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

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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 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 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.

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 (Chandler 1977, Ringwalt 1888, Taylor 1951, Thompson 1925, Van Metre 1939). Telegraph, the kindred technology that "marched across the continent in unison" with the railroad (Chandler 1977, p. 195), for some reason received significantly less scholarly attention (Thompson 1947, Carey 1989). Thereafter electricity, telephone, automobility[1], Internet, and other major network technologies that succeeded them have all been studied at considerable depth (Abbate 1999, Brooks 1976, Brock 1981, Childs 1974, Flink 1975, Hafner and Lyon 1996, Nye 1990). However, these studies have generally tended to record history or analyze the economics and politics behind the creation of particular networks. In effect they have basically been mega case studies of sorts, albeit very valuable ones. Whenever an effort was made to theorize beyond particular cases, it was limited to issues related to the management and control of complex systems (Chandler 1977, Beniger 1986).

Attempts to conceptualize how network technologies themselves are created have been relatively recent and rare. The ground breaking work on this front was done by Hughes (1983) who developed a process model based on his research on electrical power systems. He conceptualized the network development process as having 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 (1983) 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" (p. 14). 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 inventers 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 system, 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’” (p. 140). 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.[2] The contents of three edited collections, Myantz and Hughes (1988), La Porte (1991), and Summerton (1994), 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 (Akrich 1992, Callon 1987), derived from sociology of science (Latour, 1987), and multidisciplinary communications research involving a mix of political economy, history, and cultural studies (Mansell 1993, Samarajiva and Shieds 1990, Sandvig 2002, and Sawhney 2001).

The above-mentioned studies have tended to study a specific technology at 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 (2002), who looks at the changing nature of the relationship between Western Union (telegraph) and AT&T (telephone) over a century, is a rare exception. 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" (Hochfelder 2002, p. 705). Hochfelder instead argues that "these processes were linked by a porous and shifting boundary between the two industries" (p. 705). 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 (Sawhney 1992, 2003, forthcoming). This research shows that in the U.S. a new network technology first strikes roots as a feeder to the established system.[3] 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 WiFi, 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 inter-modality 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 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.

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.[4] His generator was an analog of gas-making plants and electrical lines that of gas supply pipes. 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 (Keating 1954).[5] Edison invented the electricity meter so that he could bill customers on a monthly basis just like the gas mills. Furthermore, Edison made it a point to use the term light, in keeping with the terminology of the gas industry, instead of current till the 1890's when charging for the electric energy (Foster 1952). 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." In sum, Edison saw his challenge as fitting dynamos, switches, wiring, meters, and other components together into a system of power generation and distribution (Keating 1954). 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 (Keating 1954).[6] Thus he very meticulously set out to create his electric system.

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 (MacLaren 1943). 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 (Keating 1954). 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 (Keating 1954). Thereafter he focused on the outdoor commercial use, especially in down town shops and exclusive hotels, of electric light to keep the new technology in the public eye (Tarr & Dupuy 1988).

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 (Bright 1949). 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 7200 lamps, began operations on Sept 4, 1882 (Keating 1954). 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 (Hughes 1983). This resulted in a 60 percent saving in the amount of copper required for distributing electricity (Keating 1954). In 1885 EEIC reported a net income of 6% on its capital investment of $828800 and declared a dividend (Hughes 1983). The success of EEIC encouraged other investors to construct new central stations (Hughes 1983). Thanks to Edison's invention and promotional effort, there was a rapid growth of central stations in many American cities (Keating 1954).

First established in 1816, the gas light industry was experiencing its most rapid expansion at the very moment electric light arrived on the scene (Bright 1949). 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(Lighting a Revolution 2003). 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 (Bright 1949).

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 (Nye 1990). 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 (Nye 1990). In Chicago, the gas companies bribed the city council to prevent it from granting franchises to electric companies (Platt 1991). 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 (Platt 1991). 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 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 satisfactory service but agreed to reconsider the electric company in the following year, 1889 ("Fight between Gas and Electricity" 1889).

On the technical front, competition from electric lighting spurred the gas industry into making rapid progress in improving gas lighting (Bright 1949). 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 (Foster 1952). Furthermore, it reduced the cost of gas lighting by over 60% (Keating 1954). Another notable innovation was a new method of making water gas, which burnt brighter than coal gas (Rose 1995). For a while the resurgent gas seemed to have won the battle as it threatened the very existence of electric industry. In mid 1890s some districts in New York City had many more Welsbach gas lamps than the Edison incandescent lamps (Foster 1952). 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 $1600^{o}C$ (Bright 1949). In 1900 GE established the first industry run fundamental research laboratory in America to continue the search for a better filament (Keating 1954). 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 (Keating 1954). 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 cost, 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.[7] 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 (Keating 1954). 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 (Keating 1954).

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 lamp from $1 to 12 cents(Bright 1949). 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 (Bright 1949, Foster 1952). Industrial and commercial rates similarly declined (Bright 1949). Thanks to the price cuts, by 1911, in such big city as Chicago, 16-18% of the families became central station customers (Tarr & Dupuy 1988). In the following five years, electricity fast became a necessity of urban life among the middle class. In 1920s falling rates further accelerated the rising demand for energy by every type of consumer (Tarr & Dupuy 1988).

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. Two, they started acquiring electric companies or merging with them (Bright 1949, Nye 1990).

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.

Original Stance

At the time of the founding of the Bell Company in 1878, Alexander Graham Bell 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" (Kingsbury, 1915/1972, p. 90). However, interestingly, just two years earlier in 1876, Alexander Graham Bell had offered to sell his telephone patents to Western Union for $100,000. It was Western Union's refusal to buy the patents that induced Alexander Graham Bell to set up his own company. 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 intraurban 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 (Brooks 1976). Bell cried foul and filed a patent infringement lawsuit. Meanwhile, Bell regained the technical lead. At the end of 1878, the Bell acquired rights of the Blake transmitter, which performed better than the Edison transmitter.

Western Union's entry as a competitor energized Bell's "big vision." The ensuring 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, the 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 increasing doubtfulness of its legal case and also the urgent need to counter severe attacks by Jay Gould who sought to gain control of the telegraph business (Brooks 1976). The terms of the settlement 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 (Brock 1981). 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" (Brock 1981, p. 96).

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 telephone, which did not provide a written record (Garnet 1985).

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.

> Examining the company organization in the Midwest, Doolittle concluded that Bell's territorial structure inhibited necessary toll line construction. Though he believed that the managers of the Midwestern Central Union Company were 'unusually capable', he found them inexplicably unwilling to make the necessary 2.3 to 3 million dollar investment his strategy called for. The problem, Doolittle reasoned, was that Bell had left the major Midwestern commercial centers in the hands of several different firms. In this situation, the managers of Central Union '[were] very apt to fix an imaginary center in [their] territory, overlooking the requirements of adjoining territory'. As a result, they tended to discount the value of toll lines whose main trunk joined two cities outside their territory, but which nonetheless could be of benefit to all. By ignoring such 'extraterritorial' connections, operating companies underinvested in local and long-distance plant, resulting in the dreaded problem of inadequate capacity, which strangled system growth (Lipartito 1989, p. 122).

In general, the local telephone companies were more interested in investing in efforts which would increase the service penetration within their own franchises. The long-distance telephone service seemed to have an uncertain future and the earning potential appeared to be modest. Therefore the local telephone companies paid little attention to plans which sought to develop long-distance service (Garnet 1985). 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 Bell-Western Union relationship over 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 U.S. Steel and Standard Oil emboldened Bell to try and acquire Western Union. After a failed attempt in 1902-03, Bell secured 30 percent 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 (Hochfelder 2002).

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 antitrust actions by the Department of Justice forebode similar fate of AT&T if it persisted with its monopolistic ways. The Western Union that Bell let go was a revitalized organization with a modernized networked. But then, Bell retained critical assets that ensured that Western Union would remain in a subservient position.[8] Bell maintained its hold on 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 (Hochfelder 2002). Yet, Western Union lingered on till 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 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 A.T. &T" (Hochfelder 2002).

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" (Hochfelder 2002, p. 731).

Conclusions

Hochfelder (2002) and Hughes (1983) make a major contribution to the literature via their "boundary" and "reverse salient" concepts respectively. 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 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 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 lobbing effort did not succeed. Over time developments in telecommunications technologies made the very idea of a separate "record communications" category untenable (Hochfelder 2002). 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 choose to study 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 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 (1983) points out, momentum can also mean inertia. 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 telegraph was already a mature technology when competition started, gas was still a young one with its potential not yet fully exploited.

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 myriad 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 myriad 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.

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Notes

[1] 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 (1961) offers "automobility" as a term for the concept that encompasses the automobile and other entities related to it. According to Flink (1975), 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" (pp. 1-2).

[2] The term "large-scale systems" has been intentionally used here because the influence of Hughes work goes beyond network technologies that are the focus on this paper. It also includes nuclear power plants, space shuttle, supercomputers, and other large technical systems.

[3] While research on other countries is limited, studies how that the relationship between old and new network technologies in France and Canada is very different from that of the U.S. (Sawhney 1993, 1999). The analysis presented in this paper is applicable only to the evolution of network technologies in the U.S.

[4] Today we see a parallel in Internet phone service providers piping in fake dial tone to make the new technology feel familiar (Leonhardt 2003).

[5] His dynamo reached 90% efficiency in converting mechanical energy to electric energy and produced 110 volts which later became the standard (Keating 1954).

[6] For example, Edison Machine Works built dynamos and other heavy machinery. Electric Tube Co. produced underground tubing, junction boxes, and associated equipment (Keating 1954). Fixtures, sockets, and similar auxiliary appliances were made for Edison by Sigmund Bergmann & Co (Bright 1949). Similarly, there were other companies that built other system components.

[7] 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 1949).

[8] 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 that allowed twenty 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 2002, p. 726). However, Bell was willing to lease carrier channels to Western Union.