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Battle of Systems: Learning from Erstwhile Gas–Electricity and Telegraph–Telephone Battles

HARMEET SAWHNEY & XIAOFEI WANG

ABSTRACT *This paper seeks to understand how the possibility of a complementary relationship or its lack impacts dynamics of competition between two competing network technologies. It examines the cases of gas–electricity and telegraph–telephone competition. The two case studies suggest that the degree of complementarity greatly shapes the dynamics of competition between an entrenched network technology and a new competitor. When there is little scope for a complementary relationship, as in the case of the gas–electricity battle, the strategists for the new technology have to subvert the old system and build a new one on its ashes since there is little chance of coexistence. On the other hand, the possibility of a complementary relationship, as in the case of the telegraph–telephone battle, allows for the emergence of complex situations marked by coexistence interwoven with competition. These compromise positions, invariably involving re-negotiation of boundaries, are tempting resting spots for battle weary contestants. As the relationship between the old and the new system evolves, the nature of the complementary relationship changes, especially in the relative power of the two systems, and even if eventually the old system fades away the process is a long and gradual one.*

Keywords: telecommunications competition; network competition; system competition; convergence.

Introduction

Much has been written about large-scale network technologies over the years. The railroad, the 'grand daddy' of all network technologies, has in particular drawn a lot of attention.[1] Telegraph, the kindred technology that 'marched across the continent in unison' with the railroad,[2] has been studied by historians[3] but as Carey[4] notes has for some reason received significantly less attention from communications scholars, which is surprising because telegraph was the first telecommunications technology. Electricity, telephone, automobility,[5] Internet, and other major network technologies that succeeded them have all been studied at considerable depth.[6] These studies have generally tended to record history or analyze the

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economics and politics behind the creation of particular networks. Attempts to theorize beyond particular cases have been relatively recent and rare.

Hughes, who developed a process model based on his research on electrical power systems, did the groundbreaking theoretical work.[7] He conceptualized the network development process as having the following phases: (1) invention and development of a system (inventor-entrepreneurs play a dominant role); (2) transfer of technology from one region and society to another; (3) scaling-up of the network and emergence and resolution of critical problems or reverse salients (researchers and engineers play a dominant role); (4) system acquires momentum (managers play a central role); and (5) qualitative change in critical problems from technical to organizational ones (rise of financiers and consulting engineers). While this loose template has served a useful backdrop for subsequent analyses by researchers inspired by Hughes' pioneering work, two concepts—reverse salient and momentum—embedded in his larger framework have lent an analytical edge to their work.

Hughes borrowed the term 'reverse salient' from military historians who use it to identify a segment of an advancing battle line which has not been able to keep pace with other sections of the front. Hughes feels that this 'metaphor is appropriate because an advancing military front exhibits many of the irregularities and unpredictable qualities of an evolving technological system'.[8] In the case of technological systems, the 'reverse salients' arise whenever there is uneven growth between the different components of a system. The resulting imbalance leads to dysfunctional system development. The growth of the entire system is hampered and there is a need for an innovative solution if the expansion is to proceed. Thus reverse salients induce technological innovations by attracting institutional attention and resources and also independent inventors and entrepreneurs seeking fame and fortune. Momentum, the second metaphor Hughes employs, deals with the direction and pace of system development. According to Hughes, as the system grows, its span expands beyond technical objects to include the institutions that maintain and operate it, government agencies that regulate it, educational institutions that supply skilled professionals, and other 'institutional components' that sustain it. While discussing the development of polyphase universal electric supply systems, Hughes observed, 'the systematic interaction of men, ideas, and institutions, both technical and nontechnical led to the development of a supersystem—a sociotechnical one—with mass movement and direction. An apt metaphor for this movement is "momentum"'.[9] In other words, as more and more institutions and groups get aligned and invested in the system, it becomes difficult to change the direction of its development.

Hughes' pioneering effort attracted researchers of many hues to the study of large-scale systems.[10] The contents of three edited collections, Myantz and Hughes,[11] La Porte,[12] and Summerton,[13] give a sense of the scope of the subsequent activity in this new area of research. They include studies of railroads, electricity, telephone networks, aviation and aerospace systems, computing and information systems, automobility, off-shore oil production, and military systems. Over time, researchers have drawn on other theoretical approaches, beyond Hughes' historical approach, to analyze the development of large-scale systems. They include the actor–network theory,[14] derived from sociology of science,[15] and multidisciplinary communications research involving a mix of political economy, history, and cultural studies.[16]

The above-mentioned studies have tended to study a specific technology in depth or they have looked for patterns across multiple technologies. However, there have been few studies that have explicitly looked at relationships between network technologies. The other network technologies have at best been part of the backdrop of the 'life and times' of the technology that is the focus of study. Hochfelder, who looks at the changing nature of the relationship between Western Union (telegraph) and AT&T (telephone) over a century, is a rare exception.[17] The typical historical accounts mark the decline of Western Union and the rise of AT&T with the 1879 contract, in which Western Union misjudged the feasibility and potential of long distance telephony, between them. 'Historians typically view this contract as the start of both Western Union's decline and Bell's rise, and they have treated these as largely separate processes.'[18] Hochfelder instead argues that 'these processes were linked by a porous and shifting boundary between the two industries'.[19] Beyond the particulars of the Western Union–AT&T case, it is in his notion of a 'boundary' between competing network technologies, discussed later in the paper, where he makes contributions of a lasting value that can be ported to other technological contexts.

This paper emerges out of a stream of research that has included the study of the relationship between canals and railroads, railroads and automobility, telegraph and telephone, wireline telephone and cellular, and Internet and Wi-Fi.[20] This research shows that in the US a new network technology first strikes roots as a feeder to the established system.[21] The ensuing relationship between the new and old technology seems symbiotic and thereby stable and enduring. In effect, the new technology appears to have strengthened the entrenched paradigm but it is later shattered with the unanticipated development of an independent system based on the new technology. For example, the first major commercial application of railroads was to transport coal from the mines to canals. The canal companies invested heavily in the development of railroads because they saw them as complementary networks that fed traffic into canals from the outlying areas. At this point in time, long-distance railroads were beyond imagination as it seemed fanciful to suppose that the railroads would ever displace waterways for long-distance transportation of bulky cargo. Eventually, with the development of long-distance capabilities the railroads became competitors to the canals, and the earlier complementary relationship was broken. Similarly, long-distance automobility ruptured the complementary railroad–automobile relationship, long-distance telephony ruptured the complementary telegraph–telephone relationship, and long-distance wireless, especially Wi-Fi, portends to disrupt the established wireline–wireless relationship.

The above examples are limited to transportation and communication technologies where network externalities create an incentive to develop inter-modal compatibility and thereby a complementary relationship even when it is not readily available. For example, the first commercial use of railroads was as short-haul links between the coalmines in the hills and the canals down in the valley. Here intermodality was cumbersome—coal had to be physically carried from the railroad to the barges—but both parties were invested in it as it expanded the reach of their networks into areas they could not go on their own. Today, in our digital environment, inter-modal compatibility is much less of an issue since information can be relatively easily transferred from one mode to another, mobile to wireline to mobile. This was not always the case with earlier communication technologies. For example, telegraph messages could not be seamlessly carried over to telephone and vice versa. But even here efforts were made, first by Western Union via the 1879 contract and then by Bell in 1909 through its acquisition of a controlling stake in Western Union, to forge a complementary relationship between the two technological systems.

This paper expands the analysis of competition between an 'old' and 'new' technology beyond situations marked by complementarity. It employs two historic case studies—competition between gas and electricity and telegraph and telephone—as vehicles to generate insights into the modalities of competition between old and new network technologies. The two case studies share a similarity in that right from the very beginning both electric and telephone interests were confronted with an entrenched network technology, gas and telegraph respectively, that they had no choice but to deal with. But there is also a critical difference that was the determining factor in the selection of the two cases. In the case of telegraph and telephone, from the very outset, there was a potential for a complementary relationship since the telegraph wires could be used for the telephone service and vice versa. Gas and electricity, on the other hand, were pitted in a battle from the very beginning, with fewer chances of compromise because of the lack of potential complementarity in the distribution and consumption of the two services. The only place where there was some complementarity was in the production of electricity where gas could be used to run the generators. This contrast between the two competitive situations allows an examination of the impact of complementarity on dynamics of network competition.

The case studies of gas–electricity and telegraph–telephone competition are first presented in the next two sections. Thereafter Hughes' concepts of reverse salient and momentum and Hochfelder's notions of boundary are employed to analyze the dynamics of competition in the two cases.

Electricity

We start our analysis of gas–electricity competition by considering the original stance of the challenger, Edison. We then examine the dynamics of the ensuing competition between gas and electricity interests and the choices made by the consumers.

Original Stance

Edison was very aware that in order to beat gas he had to create a network system of his own. The system nature of both his competition and his own creation dominated his thinking. He mimicked gas to get electricity, which was then a radically new technology, accepted by consumers and thereby gain a toehold in the marketplace.[22] Aware that interior lighting generated 90% of the revenue of the gas industry, Edison poured his energies into developing a small 16 candle-power electric light (equivalent to the standard gas jet of the 1880s) that would be appropriate indoors. In Edison's own words, as he noted in his notebook:

> Object. Edison to effect exact imitation of all done by gas so as to replace lighting by gas by lighting by electricity … Edison's great effort not to make a large light or a blinding light but a small light having the mildness of gas.[23]

This determination was remarkable at a time when arc lamps of 1,000 candle-power and more were the state-of-the-art and the idea of a 16 candle-power electric light was considered as far fetched as the perpetual-motion machine.[24] It was Edison's much celebrated genius that eventually delivered the breakthroughs.

Edison presented his generator as an analog of gas-making plants and called his underground distributors 'mains' and 'tubes'.[25] Since people could control each gaslight individually, Edison developed a multiple distribution circuit that permitted any lamp in the circuit to be operated individually without affecting the operation of others. To meet the requirements of the multiple distribution circuit, Edison built a new type of dynamo that could provide constant voltage.[26] Edison called his electric bulbs burners and invented the electricity meter so that he could bill customers on a monthly basis just like the gas mills.[27] He set the prices at a level comparable to gas for the same amount of light.[28] Edison also made it a point to use the term light, in keeping with the terminology of the gas industry, instead of current until the 1890s when charging for the electric energy.[29]

In his quest to create an integrated system that generated, transmitted, controlled, and stored electricity, Edison invented a whole gamut of system components such as dynamo, conductors, filament, and battery. Edison is famously quoted as saying, 'All parts of the system must be constructed with reference to all other parts, since, in one sense, all the parts form one machine'.[30] In sum, Edison saw his challenge as fitting dynamos, switches, wiring, meters, and other components together into a system of power generation and distribution.[31] In order to efficiently implement this system vision, he created specialized companies each of whom concentrated on one major part of the system—dynamos, underground conduits, wires and other components.[32] Thus he very meticulously set out to create his electric system and 'gas served as a guiding analogy every step of the way'.[33]

Dynamics of Competition

Edison's first priority was to dramatically increase the illumination quality of the electric lamp. At first when electric lamps used relatively thick, low-resistant burners, incandescent lighting was not much better than gas light.[34] Edison figured that the solution lay in finding a very thin thread-like metal with a small radiating surface that would require only a small flow of current. After trying numerous materials and methods, Edison successfully used a carbonized thread for his first high-resistance filament in 1879.[35] To demonstrate this superior means of lighting to the public, Edison created a sensation by lighting 115 lamps on Columbia, a new steamship, during its maiden voyage.[36] Thereafter he focused on the outdoor commercial use, especially in downtown shops and exclusive hotels, of electric light to keep the new technology in the public eye.[37]

After inventing the filament, the heart of his electric lighting system, Edison went on to develop the physical infrastructure for an electricity distribution system. He was a strong supporter of central station generation and distribution of electric energy. He believed that supplying electricity for a large area from a single station would be most efficient and cost effective.[38] After two years of preparation, the first central station company—Edison Electric Illumination Co. of New York (EEIC)—was established. The Pearl Street Station, which was capable of illuminating up to 7,200 lamps, began operations on 4 September 1882.[39] EEIC did not charge customers for electricity in 1882 and showed a net loss for 1883. Realizing that the central station would not survive unless the high cost of long distance transmission was cut, Edison designed his three-wire system in 1883.[40] This resulted in a 60%

saving in the amount of copper required for distributing electricity.[41] In 1885 EEIC reported a net income of 6% on its capital investment of $828,800 and declared a dividend. The success of EEIC encouraged other investors to construct new central stations.[42] Thanks to Edison's invention and promotional effort, there was a rapid growth of central stations in many American cities.[43]

First established in 1816, the gas light industry was experiencing its most rapid expansion at the very moment electric light arrived on the scene.[44] By that time, the gas infrastructure was already in place, franchises had been granted, and manufacturing facilities for both gas and equipment were operating profitably.[45] The gas companies were quickly alarmed by the improving cost, safety, quality, and convenience of incandescent lamps. They resisted the advance of electric light in every possible way—political, technical, and economic.[46]

To prevent electric companies from building their physical infrastructure, gas companies tried hard to influence municipalities on matters concerning assignment of franchises, charters, rights-of-way, and street-lighting contracts.[47] Wherever possible, they would use bribes or contributions to election campaigns to achieve their objectives. In Cleveland many members of the city council were bribed for votes on franchise expansions and extensions.[48] In Chicago, the gas companies bribed the city council to prevent it from granting franchises to electric companies.[49] To counteract these political maneuvers, the electric companies competed with gas companies for political favors by bribing politicians. The ensuing public outrage induced political reform.[50] In addition to these corrupt practices, gas and electric interests also employed legal machinations to block the development of the rival system. In a village of New York City, an electric light company sought an injunction to prevent a gas light company from getting a contract for street lighting, and offered a lower price. After an investigation, the trustees of the village concluded that the electric company was not capable of providing a satisfactory service but agreed to reconsider the electric company in the following year, 1889.[51]

On the technical front, competition from electric lighting spurred the gas industry into making rapid progress in improving gas lighting.[52] Invented by Carl von Welsbach in 1885, the Welsbach gas mantle was able to produce a light six-fold better than the old flat flame or slip-tip burner.[53] Furthermore, it reduced the cost of gas lighting by over 60%.[54] Another notable innovation was a new method of making water gas, which burnt brighter than coal gas.[55] For a while the resurgent gas seemed to have won the battle as it threatened the very existence of the electric industry. In the mid-1890s some districts in New York City had many more Welsbach gas lamps than the Edison incandescent lamps.[56] While the mantle light was posing a formidable threat to electric light, the old carbon filament lamp had apparently reached its limits—no fundamental improvements had been made since 1884. What was needed was a breakthrough in the development of an illuminant that could be heated to well above 1,600°C.[57] In 1900 GE established the first industry-run fundamental research laboratory in America to continue the search for a better filament. The GE lab invented the GEM lamp in 1905, which operated at 25% higher efficiency than regular carbon lamps and lasted 4.75 times as long. GE started manufacturing tungsten lamps in 1907, which were more than twice as efficient as carbon ones.[58] It was the successful introduction of metallic filaments at the turn of the century that gave electric light a decisive and permanent lead over gas lighting.

The battle on the economic front was marked by consolidations and rate wars. As the gas companies merged to reduce costs, the Edison companies sought higher efficiency and cost savings by combining their separate operations. Accordingly, Edison started consolidating the companies that had specialized in manufacturing different parts of the system.[59] The complete consolidation of the Edison lighting companies occurred in 1889, when the Edison General Electric Co. was formed to include all the companies except those operating central stations.[60] In 1892 Edison General Electric Co. and Thomson-Houston Electric Co. merged to form General Electric Co. The two industry leaders pooled their talents and complemented each other. The former had arc-lighting business plus valuable AC technology; the latter had fundamental incandescent lamp patents and the Edison system of distributing electric energy.[61]

It took a long time for electric light to counter gas in the rate war. Due to the difficulties in improving manufacturing and distribution, it was not until 1896 that electric light companies were able to cut the price of lamps from $1 to 12 cents.[62] Residential electric energy rates per kilowatt-hour were reduced from 24 cents in 1883, which was about the same price as gas at that time, to about 9 cents in 1912.[63] Industrial and commercial rates similarly declined.[64] Thanks to the price cuts, the electricity service became affordable by more and more sections of the population.

Losing the battle on all three fronts—political, technical, and economic—and realizing the eventual dominance of electric lighting, gas companies adopted a two-pronged strategy: one, they started specializing in heating, conceding lighting to electric companies; and two, they started acquiring electric companies or merging with them.[65]

Consumers and Technology Choices

Like any new invention, electric light arrived on the scene with many imperfections. The light from arc lamps did not spread well and also the illumination was not as good as claimed. It generated fears of 'man-killing' electric wires and raised concerns about the nitrous gas produced by arc lights.[66] Many observers were of the opinion that gas would hold its own in domestic lighting, especially for the poor.[67]

Electric companies lit up prestigious hotels and the homes of the rich and the famous as public spectacles to educate the public and overcome resistance. As electric light became a symbol of class, posh clubs, shops, and theaters embraced it and the lesser prestigious establishments in turn felt pressured to follow suit.[68] For instance, when electric light was installed by a New York store in the 1880s, nearby competitors often saw it as an unproven experiment. But the increased traffic and business generated by brightly lit shop windows, to which gas lit shop windows were no match, forced the 'laggards' to follow suit. Thus electric light spread from one shop to another and one street to another. The success of outdoor commercial lighting generated interest and support for electric street lighting.[69]

The cities were quite receptive to electric street lighting. In many cases they awarded contracts to the electric companies even when the bid from the gas companies was lower. Often the cities even set up their own electricity generation plants to bring down the costs. However, the switch from gas to electric light was not smooth as some cities also switched back for a while to gas because of dissatisfaction with the electric service, competitive bids by gas companies, and other such reasons.[70] But, within nine years from the first use of electric streetlights in Paris, the new lighting technology had superseded gas lighting.[71]

Some of the first industrial users of electricity were concerns where the discernment of color was of particular importance. They included textile mills, printers, and furniture factories.[72] The managers of Hinds, Ketcham & Company, lithographers and printers in New York, found that with electricity they could 'match their colors and do their colored printing by artificial light', a critical activity that was earlier limited to daylight.[73] Electricity also facilitated work in the night for newspapers, shipyards, and builders. The other great advantage of electric lighting was that it did not have an open flame, making it attractive for industries such as flour-mills and chemical factories where the environments are highly inflammable.[74] As early as 1881, fire insurance companies started offering lower rates for companies that used electricity instead of gas.[75] Electric light also improved the overall working environment by removing the problems caused by gas—reduction in oxygen levels, heat, increased humidity, and acidic fumes. These features made electric light especially attractive in situations were a small light had to be placed near a worker. The clean nature of electric light was also attractive to clothing retailers and department stores because they no longer had to suffer the harm caused by smoke and fumes on fabrics and moisture that damped interiors and fogged shop windows.[76]

The introduction of electricity in the home occurred far more slowly than in the business world.[77] To quite some extent this was due to the infrastructure investments required in power lines and drops to individual houses before a 'private installation' could be made possible. Also, the cost of the service had to be brought down to an affordable level.[78]

Electric companies offered free installation and discounted rates to get residential users to sign up for electricity.[79] For instance, in 1898 Samuel Insull directed a door-to-door sales campaign of the affluent homes in Chicago. He offered to install six outlets for free and to wire the rest at cost, which could be paid via a deferred-payment plan. This offer was complemented by reduced rates for electricity consumption.[80] To extend electricity to apartment dwellers, the electric company got the landlords to sign up for hall lighting by installing wiring for free and providing service at a discounted rate.[81] Not unlike what telecom companies are currently doing with regard to the deployment of fiber optics for residential use, the electric companies sought to get electric wiring to be part of the basic infrastructure of houses that were under construction. In the early 1910s, Harrisburg Light and Power Co. ran the advertisement: '"if you are planning a home would you leave out electric light?" Of course, not!'[82] The architects, lawyers, and developers were supplied with literature on model plans that subtly emphasized the advantages of electricity over gas by placing electric fixtures in pantries, closets, and other confined spaces where gaslight was not feasible.[83]

The gas companies fought back. They also offered free installation, reduced rates, and promised top-notch maintenance.[84] By 1911, 16–18% of urban households had become consumers of central station supplied electricity. Still most middle class families could not afford to switch from gas to electric lighting. With declining electric rates, between 1911 and 1916, electricity spread rapidly among the middle class.[85] However, older houses and the poor households continued to rely on gas.[86] The rates fell further in the 1920s and then the electric service reached 'every type of consumer'.[87]

The diffusion of electricity within the house also occurred in stages. Initially electric light was limited to the dining room and the parlor, the places where guests were entertained. For the rest of the house, consumers felt that gaslight was adequate. Furthermore, even in the dining and living rooms, dual gas/electric chandeliers were popular until at least 1910, suggesting that consumers used electricity for special occasions and then reverted back to gas once the guests had departed.[88] Edison preferred placing electric wires in the gas conduits when the consumer had gas lighting. If the consumer refused to give up gas service completely or did not have gas in the first place, Edison would try to get the consumer to install another set of tubes in order to keep the wires hidden. In any case, starting as early as 1883, Edison required installation of white wires so that they would blend in with the wall and not disrupt the aesthetics.[89]

Electric companies also gave away electrical appliances such as electric irons. These promotional efforts had dual objectives. In addition to making electricity more attractive, they sought to balance demand. Their power generation plants were built to handle night-time peak loads when the demand was inelastic, which resulted in idle capacity during the daytime. They sought to build up daytime demand to make use of this idle capacity and thereby spread the large fixed costs of setting up and running power generation plants to satisfy peak time demand. The market for electric appliances grew in time and by the early 1900s electric merchandisers had their own magazines such as *More Juice*, *Selling Electricity*, and *Electrical Merchandising* promoting the art of marketing electric appliances. The effort to promote the sale and usage of electrical appliances included advertisements, public demonstrations, fancy showrooms, bill inserts, promotional giveaways, cook books, and manuals for planning kitchens.[90]

It was the sharp increases in the illumination power that started winning ground for electric lights. Therein the other attractive features of electric light—cleanness, convenience, and comfort—became even more attractive. With declining prices for electric lighting, gas was gradually pushed out of the market.

Telephone

As in the previous section, we start by considering the original stance of the new competitor, Bell. We then examine the dynamics of the ensuing competition between telegraph and telephone interests and consumers' response to technology choices.

Original Stance

At the time of the founding of the Bell Company in 1878, Alexander Graham Bell (hereafter A. G. Bell)[91] had an expansive vision akin to that of Edison's for the future of telephone which he thus articulated:

> cables of telephone wire would be laid under ground, or suspended overhead, communicating by branch wires with private dwellings, country houses, shops, manufacturers, … and a man in one part of the country may communicate by word of mouth with another in a different place.[92]

However, interestingly, while the evidence is mixed as to whether or not in 1876 an actual offer was made to Western Union for the sale of Bell patents for $100,000, Bell seems to have at least entertained that possibility just two years before he advanced his above articulated expansive vision.[93] This footnote is important because it marks Bell's first swing between the 'small vision' (co-existence with telegraph) and the 'big vision' (creation of an independent system) for its network. We will soon see that the entire history of the telephone–telegraph relationship is marked by such swings.

Dynamics of Competition

In July 1877 the Bell Telephone Company started business as a manufacturer of telephone sets rather than a network service provider. The customers were expected to string and maintain their own wires for simple point-to-point connections, say between a doctor and a pharmacist. Bell would lease and maintain the telephone sets for $40 per year for business customers and $20 per year for residential customers. The telephone started weaning customers, especially New York brokers, away from Western Union's Gold and Stock Telegraph Company, which provided intra-urban telegraph service to businesses, and that alerted the telegraph giant. Western Union launched the American Speaking Telephone Company in December 1877 and entered the telephone business. At that time, Western Union had formidable financial clout, a national network which could be transformed into telephone use, and the talent of Edison, who invented a magneto transmitter that performed much better than the Bell transmitter.[94] Bell cried foul and filed a patent infringement lawsuit. Meanwhile, Bell regained the technical lead. At the end of 1878, Bell acquired the rights to the Blake transmitter, which performed better than the Edison transmitter.

Western Union's entry as a competitor energized Bell's 'big vision'. The ensuing competition propelled network development as each competitor sought to be the first to establish networks, which by 1878 had evolved beyond simple point-to-point ones to switched ones in major markets and thereby secure a strong competitive position. Within each locale, the benefits of network externalities, which are particularly critical in a competitive situation, impelled the competitors to expand their networks as fast as possible. Unlike in technical and patent battles, Bell seemed unable to hold its own in the financial war, which was draining up its treasury. Yet, after much bloodletting, Western Union decided to withdraw from the telephone business in 1879 because of the urgent need to counter severe attacks by Jay Gould who sought to gain control of the telegraph business.[95] The terms of the settlement that Western Union reached with Bell before its withdrawal are noteworthy.

Under the terms of this deal, Bell and Western Union agreed to limit themselves to telephone and telegraph businesses, respectively, and not enter each other's markets. Furthermore, Bell agreed to pay Western Union 20% of telephone rental receipts over the 17-year life of the Bell patents.[96] However, the mutuality of the agreement could be undermined if Bell developed long-distance capabilities. This was the trickiest part of the agreement.

> The negotiations hung on the condition denying to the Bell interests the right to connect their exchanges by means of toll lines. Few had faith in the future of the toll lines or their value as compared with the private lines, but if long distance conversation should be developed the Western Union feared it might be a menace to the telegraph business.
>
> The conferees of the Bell were divided about the toll business; some of them tired of the contest, preferred half a loaf in peace and comfort, rather than a struggle for a whole loaf; if yielding would bring about a settlement some were

> willing to yield. To me the idea of yielding the toll line use meant the curtailment of our future—the absolute interdiction of anything like a 'system'.[97]

Eventually Western Union acquiesced because it did not think that long-distance telephony, even if it became technically possible, would pose a competitive threat. Western Union's customers were primarily businessmen and it could not imagine them conducting transactions over the telephone, which did not provide a written record.[98]

This agreement is notable because it reveals a marked tendency within Bell to prefer 'half a loaf in peace and comfort' or slide towards the 'small vision' whenever offered an opportunity to peacefully co-exist with telegraph. It was Theodore Vail's vision and determined leadership that got Bell to keep its long-distance options open and then to act on it.

For a long time the very idea of long-distance telephony was considered farfetched if not absurd even after the Western Union–Bell agreement. Ironically, there were few believers even within the Bell system. So much so, in order to create a more positive organizational environment for the development of long-distance telephony, Vail set up a separate wholly owned subsidiary—AT&T—in 1885. Even then there were internal obstacles to the creation of a long-distance network. One of the biggest problems that Thomas Doolittle, Vail's senior manager assigned with the task of creating a long-distance network, faced was the reluctance of the regional operating companies to invest in the facilities required for developing long-distance-capabilities. The problem was that the managers of the regional companies '[were] very apt to fix an imaginary center in [their] territory, overlooking the requirements of adjoining territory'.[99] Accordingly, they tended to undervalue extraterritorial links that were necessary to create a system that benefited everybody. They would rather invest in network expansion within their own franchises than in extraterritorial long-distance links that seemed to have a modest earning potential.[100] It was because of Vail's and Doolittle's persistence that the long-distance telephone network eventually started materializing.

In 1886 Bell developed the first long-distance link between New York and Philadelphia over which it started leasing private lines for both telephone and telegraph use. This initial penetration of the boundary that Western Union thought it had secured in 1879 was part of a deliberate strategy to dominate the entire communications industry. Yet, on the other hand, Bell did not want to draw the government and the public's ire as a monopolist. This tension between a deep-seated desire to dominate and yet not get perceived to be a monopolist marked the Bell–Western Union relationship over the next several decades. Since an outright purchase of Western Union was politically hazardous, Bell pursued dominance via technological prowess and market power. Among other things, it started offering a 'composite' service that allowed one voice and two telegraph circuits over one pair of wires. Eventually, the wave of mergers in the 1890s that led to the formation of industrial giants such as US Steel and Standard Oil emboldened Bell to try and acquire Western Union. After a failed attempt in 1902–03, Bell secured a 30% stake and thereby working control of Western Union in 1909. Bell envisioned an integrated system whereby subscribers would use the telephone to call the telegraph office to send messages and vice versa. It started modernizing the telegraph network by, among other things, replacing the Morse equipment with a multiplex printing telegraph system.[101]

However, it divested Western Union in 1914 mainly because of the political heat its monopoly was generating. The independent telephone companies it was battling had filed an anti-trust suit and there was talk within the Wilson administration of nationalizing telephones and telegraphs. The recent breakups of Standard Oil and American Tobacco as a result of anti-trust actions by the Department of Justice forebode a similar fate for AT&T if it persisted with its monopolistic ways. The Western Union that Bell let go was a revitalized organization with a modernized network, but then, Bell retained critical assets that ensured that Western Union would remain in a subservient position.[102] Bell maintained its hold on the leased-wire business, Western Union's railroad rights-of-way, and printer patents that enabled it to later launch the very successful teletypewriter exchange (TWX) service. Furthermore, Western Union continued to depend on Bell for leased lines and also equipment and new technology. The tide was clearly against telegraph as other means of long-distance communication such as telephone and airmail steadily improved. By World War II it was 'a beer and pretzels business' or a 'very sick' industry.[103] Yet, Western Union lingered on until the 1990s.

Western Union was in many ways propped up by FCC and Bell. FCC sought to ensure the survival of Western Union to maintain some semblance of competition in the long-distance telecommunications business. Among other things, along with the Department of Justice, it supported the amendment of the Communications Act of 1934 to allow Western Union to buy out the Postal Telegraph Company. Once the enabling legislation was passed, FCC pressured Western Union to merge with Postal because it felt that the combined company would have a better chance of survival. Bell, on the other hand, leased circuits, supplied terminal equipment, and provided other technological assistance. The situation was very nicely captured by the title of a 1959 *Fortune* magazine article—'Western Union, by grace of FCC and AT&T'.[104]

Over the years Western Union made a number of attempts to reinvent itself but to no avail. 'In 1990, Western Union sold AT&T its communications businesses for $180 million of sorely needed cash, thereby completing the process begun in 1876. Within a few years the corporation itself had ceased to exist, and today only its logo remains.'[105]

Consumers and Technology Choices

The first challenge A. G. Bell faced was to get the public over the strangeness of the new technology. He conducted a series of lectures and public demonstrations to introduce the new technology. Even though the public applauded the technological genius behind the telephone, they had no 'obvious use' for it.[106]

The first telephones that connected two points were substitutes of existing point-to-point telegraph lines. The telephone's big advantage was that it did not require the services of trained operators.[107] Yet, Bell had to reassure the public that the telephone was not difficult to use and 'conversation can be easily carried on after slight practice and with occasional repetition of a word or sentence'.[108]

While the telegraph provided effective inter-city communication, intra-city communication was a problem. A large number of messengers were employed by various organizations to hand carry messages to and from the telegraph offices—a slow and labor-intensive process. Over the years various adaptations of the telegraph—indicators, call boxes, printing telegraphs, and others—were developed to enhance intra-city communication. For example, the above-mentioned Gold &

Stock Telegraph Company connected about 50 New York banks with the clearing-house via a printing telegraph. Beyond these specific purpose networks, there were the district telegraph networks that served commercial and residential users. They typically had a mechanism for signaling to the central office the type of service requested. For example, in the case of American District Telegraph Company in New York, the number of turns of the signaling box's crank indicated the service desired—messenger, police, fire, physician, horse and buggy, and others. These district telegraph networks were Bell's next targets. Bell instructed its agents to 'use their best efforts for the introduction of the Telephone into the district Telegraph system … since the advantages of the telephone over the District System are apparent'.[109]

In the first decade, the telephone was overwhelmingly a business service because it developed as a substitute for the telegraph and also Bell's thinking was influenced by the practices of the telegraph industry. Furthermore, only businesses could afford Bell's rates. For example, only six out of 300 telephones in Pittsburgh's 1879 telephony directory were residential. Even these were of businessmen who wanted to keep in touch with their business operations while at home.[110]

The crucible for the development of the first telephone exchange was the Bridgeport Social Telegraph Association, which started in 1874 when a group of friends used private telegraph lines to send messages to each other in Morse code as a hobby and it later grew to include some other homes and local businesses. The exchange concept had existed in the telegraph business. For instance, the Gold & Stock Telegraph network had limited switching capability that allowed one bank to communicate with another. Even A. G. Bell had spoken about a telephone exchange. So, the concept was well known. The issue was how to make it a practical mechanism. When the telephone became available, the association members started replacing the telegraph with telephone and through trial and error developed a rudimentary telephone exchange.[111]

The first inter-town toll line, which connected Bridgeport to Black Rock, also grew out of the activities of the Bridgeport Social Telegraph Association in the 1870s. This line was a quick success. Interestingly, according to Walsh, one key factor for its success was that the telephones were installed in closed booths, the first known usage of telephone booths. The *Bridgeport Daily Standard* on 15 June 1878 observed that 'the new system … gives privacy on the line and prevents eavesdropping'.[112] Thereafter another line was created which connected Southport, Fairfield and Bridgeport and which in turn was connected to the Black Rock line. This line was also a quick success.[113] However, as the lines got longer, the development of long-distance telephony was no longer smooth. For instance, the Boston–Providence line, which started providing a commercial service in January 1881, was generating only 21.5 messages on average per day after four months of operation. The reasons were twofold: (1) the set up time for a call was about 45 minutes; and (2) the audible interferences generated by induction made it difficult to communicate. Similarly, the Boston–New York line for a long time did not give a satisfactory service or reasonable financial returns.[114]

Reflecting on the slow pick-up of early long-distance lines, Walsh offers the following reasons: (1) long-distance telephony was a novelty and people were not familiar with it; and (2) transmission problems. Interestingly, he believes that

> the chief deterrent to patronage was the matter of inconvenience. To make a long-distance call it was necessary to go to the central office in one city in

> order to call a subscriber in another city. The only alternative was to telephone the message to the central office and have the operator relay it. In that case, however, the great advantage of the telephone over the telegraph—its privacy—was lost, and it was just as easy to use the older form of communication.[115]

Even when a user took the pains to go to the central office, the availability of a reliable circuit was uncertain and the set up time for the call quite long.[116] The lack of enthusiasm for long-distance on the part of ordinary users is evident in a simple statistic—between 4 September and 31 October 1884, there were only 19 paid calls, generating $9.50 total revenue, between New York and Connecticut.[117]

The introduction of metallic circuits eliminated the need for a trek to the central office to make a long-distance call. The vacuum tube based amplifier and other technological developments brought the long-distance costs down and improved the overall quality of the telephone service. Also, Bell Telephone assiduously educated the people about long-distance telephony. One particularly popular device was to set up special booths at fairs, railroad stations, and other public places from where people could make free long-distance calls for the fun of it.[118] While long-distance usage grew, in the early 1900s approximately 90% of the long-distance calls were limited to a 50-mile radius.[119] For longer distances, telegraph remained a much cheaper alternative. Gradually technological breakthroughs eliminated the problems and accentuated telephone's decided advantages over the telegraph—immediacy of communication and privacy.[120]

The public officials and the bankers were among the slowest to adopt the telephone. The public officials were immersed in a culture of written documents and uniformed messengers.[121] Under Presidents Cleveland and Harrison, there was only one telephone in the White House that was used mainly by the servants. President Garfield was the first president to make extensive use of the telephone including for the organization of election campaigns, but then his successor, President Roosevelt, used the telephone only for emergencies. With the next president, President Taft, the White House got its own branch exchange and thereafter the usage of the telephone continued to grow. The bankers were also 'slow to abandon the fallacy that no business can be done without a written record'.[122]

The hotel industry was quick to adopt the telephone. In the pre-telephone days hotels had to employ an army of messengers. Furthermore, each service call necessitated two trips by a messenger—one to get the order and the second to deliver the requested service. By 1900, almost all the large and mid-sized hotels had installed telephones in every room. In 1909 the hundred largest New York City hotels had about 21,000 telephones—about the number that were on the entire continent of Africa and greater than the number in Spain.[123] On the other hand, the railroads were also slow to develop trust in the telephone and they continued to use the telegraph for many decades. Pennsylvania Railroad became the first railroad to install a phone in 1879 but the telegraph continued to be used for routine transfer of information on reservation, car orders, and other administrative matters into the mid-1950s.[124]

In the beginning the potential for residential use of the telephone was uncertain and many Bell executives had doubts whether it was worth the trouble and expense. Bell focused on business users and neglected residential users, especially those in small towns and rural areas, prompting Fischer to characterized residential service as a 'stepchild in the system'.[125] Even when marketing to the residential market, Bell focused on the 'business' of the household. The company made the pitch that the telephone would make running the house more efficient by saving time and labor and also be valuable in a time of emergency. It also undertook social education to mold how people conversed over the telephone. Bell sought to curtail profanity and yelling and instill telephone etiquette in the users. In particular Bell tried to eliminate 'hello', a vulgarity in its view. Bell also tried to teach its customers not to talk for too long on the telephone and sent warning letters to particularly talkative ones. The social uses of the telephone in Bell advertisements were limited to brief messages—greetings, invitations, and notification of safe arrival. The entire exercise was geared towards furthering instrumental uses of the telephone and minimizing social ones. It was only in the 1920s that Bell accepted and embraced sociability, especially for drumming up business for its long-distance service.[126]

The telegraph was not a stumbling block for the spread of the telephone. What slowed telephone's growth, at different points in its development, were shortfalls in technological capabilities and the established practices of the users. With each new technological breakthrough, a new portion of the telegraph market opened up for the telephone. For example, the metallic circuit removed a nuisance factor—the trek to the central office—and thereby underscored telephone's decided advantages over telegraph for long-distance communication. As the cost difference between the telegraph and the telephone diminished, the telegraph had to cede the market to the technologically superior telephone. The established practices, on the other hand, were changed gradually via marketing and also the passage of time.

Conclusions

Hochfelder and Hughes make a major contribution to the literature via their 'boundary' and 'reverse salient' concepts, respectively.[127] Interestingly, they generate similar figurative images: a shifting boundary for Hochfelder and a marching line for Hughes. It seems as if Hochfelder is sitting on the boundary and watching both sides while Hughes is viewing the battle from the perspective of the new system. This paper brings together the perspectives of Hochfelder and Hughes to examine the dynamics of competition between competing network technologies.

The two case studies suggest that the degree of complementarity greatly shapes the dynamics of competition between an entrenched network technology and a new competitor. When there is little scope for a complementary relationship, as in the case of the gas–electricity battle, the strategists for the new technology have to subvert the old system and build a new one on its ashes since there is little chance of coexistence. Correspondingly, the aggressiveness of the new system makes it futile for the old system to even get into the boundary maintenance posture. The old system is forced to grow and enhance its competitiveness. It is in many ways a battle of the reverse salients in the sense that their continual occurrence and resolution is a marker of system growth. On the other hand, the possibility of a complementary relationship, as in the case of the telegraph–telephone battle, allows for the emergence of complex situations marked by coexistence interwoven with competition. These compromise positions, invariably involving re-negotiation of boundaries, are tempting resting spots for battle weary contestants. As the relationship between the old and the new system evolves, the nature of the complementary relationship changes, especially in the relative power of the two systems, and even if eventually the old system fades away the process is a long and gradual one.

Complementarity was also a factor in determining the aftermath of the battle. After vacating the lighting market to electricity, gas companies started specializing in heating where they had a cost advantage over their rival. Western Union also tried to survive by specializing in what seemed like an area of unique strength—record communications. It even lobbied the Congress to get it designated as the 'chosen instrument' of the 'record communications industry'. In effect, Western Union wanted a monopoly over all telecommunications services, domestic and international, that entailed the production of a written record. However, this lobbying effort did not succeed. Over time developments in telecommunications technologies made the very idea of a separate 'record communications' category untenable.[128] The problem was that the complementarity between telegraph and telephone kept the boundary between them porous and innovations in the latter, the more scientifically advanced technology, always had the potential to undermine the former no matter what it chose to focus on.

We chose to study the gas–electricity and telegraph–telephone cases because, as explained earlier, we were interested in understanding how the possibility of a complementary relationship or its lack impacts dynamics of competition between two competing network technologies. We saw in the two case studies that its presence or absence alters the dynamics of competition. On the other hand, the two case studies also brought into play another difference between the gas–electricity and telegraph–telephone cases that was not salient to us before—the 'old' network technology in the case of gas–electricity competition was actually much 'younger' than its correspondent, telegraph, in telegraph–telephone competition. The implications of this difference are evident in the competitive responses of the two incumbent network systems.

Gas battled electric interests on all fronts—political, technological, and economic. On the other hand, Western Union's defensive strategy after the 1879 contract was largely a political one—eliciting governmental support for boundary maintenance. The difference is particularly striking on the technological front. Gas's response on the technological front was extremely vigorous. In fact at one point, after the invention of the Welsbach gas mantle, it seemed that gas had won the battle on the technological front. Western Union, on the other hand, showed technological vigor only in its pursuit of telephone technologies in the pre-1879 competitive period. There was no corresponding burst in the enhancement of the telegraph technology itself. In fact Bell, after it secured a working control of Western Union in 1909, modernized the telegraph network. As Hughes points out, momentum can also mean inertia.[129] We see forward momentum in the development of gas and inertia in the case of telegraph. Perhaps it could not have been different in any significant way. While the telegraph was already a mature technology when competition started, gas was still a young one with its potential not yet fully exploited.

At the user level, there was a notable difference in consumer resistance to the new technology. It was higher for electric lighting than for the telephone. The gas users already had the piping and other infrastructure installed in their homes and hence faced a significant switching cost. The situation was very different in the case of the telephone on two levels. One, the internal infrastructure required for the telephone service was far less extensive than that for the electric service with multiple outlets in each room. Two, adoption of the telephone meant wiring up interior spaces that almost never had prior telegraph wiring. In even those rare cases, the telegraph wires, at least in the initial stages of the telephone's development, could be used for the telephone service. The existence of prior gas infrastructure also allowed consumers to adopt electric light in phases, starting with the dining room and the parlor. The adoption of the telephone, on the other hand, was a one step process. These differences at the consumer end varied the texture of the terrain over which gas–electricity and telegraph–telephone battled each other.

Today, in a perhaps much more complex environment, we are seeing a combination of what seemed like distinct elements in the above analysis. The digital technologies, as noted earlier, greatly facilitate inter-modal transfer of information and it is therefore easy to assume complementarity between communications systems. But we know from a myriad of failed mergers, most notably AT&T's acquisition of cable assets, that while digital bits readily mix the institutions are a whole different ball game. In reality then, even in the case of communications technologies, the degree of potential complementarity ranges from very high to very low. The gas–electricity and telegraph–telephone cases help set up a continuum of sorts for analyzing how the competitive dynamics may play out for various old and new network systems that are competing today. We also have multidimensional competition involving all kinds of permutations and combinations between 'old' incumbents, 'young' incumbents, and 'new' upstarts of various hues. Furthermore, instead of one-on-one competition in the cases discussed, the competitive situation today often involves multiple network technologies in a myriad of configurations. Quite clearly, the cases we have studied cannot help us make sense of all this complexity in its entirety, but we do hope that we have provided insights that will allow for more sophisticated analyses in the future.

Notes and References

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2. Chandler, *op. cit.*, p. 195.
3. E. Gabler, *The American Telegrapher: A Social History, 1860–1900*, Rutgers University Press, New Brunswick, NY, 1988; P. Israel, *From Machine Shop to Industrial Laboratory: Telegraphy and the Changing Context of American Invention, 1830–1920*, Johns Hopkins University Press, Baltimore, MD, 1992; R. R. John, *Spreading the News*, Harvard University Press, Cambridge, MA, 1995; R. L. Thompson, *Wiring a Continent*, Princeton University Press, Princeton, NJ, 1947.
4. J. Carey, *Communication as Culture: Essays on Media and Society*, Unwin Hyman, Boston, MA, 1989.
5. The automobile-highway system is in one fundamental aspect very different from the railroads. Unlike the railroads, the automobiles are not common carriers but instead are individually owned. Though it lacks the formal integration of the railroads, the diverse elements which make automobile transportation possible function as one mammoth system. Burnham offers 'automobility' as a term for the concept that encompasses the automobile and other entities related to it (J. C. Burnham, 'The gasoline tax and the automobile revolution', *Mississippi Valley Historical Review*, 48, 1961, pp. 435–59). According to Flink, the term 'conveniently sums up the combined impact of the motor vehicle, the automobile industry, and the highway plus the emotional connotations of this impact for Americans' (J. J. Flink, *The Car Culture*, MIT Press, Cambridge, MA, 1975, pp. 1–2).
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Cambridge, MA, 1981; M. Childs, *The Farmer Takes a Hand: The Electric Power Revolution in Rural America*, Da Capo Press, New York, 1974; K. Hafner and M. Lyon, *Where Wizards Stay up Late: The Origins of the Internet*, Simon & Schuster, New York, 1996; D. E. Nye, *Electrifying America: Social Meanings of a New Technology, 1880–1940,* MIT Press, Cambridge, MA, 1990.

7. T. P. Hughes, *Networks of Power: Electrification in Western Society, 1880–1930*, Johns Hopkins University Press, Baltimore, 1983.
8. *Ibid*, p. 14.
9. *Ibid*, p. 140.
10. The term 'large-scale systems' has been intentionally used here because the influence of Hughes' work goes beyond network technologies that are the focus of this paper. It also includes nuclear power plants, the space shuttle, supercomputers, and other large technical systems.
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14. M. Akrich, 'The de-scription of technical objects', in W. E. Bijker and J. Law (eds), *Shaping Technology/Building Society: Studies in Sociotechnical Change*, MIT Press, Cambridge, MA, 1992, pp. 205–24; M. Callon, 'Society in the making: the study of technology as a tool for sociological analysis', in W. E. Bijker, T. P. Hughes and T. J. Pinch (eds), *The Social Construction of Technological Systems,* MIT Press, Cambridge, MA, 1987, pp. 83–103.
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17. D. Hochfelder, 'Constructing an industrial divide: Western Union, AT&T, and the federal government, 1876–1971', *Business History Review*, 76, 4, 2002, pp. 705–32.
18. *Ibid*, p. 705.
19. *Ibid*, p. 705.
20. H. Sawhney, 'Public telephone network: stages in infrastructure development', *Telecommunications Policy*, 16, 1992, pp. 538–52; H. Sawhney, 'Wi-Fi networks and the rerun of the cycle', *Info: The Journal of Policy, Regulation and Strategy for Telecommunications, Information and Media*, 5, 6, 2003, pp. 25–33; H. Sawhney, 'Wi-Fi networks and the reorganization of wireline–wireless relationship', in R. Ling and P. Pedersen (eds), *Mobile Communications: Re-negotiation of the Social Sphere*, Springer-Verlag, London, 2005, pp. 45–61.
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22. Today we see a parallel in Internet phone service providers piping in a fake dial tone to make the new technology feel familiar (D. Leonhardt, 'A voice in the calling wilderness', *New York Times,* Thursday, 18 December 2003, p. E1).

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24. *Ibid.*
25. H. L. Platt, *The Electric City: Energy and the Growth of the Chicago Area, 1880–1930*, The University of Chicago Press, Chicago, 1991.
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38. Bright, *op. cit.*
39. Keating, *op. cit.*
40. Hughes, *op. cit.*
41. Keating, *op. cit.*
42. Hughes, *op. cit.*
43. Keating, *op. cit.*
44. Bright, *op. cit.*
45. *Lighting a Revolution: Promoting Edison's Lamp*, 2003, available at: http://americanhistory.si.edu/lighting/19thcent/promo19.htm, last accessed 24 August 2004.
46. Bright, *op. cit.*
47. Nye, *op. cit.*
48. *Ibid.*
49. Platt, *op. cit.*
50. *Ibid.*
51. 'Fight between gas and electricity', *New York Times,* 4 April 1889, p. 8.
52. Bright, *op. cit.*
53. Foster, *op. cit.*
54. Keating, *op. cit.*
55. M. H. Rose, *Cities of Light and Heat: Domesticating Gas and Electricity in Urban America*, Pennsylvania State University Press, University Park, PA, 1995.
56. Foster, *op. cit.*
57. Bright, *op. cit.*
58. Keating, *op. cit.*
59. *Ibid.* The Edison Electric Light Co. took over the Edison Company for Isolated Lighting in 1886. In the same year, Edison United Manufacturing Co. was formed to consolidate Edison Machine Works, the Edison Lamps Co., and Bergmann & Co. (Bright, *op. cit.*).
60. Keating, *op. cit.*

61. *Ibid.*
62. Bright, *op. cit.*
63. *Ibid*; Foster, *op. cit.*
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65. *Ibid*; Nye, *op. cit.*
66. *New York Times,* 6 September 1880, p. 4; Platt, *op. cit.* To explain the new technology to the public Edison compared electric current to water moving through pipes that goes around a loop, the electricity generator being the pump that keeps the water moving. Not only did this analogy provide a prop to visualize the current, it also suggested that electricity was safe (M. A. Hellrigel, *The Quest to be 'Modern'; The Adoption of Electric Light, Heat, and Power Technology in Small-Town America, 1883–1929*, Doctoral dissertation, Case Western Reserve University, 1997).
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70. Article 2, *New York Times*, 29 May 1887, p. 4; 'Once again in darkness', *New York Times,* 17 October 1889, p. 2; F. McDonald, *Insull*, University of Chicago Press, Chicago, 1957.
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73. Nye, *op. cit.*, p. 192.
74. Commenting on the electricity in the Sibley Mill Plant, in 1882 *Augusta Chronicle and Constitutionalist* wrote: 'So safe is the system … that a drop light can be used about in the lint of the mill and sawdust of the workshop without danger' (quoted in Nye, *op. cit.*, p. 191).
75. Orange County Woolen Mills testified in 1882 that the lowered insurance costs within two years paid for the installation costs (Nye, *op. cit.*).
76. *Ibid*; Passer, *op. cit.*
77. Tarr and Dupuy, *op. cit.*
78. Marvin, *op. cit.*
79. Hellrigel, *op. cit.*; Platt, *op. cit.*
80. Platt, *op. cit.*
81. *Ibid*; Tarr and Dupuy, *op. cit.*
82. Hellrigel, *op. cit.*, p. 211.
83. Platt, *op. cit.*
84. Foster, *op. cit.*
85. Tarr and Dupuy, *op. cit.*
86. Rose, *op. cit.*
87. Tarr and Dupuy, *op. cit.* Education in the public schools played an important role in the spread of electricity in the domestic sphere. The students, familiarized with the new technology in their schools, later went on to become consumers.
88. Platt, *op. cit.*
89. Hellrigel, *op. cit.*
90. *Ibid.*
91. At times it is necessary to distinguish Alexander Graham Bell, the inventor, from the Bell Telephone Company, the company he co-founded. But this distinction is often difficult to make because both are referred to as 'Bell' in the literature. The most logical solution would be to write their complete names each time the inventor or the company is mentioned, but that would make the text very cumbersome for the reader. So, for the purposes of this paper, whenever something is said specifically with reference to the inventor, he will be identified as A. G. Bell. When he and his associates or his company is involved, only 'Bell' will be used.

92. J. E. Kingsbury, *The Telephone and Telephone Exchanges: Their Invention and Development*, Arno, New York, 1972 (original work published 1915), p. 90.
93. According to the standard account, which has been retold time and again by scholars and lay commentators, Bell offered to sell his telephone patents to Western Union for $100,000 but the offer was turned down. But Hochfelder challenges this account as he fails to find conclusive evidence of such an offer. He discounts testimonies, including one before the Congress, by Norvin Green, president of Western Union, and Thomas Watson, A. G. Bell's research and business partner, because of discrepancies he painstakingly details. At best, he finds 'oblique references' to negotiations between Bell and Western Union in the papers of Gardiner Hubbard, Bell's business partner (Hochfelder, *op. cit.*).
94. Brooks, *op. cit.*
95. Hochfelder, *op. cit.*
96. Brock, *op. cit.*
97. Vail quoted in *Ibid*, p. 96.
98. R. W. Garnet, *The Telephone Enterprise: The Evolution of the Bell System's Horizontal Structure, 1876–1909*, John Hopkins University Press, Baltimore, MD, 1985.
99. K. Lipartito, *The Bell System and Regional Business: The Telephone in the South, 1877–1920*, John Hopkins University Press, Baltimore, MD, 1989, p. 122.
100. *Ibid*; Garnet, *op. cit.*
101. Hochfelder, *op. cit.*
102. Bell's desire to keep Western Union in a subservient position is especially revealing in how it dealt with its carrier-current technology that allowed 20 simultaneous telegraph transmissions over one pair of wires. Bell refused to license its carrier-current technology to Western Union because it could enable the latter 'to compete on equal, or perhaps even superior terms, with the Long Lines Department for leased telegraph wire business' (quoted in Hochfelder, *op. cit.*, p. 726). However, Bell was willing to lease carrier channels to Western Union.
103. Hochfelder, *op. cit.*
104. *Ibid*, p. 725.
105. *Ibid*, p. 731.
106. S. H. Aronson, 'Bell's electric toy: what's the use? The sociology of early telephone use', in Ithiel de Sola Pool (ed.), *The Social Impact of the Telephone*, MIT Press, Cambridge, MA, 1977, pp. 15–39. Furthermore, they had difficulty distinguishing between the telegraph and the telephone, associating the latter with the transmission of music (*Ibid*). Later Bell faced challenges such as persuading non-English speakers that the telephone 'spoke' their language (C. Fischer, *America Calling*, University of California Press, Berkeley, 1992).
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110. Aronson, *op. cit.*
111. *Ibid*; J. L. Walsh, *Connecticut Pioneers in Telephony: The Origin and Growth of the Telephone Industry in Connecticut*, Morris F. Tyler Chapter, Telephone Pioneers of America, New Haven, CT, 1950.
112. *Ibid*, p. 332.
113. *Ibid.*
114. *Ibid.*
115. *Ibid*, p. 142.
116. R. Abler, 'Effects of space-adjusting technologies on the human geography of the future', in R. Abler, D. Janelle, A. Philbrick and J. Sommer (eds), *Human Geography*, Duxbury Press, North Scituate, MA, 1975, pp. 35–56; J. V. Langdale, 'The growth of long-distance telephony in the Bell System: 1875–1907', *Journal of Historical Geography*, 4, 2, 1978, pp. 145–159.

117. Walsh, *op. cit.*, p. 143.
118. H. N. Casson, *The History of the Telephone*, A. C. McClurg, Chicago, 1910.
119. M. Mobius, 'Death through success: the rise and fall of local service competition at the turn of the century', 15 January 2001, available at: http://www.economics.harvard.edu/faculty/mobius/tele.pdf, last accessed 23 February 2006.
120. Langdale, *op. cit.*; in the days before automatic telephone exchanges, when human operators established connections, telephone had its own privacy problems. These human operators were often served as 'newscasters' supplying news on fires, crimes, missing persons, and other local events and also gossip (Aronson, *op. cit.*). Another factor why the telephone eventually prevailed over the telegraph was sheer geographic reach of the former which went way past the urban centers to which the latter was limited (Langdale, *op. cit.*). In 1909 there were telephone exchanges in 50,000 cities and towns compared to telegraph offices in 21,000 cities and towns (Brock, *op. cit.*).
121. Interestingly, the telephone was greatly favored by the 'robber barons' who did not want to leave behind a written trail (Aronson, *op. cit.*).
122. Casson, *op. cit.*, p. 203.
123. Aronson, *op. cit.*
124. *Ibid*; L. Coe, *The Telegraph*, McFarland, Jefferson, NC, 1993.
125. Fischer, *op. cit.*, p. 42.
126. *Ibid.*
127. Hochfelder, *op. cit.*; Hughes, *op. cit.*
128. Hochfelder, *op. cit.*
129. Hughes, *op. cit.*