Faster rate of technology transfer and information
- Privatization of utility companies

Not all sewers, water lines and gas pipes are amenable to installation of optical fiber cables. Companies that support strong engineering talent on their staffs will focus attention on those lines that satisfy proper engineering criteria.

The deployment of optical fiber cables in existing pipelines offers a win-win situation for all parties involved if proper standard of care is afforded. However, working in sewers and natural gas pipes requires sound pipeline engineering input and anything less than that would be shortsighted. If telecommunication companies do not follow proper engineering know-how, it would only be a matter of time before we will face major problems and the cost to return these sewers, waterlines, and gas lines to normal working order would be far greater than the lease revenue fiber installers are offering at the present time.

For telecom carriers and network service providers, it's a true, end-to-end

The deployment of optical fiber cables in existing pipelines offers a win-win situation for all parties involved if proper standard of care is afforded. However, working in sewers and natural gas pipes requires sound pipeline engineering input.

first-mile optical fiber network, which they could control. For sewer, water, and gas pipe owners, it's a unique and powerful economic development tool, providing added revenue from an existing infrastructure (and of course, protection from most damage to roads and disruptions to traffic). And for building owners, it provides a major upgrade for their buildings for free, bringing extra value to the buildings.

The problem of the first mile bottleneck in America is similar to the lack of health care for many Americans. It has never been either the lack of funds or the lack of technology know-how. As long as we continue to support various special-interest groups, we will continue to fall behind in our quest to be the global leader in providing true broadband to the masses. **BBP**

About the Author

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Dr. Jeyapalan chaired ASTM International committee F-36 writing global standards on first mile technologies, FTTx, underground utilities, cables, and so forth. He is the author of over 150 papers and has taught over 100 seminars on solving the first mile bottleneck and underground pipelines to over 5,000 engineers and contractors worldwide.

He is a graduate of the University of California at Berkeley and was a civil engineering professor. He has over 35 years of experience in market positioning new technologies and construction methods. He has completed projects in Algeria, Australia, Austria, Canada, Chile, China, Egypt, Germany, Iceland, Italy, Japan, Korea, Oman, Pakistan, Philippines, Saudi Arabia, Singapore, Sweden, Switzerland, United Arab Emirates, United Kingdom, and the United States.

Dr. Jeyapalan's writings on pipelines, cables, FTTX, and underground structures are used widely in engineering practice. He chaired the Executive Committee of the Pipeline Division of the American Society of Civil Engineers (ASCE) and the 1st and 2nd International Conferences on Advances in Underground Pipeline Engineering sponsored by the ASCE.

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