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MODULE

THE ORIGINS AND DEVELOPMENT

CROSS-SECTOR INFRASTRUCTURE SHARING TOOLKIT
1 The origins and development of cross-sector infrastructure sharing

58. From the very beginning, the entrepreneurs who have established and operated telecommunications networks have sought to partner with the owners of existing or planned network corridors and infrastructure as a means to reduce their costs and accelerate the rollout of their networks. Also, from the very beginning, telecommunications networks which share network corridors and infrastructure have been used to support the internal telecommunications needs of the network operator as well as to provide public telecommunications services.

The telegraph and railroads paved the way

59. In 1837, British inventor and entrepreneur William Cooke demonstrated an early telegraph to officials of the London & Birmingham Railway and built an experimental telegraph link of 1-1/4 miles in length between the Euston and Camden Town stations. He then proposed to establish a telegraph system for both public and railway use linking London to Birmingham, Manchester, Liverpool and Holyhead. The London & Birmingham Railway rejected his plans. Cooke then approached the Great Western Railway, from whom he secured funding to build an initial 13-mile link from Paddington to West Drayton. In 1843, when the Great Western Railway declined to spend its own money to extend the telegraph line, Cooke himself funded an 18-mile extension to Slough. Under the arrangements with the Great Western Railway, Cooke was permitted to “make the telegraph available to the public, on the condition that railway messages were carried for free.”

Figure 1: Public demonstration of Cooke’s telegraph at Paddington Station in 1840

60. Meanwhile, American inventor and entrepreneur Samuel Morse obtained an appropriation from the US Congress in 1842 to establish a 40-mile commercial telegraph line along a railway

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connecting Washington and Baltimore. “The Baltimore & Ohio Railroad Company . . . granted permission on the condition that the line could be built ‘without embarrassment to the operations of the company’ and . . . demanded free use of the telegraph . . . .”

Figure 2: Marker commemorating Morse’s first telegraph line

Source: This Day in Tech History, 24 May 1844

61. Though they had to install their own poles and lines, telegraph operators universally used existing network corridors. Pioneered by the early work of Cooke in England and Morse in the United States, telegraph operators had a strong preference for sharing corridors with railroads, but would use roadways and other corridors when necessary.

62. The advantages of sharing railway corridors were readily apparent to the telegraph operators. Telegraphy was being introduced primarily as a means of high-speed intercity communications. The railways had established corridors with ample room to accommodate a parallel telegraph line and had also established centralized train stations in each city and town of any size. The railway corridors were superior to roadway corridors for the placement of telegraph lines due to the relative absence of obstructions and incompatible uses between the railway stations. The railways also provided a more efficient means than roadways to transport the poles and wires needed to erect the telegraph lines and to maintain those lines once installed. The railway stations themselves offered the telegraph operators prime centralized locations for placement of a telegraph office and established local transport connections for the carriage of telegrams to recipients.

63. Moreover, the telegraph offered significant potential benefits to railroad owners, which would enable the telegraph operators to barter services in exchange for use of the railway corridors and stations. Access to the telegraph enabled railway operators to ensure better safety on single-track railroads through synchronization of clocks and proper sequencing of rail traffic, to monitor delays and to communicate weather and other conditions.

64. Not all railway operators immediately recognized the mutual benefits of sharing their rights of way and stations with telegraph operators or of using the telegraph for internal railway-related communications. However, as the nascent telegraph industry matured, railway operators soon

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3 Tom Standage. *The Victorian Internet* at 47.

4 Available at [https://thedayintech.files.wordpress.com/2013/05/1-st_telegraph_1844-295x300.jpg](https://thedayintech.files.wordpress.com/2013/05/1-st_telegraph_1844-295x300.jpg) (last visited 13 Feb 2017). The message “What God Hath Wrought” was the first telegram sent over Morse’s telegraph line from Baltimore to Washington.
understood the mutual benefits of sharing rights of way and other infrastructure, and telegraph lines came to be installed primarily along railway lines.

**Box 1: Rails and telegraph as the Siamese twins of commerce**

In the mid-twentieth century, historian Robert Luther Thompson chronicled the evolution of the symbiotic relationship between railway and telegraph lines throughout the United States, Europe and the rest of the world⁵:

The introduction of the railroad into the United States parallels so closely the advent of the telegraph that the story of the one cannot be told properly without touching upon that of the other. . . . Telegraph leaders had become aware almost at once of the advantages to be derived from constructing their lines along the railroads, but the restrictions with which the Baltimore & Ohio hedged its first telegraph agreement gave evidence that the railroad, far from seeing any value in the telegraph, barely suffered it to build along the railroad right of way. In fact, many less liberal railroads refused to be bothered with electric wires along their roadbeds. Some years were to pass before the natural affinity of wire and rail came to be recognized by the conservative railway managements. . . .

. . . It was during the next decade – 1850 to 1860 – when sober consolidation began to bring order out of enthusiastic chaos, that the railroad and the telegraph came to be recognized as the indispensable “Siamese twins of commerce. . . .”

Because of the comparative ease and lower cost of construction, telegraphic development rapidly eclipsed railroad growth during the period. “Lightning lines” reached out to embrace every town and city connected by rail, and then pushed on beyond the railroad frontiers. In most parts of the West, the “iron cord” preceded the “iron horse.” Hiram Sibley [founder of Western Union Telegraph Company] succeeded in pushing a “lightning line” all the way to the Pacific, eight years in advance of the railroad. . . .

That the telegraph was the natural complement of the railroad had been quickly recognized in Europe, where wires were commonly strung along the railroad rights of way. C.A. Saunders, secretary of the British Great Western Railway Company, testified that Cooke and Wheatstone’s telegraph had been brought into actual operation upon the Great Western Railway as early as 1839 and its capabilities severely tested. Shortly thereafter, the Yarmouth & Norwich Railway issued a circular explaining at length Cooke’s new system of train dispatching by telegraph which the road had adopted in 1844. Through the use of this system, the railway officials claimed that they had been free from accidents arising from trains meeting or overtaking one another, even though the Yarmouth & Norwich was a single-track line. . . .

Despite the evident need for some system of determining the location of trains along the route, railroaders were reluctant to trust the telegraph for the movement of their trains . . . . It took several years to perfect the telegraph lines to the point where they were worthy of the full confidence of the railroad officials. . . .

Gradually, the advocates of a railroad-telegraph alliance began to overcome the opposition of conservative railway managements. In a circular letter dated July 1852, Henry O’Reilly tried to show the many benefits which a railroad might enjoy through the use of telegraphic facilities.

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The necessity for increased safety in conjunction with the increased speed in Railroad traveling, as well as the general convenience of transacting business among employees along railroad routes, should turn Public Attention promptly and strongly upon the vast importance of Telegraphic facilities in connection with Railroad operations,” explained O’Reilly. A “well-arranged telegraph for railroad purposes would, each and every year, render sufficient benefits to counter-balance the whole cost of construction. . . ."

By 1855, the advantages of a railway telegraph system were becoming too obvious to be ignored by the railroads any longer. In his report to the Erie directors for that year, D.C. McCallum . . . declared: “A single track railroad may be rendered more safe and efficient by a proper use of the telegraph than a double track railroad without its aid. . . . It would occupy too much space,” he went on, “to allude to all the practical purposes to which the telegraph is applied in working the road; and it may suffice to say that without it, the business could not be conducted with anything like the same degree of economy, safety, regularity, or dispatch.”

McCollum’s report spread far beyond the narrow confines of the Erie management. His words were carefully weighed in railroad circles, and leading companies began to see the telegraph in a new light. During the next decade and a half, the use of the telegraph became almost universal, and some of the most perplexing problems of railway operation were solved.

By the close of the nineteenth century, “every railroad in every country and clime” made manifold use of the telegraph. Its weather reports aided officials in guarding against danger from approaching storms. By giving prompt warning of damage by wind or flood, it prevented disaster in many ways. It moved trains promptly and safely, and practically doubled the capacity of every single-track road. It brought the most distant stations and diverse patrons of the company into close relationship with the management, and united the officers and employees of a great railroad system into one compact and well-organized army. It transmitted observatory standard time automatically to every station at the same instant. It gave steady employment to thousands of persons. All this, and much more, was done by the railway telegraph at a cost of less than 3 percent of the total expense of the operation and maintenance of the railway. The railway telegraph had, indeed, come into its own; it had become an absolute necessity for the safe and efficient operation of the railroad.

65. By early in the Twentieth Century, telegraph networks had achieved near universal service in developed countries. The following decades saw the gradual demise of the telegraph network which coincided with the continued rise of the copper telephone network (discussed in Submodule 1.2 below). Western Union, an operator of telegraph lines which once held a monopoly over 90% of the US market, faced stiff and increasing competition after the advent of the telephone. Telegraph use peaked during the war years of the 1940s, and subsequently declined until Western Union eventually discontinued its telegram/telegraph service in 2006. Throughout the world one can still see abandoned telegraph lines in place along many rural railways. These relics stand as monuments to the advent of cross-sector infrastructure sharing.

66. The early infrastructure sharing experience of telegraphs and railways, following a circumspect courtship, resulted in a strong marriage of interests. However, it was perhaps a simpler time – occurring early enough in the history of both industries that regulators of telegraph and railway operators did not involve themselves in the cross-sector relationship. This suggests that sharing did not require a legal mandate but simply the absence of legal and regulatory interference.
The telephone followed by sharing road corridors and then utility poles

67. The invention and commercialization of the telephone followed closely on the heels of the telegraph, with the first telephone exchange opening in New Haven, Connecticut in 1878.6 The United States and Europe again played a leading role in the development of the telephone, and related cross-sector infrastructure sharing activities.

68. In addition to obvious technological differences, the telegraph and telephone also presented very different commercial opportunities and different cost structures. These influenced and were reflected in differences in how the telegraph and telephone companies entered and developed their markets. While the telegraph was primarily used for long distance intercity communications, the telephone offered the opportunity for local communications within a single community as well as long distance communications, because it was designed to be used directly by end users, who could communicate by voice at a distance.

69. Driven by technology, cost and market factors, the development of telephone networks initially focused on local communication.

70. First, while the telegraph did not require very high signal quality because transmission was digital and at relatively low speeds, the analog telephone, on the other hand, required a higher data transmission rate and much higher signal quality. Thus, through the early 1880s, when both telegraph and telephone used unshielded iron wiring with a single live wire and a ground return, the telegraph could carry traffic much greater distances than the telephone. During this time, the telephone only supported commercial service over relatively short distances due to signal attenuation and interference.

71. Intercity telephone connectivity was initially inadequate for commercial service. Overcoming this challenge involved the introduction of a series of technological solutions, each designed to reduce signal attenuation and/or interference, but each also adding to the cost of telephone line construction. These solutions, which were developed in the late 1880s and introduced over the next two decades, included using an end-to-end pair of wires (doubling the wiring needed), twisting the pairs to cancel induction which otherwise caused cross-talk and using copper rather than steel to reduce signal attenuation.7

72. Second, because the telegraph generated asynchronous written messages, they could be transcribed and carried to recipients within a reasonable proximity of the telegraph office by physical means of transport, such as foot, horse or automobile. Telegraph messages could also be repeated (at the risk of introducing errors) at intermediate telegraph offices to extend the distance traversed.

73. Because the telephone was inherently a synchronous means of live voice communication between two individuals, however, both persons would need to be simultaneously present at a telephone device connected to the telephone line. This therefore limited the usefulness of the telephone as a communications device unless a large number of people had direct access to telephones connected to a single network or set of interconnected networks.

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7 Id.
74. The network effect required a sizeable number of connected customers to make a telephone system useful and profitable. Also, because each line required a separate circuit, telephone lines needed to run up and down every street and they required as many wires as premises passed. This led the telephone companies quickly to identify roadways as their preferred corridors for co-locating lines for local exchanges.

75. As long as telephone technology relied on uninsulated conductors in the same way as the telegraph, telephone companies had to install poles with cross bars and many, many wires. These open, overhead lines were susceptible to weather conditions and interference, unsightly and became a public nuisance.

Figure 3: Telephone and telegraph line clutter in Stockholm in 1890

Source: Tekniska Museet (The Swedish National Museum of Science and Technology)
Figure 4: Open telephone lines in New York City circa 1903

Source: Library of Congress Prints and Photographs\textsuperscript{8}

\textsuperscript{8} Available at [https://www.loc.gov/item/2002697630/](https://www.loc.gov/item/2002697630/) (last visited 13 Feb 2017).
76. Sharing of poles with electric utilities was out of the question during these early years of the telephone due to safety concerns. Contact between electricity and telephone lines could result in dangerous transmission of current across a telephone line. Even without physical contact, electromagnetic fields generated by the electricity lines could act on nearby parallel lines, such as telephone lines, inducing potentially dangerous current or static charges. Modern communications lines are shielded and attached at a safe distance from electricity lines to avoid these effects. They are also installed and maintained in accordance with rigorous safety codes which have been developed and refined by industry participants over many years.

77. Eventually, telephone companies faced pressure to improve quality of service and reduce the clutter by burying their lines in densely populated areas. For example, New York City required all telegraph and telephone operators to bury their cables in 1889. In Europe, the move toward buried cable began earlier, when the telegraph was still the only (or primary) electronic communications medium. In London, when the Post Office was nationalized in 1871, it had already begun the work of placing the City’s telegraph networks underground. Throughout Great Britain, the pace of replacing and transferring telegraph lines underground quickened after a heavy snowstorm in 1886 disrupted services and made the dangers of unanchored overhead wires apparent. In Germany, an extensive network of underground telegraph lines was constructed in 1870 and, by 1881, Germany had 5,500 km of underground lines, by far the most in Europe.

Figure 5: Access cover for buried telegraph cable in the United Kingdom

Source: Norman Ball

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12 Ibid. at 91.

13 Ibid. at 91-92.

78. The public and government pressure to bury telephone lines in densely populated areas and to reduce the clutter created by above-ground telephone lines in less densely populated areas created pressure for improvements in telephone technology to enable bundling of multiple telephone lines into cables which could be buried or which, when hung overhead, took up much less space than hanging each strand separately.

79. A period of innovation ensued. By 1914, it was reported that telephone engineers had designed a new type of cable which contained 2,400 wires capable of serving 1,200 telephone circuits and that the cable could be used in underground ducts with a minimum three-inch diameter. This new cable design was meant to solve overhead congestion issues at local exchanges in dense areas.15

80. The introduction of the telephone cable, which was insulated and shielded, not only enabled the burial of lines in conduits in densely populated areas, but also enabled the sharing of utility poles between power companies and telephone companies because many telephone lines could be connected through a single cable, which was insulated against conducted and induced electrical currents and charges. Thus, in the early Twentieth Century, electric utilities and telephone companies began to share poles systematically, particularly in the United States, where the population was spread over vast distances and buried lines were generally not economically viable. This is a practice that has continued until this day.

81. As for intercity long distance, the telephone companies initially co-located their long distance lines on existing telegraph poles in railroad rights of way. This presented great problems of inductive interference between the telegraph signals and phone calls due to the continued use of open wiring and single strands with grounding. Even still, it was a start in intra-sector infrastructure sharing, with both telecommunications network operators also sharing the same cross-sector infrastructure. In addition, the railways along which the telegraph lines were installed began to recognize the benefits of supplementing their internal telegraph communications with internal telephone service. Following the introduction of telephone cables as a replacement for open telephone lines, long distance lines were buried, still often following the same railway lines. In 1914, AT&T reported successfully completing construction and beginning operations of a buried 430-mile long distance line from Boston to Washington.16

82. However, the new telephone cables were relatively expensive and were unnecessary unless there were a large number of users or a large volume of traffic on a line. Therefore, in many areas, particularly in developing countries or rural areas of developed countries, telephone lines continued to be installed as open, uninsulated lines on their own poles. In developing countries, this pattern persisted until the open telephone lines were abandoned after the introduction of wireless mobile networks. Fixed line telephone networks in these areas therefore never shared poles with electric utilities.

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16 Id.
Box 2: Telephone evolved from competition to enfranchised monopoly

The infrastructure sharing practices which developed and persisted around the telephone must also be understood in the non-competitive environment in which the telephone business operated until recent decades. Following an initial wave of boundless competition among competing telegraph and telephone operators, investors and policymakers alike sought ways to ensure financial success of the enterprises and stable and broad service coverage for the population. This led to the view that the telegraph and telephone were natural monopolies. In Europe and much of the rest of the world, these monopolies were seen as natural extensions of the business of the post office and so were brought under the control of the government-owned postal system.

In the United States, however, the monopoly over telephone service was enfranchised under private investor ownership. As an influential development in this outcome, the American Bell Telephone Company, forerunner of AT&T, succeeded in convincing US federal and state authorities that telephone service should be treated as a natural monopoly. In public advocacy before state legislatures and regulators, AT&T committed to focus on universal service, with regulated tariffs, as the *quid pro quo* for a monopoly franchise. The company also succeeded in warding off repeated efforts by the US Postmaster General to nationalize phone lines under the auspices of the Post Office.

The history of the telephone industry in the United States for the better part of a century was therefore of a single regulated investor-owned monopoly in every service territory, with AT&T and its subsidiaries dominating all the major markets and smaller companies serving as monopolies in the smaller and rural markets. Elsewhere in the world, the monopoly model was also embraced, but government ownership through the post office (via what came to be known as the Post, Telephone and Telegraph office, or PTT) was more often the norm outside the United States. As a result, much of the early regulation of telephone rates and charges was pioneered in the United States as the only developed country with privatized telephone service.

The enfranchisement of the perceived *natural monopoly* of telephone companies over voice communications and telegraph companies over data communications persisted for many decades. During the monopoly era, the primary investment activity of telephone companies, extending lines ever deeper into less populated areas as part of their universal service pledge made to secure monopoly status, involved extending the use of the same types of cross-sector infrastructure, but not much innovation in new infrastructure owners or infrastructure types. There was little need for innovation, because there was only one telephone company in each service territory and it was assured of full cost recovery for its infrastructure through regulated tariffs (in the United States) or the tariffs set by government owners outside the United States.

83. In some developed countries, the telephone network was later joined by the coaxial cable television network as a second communication line. Cable television originated in the United States in 1948 to enhance poor reception of television signals in mountainous and geographically remote areas.17 Through a network initially known as community antenna television (CATV), community antennas were erected on mountain tops or other high points to receive television transmissions and then local homes were connected to these antennas using shielded coaxial

copper cable. By 1950, there were 14,000 cable television subscribers in the United States.\textsuperscript{18} Cable television spread throughout the developed and urban areas in parts of the developing world. The number of cable television subscribers in the United States peaked at approximately 69 million in 2000\textsuperscript{19} and had declined to approximately 54.4 million by 2013.\textsuperscript{20}

**Figure 6: Typical CATV shielded cable**

![Diagram of a typical CATV shielded cable](source: PerfectVision Manufacturing\textsuperscript{21})

84. During this time, developments in cross-sector infrastructure sharing were limited to measures to accommodate improvements in telephone technology and continued rollout of telephone coverage. Throughout the world, copper telephone lines and coaxial cable television lines made extensive use of roadways, along which they were either buried or hung from poles. In the more prosperous regions, open telephone lines were replaced with insulated telephone cables. This enabled extensive joint use of electricity distribution facilities, with which they frequently shared duct systems (for buried lines) or poles (for aerial lines).

85. For example, in the United States, electric utilities and telephone companies universally and voluntarily shared poles in smaller metropolitan areas (where cables were not buried) and suburban areas (where open wiring was no longer adequate) from the time of introduction of telephone cables – with power companies attaching their facilities to telephone poles and telephone companies attaching their facilities to power poles. The United States case study in Submodule 9.3 offers the reader a fuller discussion of this example.

\textsuperscript{18} Federal Communications Commission website, “Evolution of Cable Television,” (as of Dec 2015).


Wireless ended telephone monopoly and reduced infrastructure sharing need

86. Wireless communications grew up with the telegraph and telephone, but did not play a significant role in commercial telecommunications until the middle of the second half of the Twentieth Century, beginning soon after the end of World War II.

87. The US Army Corps of Engineers introduced a mobile AM radio receiving device in 1938. The first two-way mobile device, known as a walkie talkie, with a 25-pound SCR-300 radio transceiver, was introduced by the Corps of Engineers in 1940 for use by troops to communicate during combat. But the SCR-300 never saw any combat time because it was replaced in 1942 by Motorola’s 5-pound SCR-536. These devices communicated with each other, without any radio base stations, and therefore only permitted calls between users within a small radius of each other.

88. The first mobile phone network was introduced by Southwestern Bell, an AT&T subsidiary, in St. Louis, Missouri in 1946 using technology developed by Bell Labs. Unlike the walkie talkie, the mobile network enabled wider area coverage and long distance calling between coverage areas, as well as calls between mobile phones and fixed-line phones. By 1948, mobile phone service was available in almost 100 cities and highway corridors across the United States. However, the relatively high cost and cumbersome equipment limited the primary users to those

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with special needs for mobile communications, including *utility work crews*, trucking fleets and news reporters.\(^{25}\) Thus, utilities in non-telecommunications sectors were once again early adopters of telecommunications technology. However, in contrast with telegraphs and fixed-line telephone networks, mobile phone access networks did not need to use any utility infrastructure for the last mile of service between the tower and the end user because the link was wireless.

**Figure 8: Motorola ad comparing WWII-era analog handset to 1994 mobile phone**

89. In parallel with the introduction of wireless access networks, the introduction of microwave technology also began to reduce demand for utility infrastructure for the backhaul and long distance links in both fixed-line and wireless communications beginning in the middle of the Twentieth Century. These new microwave wireless transmission links significantly increased the capacity which could be carried on a route at much lower cost than cabling. A significant part of the cost savings derived from avoiding the need to install and maintain cable infrastructure in lateral corridors. In avoiding lateral infrastructure, these wireless links also obviated the need for using lateral corridors and hence for continued cross-sector infrastructure sharing for long distance communications.

90. An Anglo-French consortium first tested a microwave communications link across the English Channel in 1931. The technology was significantly improved though the development of radar systems in World War II. After four years of planning and testing by Bell Labs, AT&T in 1947 deployed the world’s first commercial microwave transmission network for long distance telephone calls between Boston and New York City.\(^{26}\) In 1951, replicating the coast-to-coast electronic communications link first made by the telegraph 90 years earlier, AT&T linked voice traffic from New York to San Francisco by microwave using 107 towers spaced 30 miles apart at

\(^{25}\) *Id.*

an initial investment of USD 40 million (equivalent to approximately USD 386 million in 2017). The use of microwave rather than cabling for long distance and backhaul links would soon become ubiquitous throughout the United States and the rest of the world. During the 1950s, AT&T converted a majority of its long distance lines in the United States from cable to microwave.

Figure 9: Microwave tower used in first commercial long distance telephone relay system

91. A third wireless development which further depressed demand for cross-sector infrastructure sharing was the introduction of satellite communications. It was less expensive than submarine cables for trans-oceanic links, and also enabled landlocked cities to send international and domestic intercity communications without any long corridors of cabling.

92. Satellite also served as a substitute for both fixed-line and mobile access networks in extremely remote and sparsely populated regions. Canada was the first nation to use domestic satellites to provide telephone access to poorly served rural areas. Starting with Indonesia in 1976, many developing nations purchased or leased satellites to avoid building ground-based telephone, radio or television networks.

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28 The pictured microwave relay tower was located on Jackie Jones Mountain, New York, and was one of seven towers used on AT&T’s original New York-Boston microwave radio relay transmission system of 1947. The picture is reprinted courtesy of AT&T Archives and History Center in “Telephone Transmission,” Engineering and Technology History Wiki. Available at http://ethw.org/Telephone_Transmission (last visited 7 Feb 2017).


30 Id.
93. Ultimately, however, satellite would prove to have limited application as a substitute for terrestrial cabling and terrestrial wireless networks due to its much higher signal latency (caused by the large distance the radio signals must travel to and from the satellites) and its limited bandwidth. Satellite has retained an enduring role to the present day in reaching remote and sparsely populated areas, where it can offer a more economical solution to coverage, both in providing wireless backhaul from mobile towers and as a substitute for terrestrial mobile or fixed wireless access networks.\footnote{31 See, e.g., Gilat Satellite Networks Ltd., Satellite Backhaul vs Terrestrial Backhaul: A Cost Comparison (2015). Available at http://www.gilat.com/dynimages/t_whitepapers/files/Satellite%20Backhaul%20vs%20Terrestrial%20Backhaul%20Cost%20Comparison.pdf (last visited 7 Feb 2017).}

94. Despite the significant inroads made by microwave and satellite networks on the need for intercity cabling, mobile networks continued to have limited impact on demand for fixed-line telephone networks for the first three decades after commercial mobile service was introduced. Then, in 1973, Motorola introduced the first wireless mobile phone for personal use (which was vastly smaller and less expensive than the mobile phones first introduced in 1946). By the late 1970s, mobile networks were in operation around the world. In 1983, Ameritech, an AT&T subsidiary, deployed of the first generation (1G) \textit{cellular} radio access network in Chicago using Advanced Mobile Phone System (AMPS) technology.\footnote{32 See AT&T, “Milestones in AT&T History” (2004). Available at https://www.thocp.net/companies/att/att_company.htm (last visited 7 Feb 2017).} Deployment of AMPS cellular networks quickly spread throughout the world.

95. With these technology improvements, wireless cellular access networks become affordable and convenient for end users. And they were much less expensive for network operators than fixed networks because they required no lines or lateral infrastructure. In addition to the wireless link from the cell tower to the customer, the backhaul transmission networks were also wireless, powered by the same microwave technology pioneered for landline long distance networks. It therefore became possible to construct an entire telecommunications network without using any lateral infrastructure. For the first time, entry barriers and scale were sufficiently reduced to enable end-to-end \textit{facilities-based competition}.

96. Digital cellular phones, known as second generation (2G) cellular, were introduced in the 1990s. This resulted in substantial call quality improvements over analog mobile phones and users began substituting mobile voice for fixed voice. This led to widespread displacement of fixed-line telephone networks with 2G wireless networks in developing countries, where operators were able to achieve much greater geographic coverage at a much lower unit price. The introduction of 2G mobile phones also coincided with the introduction or enhancement of competition in the mobile voice markets in the United States and the United Kingdom, as was soon followed by the rest of Europe and other developed countries around the world. Mobile networks also brought improved population coverage to most developed countries. Copper-based fixed networks continued in widespread use, but were rapidly supplemented by 2G wireless networks. For the first time in the history of the telecommunications industry, there was little need for infrastructure sharing to facilitate \textit{new investment} in deploying telecommunications networks.

97. The disruptive force of cellular, microwave and satellite wireless technologies thus began a radical change in the landscape for telecommunications access networks and reduced the demand for infrastructure sharing over the ensuing quarter century. Although telegraph, telephone and cable television operators continued to share infrastructure with railways, roadways and electric...
utilities, mobile network operators were viably able to build their own end-to-end infrastructure, comprising wireless cellular access networks, wireless microwave backhaul and transmission networks and satellite for international and very long domestic distances. The entire network was wireless.

98. The growth of wireless also firmly replaced the monopoly paradigm with the competition paradigm for the telecommunications industry.

99. But the trend of wireless domestic backhaul and international connections for wired networks and end-to-end wireless networks did not last. Even as microwave links once served a major role in national backbone networks and more recently found a new place in supporting wireless transmission networks for cellular radio access networks, the volume of traffic on the main arteries of both wired and wireless networks began to exceed the capacity of microwave. Telecommunications operators needed more advanced technology and an alternative medium to handle the greater throughput requirements. This led to the development and commercial deployment of fiber optic cable technology.

100. Inventors had been experimenting with using light as a transmission medium for as long as they had experimented with the technology of the telegraph and telephone. In 1880, four years after inventing the telephone, Alexander Graham Bell and his assistant invented and patented an optical voice communication system known which he dubbed a photophone and which used a beam of light as a carrier wave, although it did not use glass as a wave guide and had other technical flaws which precluded its commercial use. It would be a while before using light as a carrier wave would become technically and commercially feasible.

101. In 1970, some 90 years after Mr. Bell’s invention of the photophone, a team of researchers at Corning Glass patented a fiber-optic wire or optical waveguide fibers capable of carrying 65,000 times more information than copper wire, through which information carried by a pattern of light waves could be decoded at a destination even a thousand miles away.” Commercial use of this invention came soon thereafter.

102. In 1977, General Telephone and Electronics (GTE) deployed the world’s first live telephone traffic through a fiber network in California. AT&T followed one month later with an optical telephone system installed in downtown Chicago covering a distance of 2.4 km. In 1983, long distance company MCI (whose corporate acronym, ironically, stood for “Microwave Communications Incorporated”) deployed a commercial fiber optic cable system between New York and Washington, DC, which AT&T soon followed with a competitive line. During the 1980s, telephone companies in the United States continued to deploy fiber links to replace their

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35 Ibid.


existing microwave links in connecting major cities. By the mid-1980’s fiber optic installations had expanded rapidly all over the globe.\textsuperscript{38}

103. The introduction of fiber optic cable, and exponential growth of data as a major component of communications, thus enabled the gradual replacement of microwave-based national backbone networks with terrestrial fiber and of international satellite links with fiber optic submarine cable systems. More recently, growth in data use has also led to the replacement of metro microwave links and copper cables with fiber. Now, following the introduction and growing use of broadband devices, and the resulting exponential growth in demand for data throughput, the preferred material for intercity transmission networks, for mobile transmission networks and for last mile wired access networks is now also fiber.

104. The invention and introduction of wireless broadband access technologies and fiber optic networks eventually precipitated the current decline and pending abandonment of copper telephone and coaxial cable television copper networks, even in developed countries where they had remained alongside the newer wireless networks.

105. In contrast with wireless technologies, fiber networks, like telegraph and telephone lines, require the use of lateral corridors. The shift to fiber has therefore generated renewed interest in cross-sector infrastructure sharing as being less costly and leading to more efficient and rapid deployment. The advent of fiber as a preferred communications medium has thus renewed interest in cross-sector infrastructure sharing in developing countries and introduced it for the first time in many developing countries.

106. For example, in the United States intercity fiber deployment was accelerated by the Internet and data applications:

During the mid to late 1990s, the growth in the use of the Internet and other data applications resulted in the use of traditional long-distance communications carriers such as AT&T, MCI, and Sprint being supplemented by a number of newly formed communications carriers such as IXC Communications, Quest Communications, and Level 3 Communications. The newly formed companies installed more than 50,000 route miles of fiber along gas, railroad, and electric utility right of ways to develop their own long distance networks.\textsuperscript{39}

107. There are already millions of route miles of existing terrestrial fiber optic cable in service around the world.\textsuperscript{40} With the notable exception of the dry cable segments at submarine cable landings, where new corridors often have to be acquired and cleared, virtually all existing fiber optic cable systems have made some use of existing corridors. Terrestrial fiber optic cables are almost always hosted in corridors previously established for roadways, railways, pipelines or electricity transmission lines. New fiber optic cable installations also make use of improvements and fixtures from other sectors located in the same corridors whenever possible. They are sometimes installed in duct systems built for electricity lines or steam, sewer pipes or on electricity transmission towers or distribution poles.

\textsuperscript{38} Id.
\textsuperscript{40} This excludes submarine fiber optic cables as they are generally not candidates for cross-sector infrastructure sharing.
108. However, this time the landscape is much different than when the telegraph and telephone were introduced.

109. First, policymakers and consumers worldwide have experienced the benefits of competition in the telecommunications sector and will not accept a return to a monopoly environment. This means that there will now be multiple competing telecommunications operators vying for access to shared infrastructure. Because they are competing, and are not assured of recovery of their capital investments and operating costs as the monopolies once were, telecommunications operators today are constantly seeking every possible way to cut costs, both to gain an edge on their competitors and to ensure they can viably carry on their business. They are highly motivated to pursue infrastructure sharing opportunities.

110. Second, the growing importance of information and communication technology to every business and public service has driven all providers of transport services to recognize the need to provide telecommunications connectivity to the major components of their infrastructure. This enables them to monitor, measure and control the operation of their infrastructure and the volume and direction of traffic flowing through it. Today, every network sector needs robust internal communications, including electricity, roadways, railroads, water and sewer, pipelines, and others.

111. Third, the nature of the technology also enables a much broader range of infrastructure types to be shared. While land corridors remain as important as ever, the nature of fiber optic cables enables them to be run closer to power lines without interference or induction of electric current and to be placed in wet or damp environments without risk of electrical shorts or interference. Today, fiber optic cables can be installed within electricity lines, as is the case with OPGW, and they can be installed in water-filled sewer lines.

112. Thus, although the motivations for infrastructure sharing are no different today than in the early days of the telegraph and telephone, the possibilities are much greater and there is much more drive to share, due to the presence of a competitive environment, the broader range of infrastructure owners who also want their own fiber networks, and the broader range of sharable infrastructure due to nature of the technology.

113. However, the challenges faced by telecommunications operators seeking to share infrastructure from other sectors are in some ways greater than they were in the days of the telegraph and the telephone.

114. First, existing land corridors are more congested. Burying fiber optic cable in modern cities is much more difficult than burying telegraph and telephone lines once was due to significant underground congestion and the duty of any installer of new facilities not to disturb existing facilities.
115. These challenges cannot be solved by the telecommunications operators and individual owners of improvements and fixtures alone. They require proactive intervention and planning by the municipal and national governments which own or control the road reserves to rationalize the use of the limited space available and to serve as a traffic cop among the multiple users of the space.

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Second, with more telecommunications operators and infrastructure owners interested in sharing, and more infrastructure potentially sharable, stakeholders face the challenge, and opportunity, to forge creative solutions to solving congestion to enable construction of much-needed fiber installations to proceed. One approach, for example, has been the use of sanitary and storm sewers as conduits for fiber. Others have included using abandoned steam ducts or abandoned gas pipes.

Box 3: Installation of fiber optic cables in sewers and abandoned gas pipes

Tokyo’s sewer system provides an example of installation of fiber optic cables in sewer conduits. The Tokyo Metropolitan Government began installing a fiber optic network in its existing sewage conduits in the late 1980s to support an unmanned sewage management system. The network had far more capacity than the sewer system needed for its internal uses. Accordingly, it now leases unused dark fiber to major telecommunications operators and also leases space in existing fluid conduits for third parties to install additional fiber optic cables.

The city of Mumbai, India provides an example of installation of fiber optic cables in unused, obsolete gas pipes. Bombay Gas owns pipes, conduits, service-pipes and other infrastructure installed under streets and bridges over 150 years ago for the delivery of piped gas in what is now the city of Mumbai. In the mid-1980s, the piped gas business was discontinued at the direction of the Government of India, which favored development of natural gas. However, about a decade ago, investors realized the potential to utilize Bombay Gas’s existing but dormant rights of way and pipes to lay fiber optic cable. By mid-2015, Bombay Gas had installed over 100 km of fiber optic cable, enabling it to lease dark fiber to many of India’s major telecommunications network operators.

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Third, the growth of wireless broadband access networks has introduced a pressing need for locating new tower sites, in addition to lateral wired infrastructure. In the wireless segments of the telecommunications sector, cross-sector infrastructure sharing, on a strategic scale, is a relatively new phenomenon. Until recently, most cell towers were built as standalone installations. Some were opportunistically installed on roofs of buildings or water towers, but this was the exception rather than the rule. Today, however, new tower sites are increasingly finding their way to the tops of electricity transmission towers and distribution poles and water towers.

**Figure 12: Installation of cellular antenna on electric transmission tower**

Source: Wireless Estimator, Inc.\(^{43}\)

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\(^{43}\) Available at [http://wirelessestimator.com/content/articles/?pagename=Hurricane%20Ike%20Telecom](http://wirelessestimator.com/content/articles/?pagename=Hurricane%20Ike%20Telecom) (last visited 13 Feb 2017).
118. This changed environment and these new challenges have created a renewed need and opportunity for infrastructure sharing. The infrastructure which broadband network operators today seek to share includes the traditional list – corridors, conduits, ducts, towers and poles – plus, for the first time, excess dark fiber in fiber optic cables owned by non-telecommunications owners. All of this infrastructure, including fiber optic cables, can readily be shared between owners and telecommunications network operators.

119. The Figure 14 below lists some of the more common lateral broadband infrastructure sharing options that have been employed. The figure intentionally excludes sharing of utility-owned dark fiber, which would typically have been installed using one of the options listed. It also excludes co-location space, which is typically bundled with the other infrastructure shared. For example, owners of lateral infrastructure which allow telecommunications operators to install their own fiber or provide dark fiber to telecommunications operators will typically provide space at the fiber access points along a route where the telecommunications operator can install equipment, power systems and interconnect with fiber which is not on the shared infrastructure. Figure 15 below illustrates an optical ground wire (OPGW) which can be used to install fiber in the static wire on an electricity transmission line.

**Figure 14: Matrix of common broadband cross-sector infrastructure sharing options**

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120. Notwithstanding the greater options which exist today, the challenges faced by telecommunications operators seeking to share infrastructure from other sectors are in some ways greater than they were in the days of the telegraph and the telephone.

121. Cross-sector infrastructure sharing has therefore become a key component of many national and multinational broadband development policies. Lawmakers, policymakers and regulators in developed and developing countries have increasingly looked for ways to require or encourage such sharing as a means of accelerating telecommunications network deployment, both in order to increase viability, decrease deployment costs and enhance competition. Today, most countries with recently enacted or updated telecommunications laws have addressed infrastructure sharing in those laws. Some of these efforts at market intervention have been very effective in stimulating greater cross-sector infrastructure sharing, while other efforts have been less effective or even counterproductive. Similarly, economic development banks and institutions have also increasingly sought to encourage cross-sector infrastructure sharing. Modules 6 and 7 provide some insights into how best these public sector stakeholders can increase the incidence of cross-sector infrastructure sharing.

45 Previously available at www.lamifil.be/