16 The Optical Telegraph

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Technologically, the advent of electricity was certainly revolutionary. From an information point of view, however, the revolution began half a century earlier, when Claude Chappe (1763–1805) devised a way to send any message whatsoever, in either direction, much faster than any horse could gallop. That, and not the technical means (electricity, radio waves, fiber optics, or any other), is the essence of telecommunication.

It was the demand for rapid communications that created the telecommunications systems, not the other way around. Before Chappe, people who needed to send a message used Paul Revere's method: they arranged a signal in advance and lit a fire to send it. Fire signals and chains of beacons are mentioned in Homer's *Iliad,* in Aeschylus's *Agamemnon,* and in the works of Thucydides and Herodotus.[1] The Bible says: "Oh ye children of Benjamin, . . . set up a sign of fire in Bethhaccerem: for evil appeareth out of the north, and great destruction" (Jer. 6:1).[2] The Romans, better organized, built 3,197 watchtowers along the Mediterranean and Atlantic coasts and used fire and smoke signals to warn of pirates or enemy ships.[3]

The tradition persisted right up to the French Revolution. Of the Scots, Geoffrey Wilson wrote: "An Act of the Scottish parliament in 1455 laid down that on the approach of English invaders one bale or faggot could be set ablaze. Two on fire would signify that the English were 'coming indeed' and four that they were 'in great force.' "[4] In 1588, when the Spanish Armada was sighted off the coast of Cornwall, fires relayed the news to the English fleet at Plymouth and to the rest of England.[5] France also had coastal watchtowers and prearranged fire signals.[6] And during the American Revolutionary War, General Lafayette used a variety of prearranged signals: shots from a heavy gun, flashes from torches or flares, even "the sun's rays, although no definite code for sending messages appears to have been in operation."[7]

It was not for lack of ideas that the system of one-way prearranged signals persisted as long as it did. In the second century B.C., the Greek historian Polybius proposed using a system of vases that could be seen at a distance and corresponded to the letters of the alphabet, but evidently nothing came of the idea.[8] In May 1684, the philosopher and physicist Robert Hooke spoke to the Royal Society of London on "how to communicate one's mind at distances in as short a time almost as a man can write what he would have sent."[9] He presented the results of experiments in which he represented the letters of the alphabet with boards of different shapes that were to be placed on hilltops so they could be seen at a distance with a telescope. Four years later, Guillaume Amontons demonstrated a similar system in the Luxembourg Gardens in Paris.[10] In the course of the eighteenth century, several other thinkers described clever methods of communicating at a distance, but they did not even get so far as to try them out.[11]

What can we conclude from these abortive attempts? By the late seventeenth century, the idea of an open-ended, bidirectional telecommunications system was in the air. But any serious experiments would have required a substantial investment, and for that, the demand was lacking. Until the 1790s, messengers and the postal system met the everyday needs of governments and merchants, and fire signals served for emergencies.

Claude Chappe was a persistent man.[12] Starting in 1790, he tried several methods of communicating at a distance. He experimented with electricity. He tried using gongs and synchronized clocks with hands that pointed to numbers. He tried shutters painted black on one side and white on the other. Finally, he adopted the "T," a post topped by a thirteen-foot-long board called a *régulateur,* at both ends of which were six-foot boards, or *indicateurs;* all three could be moved with the aid of ropes and pulleys. The *régulateur* could be placed in four positions: horizontal, vertical, oblique right, and oblique left; only the horizontal and vertical positions were used for signaling, however. Each *indicateur* could be placed in seven positions. Thus a total of ninety-eight positions of the arms could be used for signals. The arms were painted black and placed on top of towers, steeples, or high buildings. Silhouetted against the sky, the devices could be seen at a great distance.

Chappe first set up his devices in Paris, but they were torn down by crowds fearful of royalist intrigues. In March 1792, he approached the Legislative Assembly, where his older brother Ignace was a deputy, but was ignored. A year later, he tried again; this time the deputies Joseph Lakanal and Charles-Gilbert Romme supported his proposal, and he received funding to build an experimental line from Saint-Fargeau to Saint-Martin-du-Tertre.[13]

As noted earlier, the experiment was a technical success. More important, it succeeded politically, thanks to Lakanal. French politics were then at the height of their revolutionary fervor. Louis XVI was executed in January 1793, France was at war with the rest of Europe, the Vendée was in full revolt, and the Convention was split into warring factions and heading for the Terror. In August, amid an atmosphere of frenzied crisis, the deputies ordered the construction of fifteen telegraph stations from Paris to Lille in the north of France. They appointed Claude Chappe *ingénieur-télégraphe* under the Ministry of War; his brothers Abraham, Ignace, and Pierre-François became his deputies. When the line to Lille began operating in August 1794, the first official telegram, dated September 1, announced, "Condé is restored to the Republic. Surrender took place this morning at six o'clock."[14]

Chappe's optical telegraph was made of wood, iron, ropes, and stone. It involved no electricity or other scientific innovation—nothing that the ancient Greeks, Persians, or Chinese did not have. As Alexander Field has recently shown, what made it a technical success was not its hardware but its software. The positions of the arms indicated numbers, which in turn corresponded to words or phrases in a codebook. Of the ninety-eight positions, six were reserved for service instructions, leaving ninety-two for messages.

Chappe tried several different codes. His first codebook had 9,999 entries but required four positions for each signal, which made it very slow. In his second code of 1795, each signal consisted of two positions, the first one corresponding to the ninety-two pages in a codebook, the second one to the ninety-two words or phrases on each page. Hence, the device could send any of 8,464 (92×92) words or phrases. In 1799, Chappe added another book for geographic names, bringing the total number of signals to 25,392. Yet another code, issued in 1830, contained 45,050 words and phrases.

By using long codebooks and choosing the words and phrases carefully so as to equalize the probability of each position, Chappe was able to compensate for the slow rate of transmission inherent in the hardware.[15] As Claude's brother Ignace later wrote: "Its goal was not to find a language easy to learn without a dictionary . . . but to find the means to express many things with few signs."[16]

To operate such a system, with its complex codes and many stations, required a skilled and efficient administration. Each intermediary station had two *stationnaires,* one to watch the upstream station and call out its positions in a special vocabulary, the other to move the arms into the same position for the downstream station to see. These men, usually veterans, did not understand the signals they were transmitting, but they had to be diligent and accurate so that the message would not be garbled. At each end station was a *directeur* who translated outgoing messages into telegraphic style, then turned the telegrams into code, or who turned incoming codes into messages. In addition, each line had two *inspecteurs* to oversee the line and enforce the regulations. This administrative structure was created and supervised by the Chappe brothers. By the 1830s, it included a thousand *stationnaires,* twenty *directeurs,* and thirty-four *inspecteurs.*[17]

The optical telegraph had two weaknesses. One was human, for it relied on the punctilious performance of duty by every member of the organization. Efficient operation required quasi-military discipline, something that was never in short supply in Napoleonic and Restoration France. The other weakness was natural: the system could not operate at night or in rain or fog. On average, it worked six hours a day in summer, three in winter. A survey conducted in the early 1840s showed that 64 percent of dispatches arrived the day they were sent; in winter, the rate dropped to 33 percent.[18]

On good days, the optical telegraph was remarkably efficient. A line could transmit up to three signals (a number in the codebook or a letter of the alphabet) per minute, with an average of one per minute on a long line. A signal could travel the 225 kilometers between Paris and Lille in one or two minutes, or the 760 kilometers and 120 stations between Paris and Toulon in twelve minutes. In 1820, a hundred-signal telegram took fifty-six minutes to transmit to Lille, seventy-six to Strasbourg, and ninety-five to Bordeaux. By the 1840s, improvements in training and efficiency had doubled these speeds. In addition, it took fifteen to thirty minutes to encode and decode the message at each end. In other words, a line could handle four to six one-hundred-signal telegrams on an average clear day.

To twenty-first-century people, that sounds excruciatingly slow, but if we compare the Chappe system with its predecessors, the progress is striking: a message would have taken three days from Paris to Toulon on horseback, or over a week by stagecoach. The electric telegraph that eventually supplanted Chappe's system represented a less dramatic improvement.

Optical Telegraph Networks to 1815

Through all the changes of policies and ideologies, every French government expanded the telegraph network and supported the family that ran it. Under the Directory (1795–1799), the Chappe brothers built lines east to Strasbourg, west to Brest, and north to Dunkirk and Brussels. Napoleon extended the network south to Lyon and Marseilles. As his empire grew, lines radiated to Turin, Milan, and Venice, to Antwerp and Amsterdam, and to Mainz.[19]

In addition to the elaborate Chappe network, the Napoleonic government also created a network of coastal telegraphs to warn of enemy warships. At first they used flags and pennants; later they used a simple mechanism, called a *sémaphore,* and a simple codebook. By the end of Napoleon's reign, France had several hundred such stations.[20]

Neither hardware nor software can explain the success of the optical telegraph system, which was too complex and costly and too closely tied to the government to be anything but an expression of power and culture. Like the railroads and electric power of the later nineteenth century or the television networks and airlines of our own era, it was a social construction.[21] To what social forces, then, can we attribute the success of the optical telegraph?

The first and most obvious was military necessity. In his petition to the Legislative Assembly, Chappe promised that "the legislative body will be able to have its commands reach our borders and receive the answer in the course of a single session."[22] His system got its start at the peak of the French Revolution, when the National Convention desperately needed real-time information on the battles that would determine the fate of the nation and the revolution, and wanted to keep an eye on its generals, whom it did not fully trust. Napoleon, whose success was due, more than anything, to the superior speed at which he maneuvered his armies, was just as eager for timely information as were his revolutionary predecessors.

The optical telegraph was much more than a military necessity, however. From the beginning, it had a profound political, even ideological, significance. As Chappe wrote Lakanal in 1793, "The establishment of the telegraph is . . . the best response to the publicists who think that France is too large to form a Republic. The telegraph shortens distances and, in a way, brings an immense population together at a single point."[23] Bertrand Barère, prosecutor of Louis XVI and member of the Committee of Public Safety, put it even more succinctly: "By this invention, distances vanish. . . . this is a means to consolidate the unity of the Republic."[24] In other words, the telegraph was instrumental in the formation of the French nation-state.

The French government was so aware of the value of the telegraph as a means of consolidating and defending the unity of the nation that it placed the network under the Ministry of War, and later under the Ministry of the Interior (i.e., the police). The network was owned and operated by the government, and its use was restricted to government messages. When budget cuts threatened to close down several lines, Claude Chappe suggested that the network might increase its revenues by transmitting news dispatches, ships' arrivals and departures, stock and foreign exchange quotations, and other public information. Napoleon rejected all but one of these suggestions; the only news items allowed on the network were the results of the national lottery, to discourage speculation. Otherwise, the emperor reserved the network for military orders and reports and for official proclamations such as the announcement of the birth of his son in March 1811.[25]

Even though politics and war go a long way toward explaining the success of the optical telegraph in France, they are not sufficient. After all, there had been earlier wars and uprisings, yet governments before 1794 had not felt the need to build and maintain, at great expense, elaborate telecommunications lines. As Patrice Flichy has recently argued, what had changed was a new concept, the idea that humans could reorganize space and time through the use of reason.[26] The telegraph appeared at the same time that revolutionaries were restructuring the national territory into equal departments, imposing a homogeneous system of weights and measures, and reorganizing time itself through a new calendar. The same *mentalité* led them to seek a rational solution to the problem of communicating at a distance. The optical telegraph was not only a response to war but also a child of the Age of Reason. Revolutionary fervor ebbed after 1794, but the cult of reason never faltered.

If optical telegraphy was indeed a child of reason and war, and not a product of the genius of one man or one nation, it should have spread to other countries that combined the *mentalité* of the Enlightenment with the exigencies of war. And so it did.

In Britain, the outbreak of war and news of the Chappe telegraph inspired several amateurs to invent systems of their own. In 1794, Richard Edgeworth, an Irish landowner, suggested using fourteen-foot-high stands on hilltops fifteen to twenty miles apart. Each station would have two or three men armed with telescopes and triangular boards that could point in any of eight directions, representing the digits 0 through 7. He presented his plan to the Admiralty but was turned down.[27] A year later, two inventors presented the Admiralty with devices consisting of shutters that opened and closed. The Reverend John Gamble's system consisted of five shutters indicating the letters of the alphabet. Lord George Murray's had six shutters in two columns, with sixty-three combinations indicating letters, numerals, and a few code phrases such as "line-of-battleship" or "to sail, the first fair wind, to the northward."

The Admiralty picked Murray's method and erected stations linking London with Sheerness, Deal, and Portsmouth in 1796, at the height of the French revolutionary wars. When the Napoleonic Wars broke out in 1804, the Admiralty added lines to Plymouth in 1806 and Yarmouth in 1808. The system was dismantled in 1814, in the belief that peace had come.[28]

Sweden also built optical telegraphs. The first was the creation of Abraham Clewberg-Edelcrantz, a member of the Swedish Academy and private secretary to King Gustavus IV, who read about the Chappe system in the *Gentleman's Magazine* of September 1794. He demonstrated his first line on the king's birthday, November 1. Shortly thereafter, he erected three short lines connecting the royal castle in Stockholm to nearby fortresses and islands. By 1801, in anticipation of a British attack, a line was extended to Denmark. By 1809, the Swedish telegraph network had fifty stations covering two hundred kilometers, mainly along the coast to the north and south of Stockholm. It seems to have been used for local defense and under royal auspices. With no other commercial or naval purpose, it was largely abandoned after 1815.[29]

Spain also built a few local lines in the early years of the century between Madrid and the royal palace of Aranjuez and between the fortress of Cadiz and neighboring towns; but they were abandoned in the Napoleonic invasion and the turmoil that followed.[30] . . .

There was a flurry of interest in optical telegraphy throughout Europe in the 1790s, but only a few short lines were built outside of Britain and the Napoleonic empire. Then, after a forty-year lull, interest in optical telegraphy revived in the 1830s.

In Hamburg, a private entrepreneur constructed a line to serve the local shippers and merchants. In Sweden, Carl Fredrik Akrell opened with a line from Karlskrona to Drottningskär in 1834; to defray its costs, this line accepted private messages, the first to do so. The Prussian government built a 550-kilometer-long line from Berlin to Cologne and Koblenz in 1832–1834, linking the two parts of the kingdom. The Russian government, after building local lines near Saint Petersburg in the 1820s and 1830s, built one in 1839 from Saint Petersburg to Warsaw, a distance of 830 kilometers. In both Prussia and Russia, national unity meant controlling distant provinces.[31]

In Spain, as Luis Enrique Otero Carvajal explains, "There is a clear connection between the development of the telegraph and the consolidation of the liberal State."[32] The difficulty of consolidating the liberal state (meaning one modeled on France) is reflected in the uses of telegraphy. The first short lines, reserved for the royal family, were built between Madrid and nearby royal palaces. Only in 1844 did the government decide to construct a national network linking the capital with San Sebastian in the north, Valencia and Barcelona in the west, and Cadiz in the south. In the codebook, seen only by high government officials and military commanders, 75 percent of the phrases referred to military matters or public order. The optical network, completed in the mid-1850s, was replaced within five years by an electric one.[33]

With few exceptions, these were government-owned systems reserved for official or military traffic. They consisted primarily of unconnected short lines and used a variety of structures and codes. Even when two systems met, as at the French-Spanish border, the rare message going from one system to the other had to be decoded, translated, hand carried across the gap, and encoded for further transmission. Public telecommunication had to await the introduction of the electric telegraph.[34]

Optical telegraphy also spread overseas, part of the expansion of European influence of the time. Under the Westernizing khedive Mehemet Ali, Egypt acquired a telegraph linking Cairo and Alexandria in the 1820s; it was the first non-Western country to build such a system. Algeria and Australia had very active systems, unlike South Africa and India, where telegraphy was little used before the advent of electricity.[35]

In the United States, the federal and state governments left telegraphs to private entrepreneurs. The first lines were harbor telegraphs. In 1801, Jonathan Grout opened a seventy-two-mile line between Boston and Martha's Vineyard to announce the arrival of ships; his line seems to have done poorly, for it folded in 1807. The next harbor telegraph connected Brooklyn and Staten Island, New York, during the War of 1812.

The most successful harbor telegraph was founded in Boston in 1820 by Samuel Topliff, the manager of the Exchange Coffee House. In 1822, it was taken over and expanded by John Rowe Parker, who adopted a code very similar to the one used on the Liverpool-Holyhead telegraph, established a few years later. This was no coincidence, for Boston and Liverpool had very close commercial ties at the time.

In the 1820s, speculators obtained market information before the general public by using mounted messengers who could outrun the postal coaches. Postmaster General John McLean considered creating a network of optical telegraphs for commercial information. Although Congress never authorized this project, the idea of a national telegraph system was to return a few years later when it took up Morse's electric telegraph.[36]

Not until 1840 did an optical line connect two cities, New York and Philadelphia, to convey stock prices and lottery numbers. Built by the Philadelphia stockbroker William Briggs, it was replaced five years later by the electric telegraph.[37]

The American experience shows that there existed a demand for real-time information, but only shippers and stockbrokers could afford the cost of optical telegraphy—hence the enthusiasm with which Americans adopted the much cheaper electric telegraph.

From Optical to Electric Telegraphy

Scholars have written volumes on the subject of the electric telegraph. Almost all of them describe its invention as the dawn of a new age. Thus, in his book *Emulation and Invention,* Brooke Hindle wrote:

> The electromagnetic telegraph, like the steamboat, was something new under the sun. It was not an improvement within an existing technology, and it was not a combination of existing capabilities put together in answer to a clear social need. It appeared when it did because not until then had it been possible. The door was opened by the new knowledge of electricity developed by Ampère and Oersted and of electromagnetism by Sturgeon and Henry. This understanding was the precondition for the telegraph, and consequently it has been labeled the first science-based invention.[38]

Equating telegraphy with the electric telegraph is understandable if one thinks of the latter from the perspective of the devices it used or the science involved. As a means of communication, however, the electric telegraph most certainly *was* an "improvement within an existing technology." The question then arises: What elicited this improvement in the minds of its inventors?[39]

During the 1830s, Schilling, Gauss and Weber, Steinheil, and Wheatstone and Cooke all showed that electricity could be used to transmit messages. These inventors tried to create telegraphs in which the letters of the alphabet could be read directly off the receiver. Samuel Morse's contribution was not the electric telegraph but a code that allowed the use of only one wire, with the earth serving as a return; the cost savings more than compensated for the need for trained operators.

Morse deserves all the praise he has received, but he did not come up with his invention in a vacuum. Rather, he thought of it on board the *Sully* while returning from France. Before leaving Paris, he supposedly told his friend Richard Habersham: "The mails in our country are too slow, this French telegraph is better, and would do even better in our clear atmosphere than here, where half the time fogs obscure the skies. . . . But this will not be fast enough. *The lightning would serve us better.*"[40]

International interest in electric telegraphy had several causes. On the supply side, progress in physics made electric telegraphy possible. Science had provided the necessary theory in work by Oersted, Ampère, and Faraday's on the relationship between electricity and magnetism. More practically, experimenters were able to obtain reliable batteries. By 1838, the process of invention shifted from experiments to patents, including those of Wheatstone and Cooke, Edward Davy, William Alexander, and Samuel Morse.

The electric telegraph had a far greater capacity than the optical one because it could handle more information faster. An optical line could carry, on average, one or two signals per minute; since the average word or phrase in the codebook represented by one signal was ten characters long, this meant that an optical line could carry ten to twenty characters per minute. In comparison, a Cooke and Wheatstone needle telegraph of 1837 could handle twenty-five characters per minute, and a Morse telegraph, sixty. More important, the electric telegraph was not impeded by darkness or bad weather. Whereas the French optical lines operated, on average, six hours a day in summer and three in winter, an electric line could, if needed, operate day and night. In other words, from the beginning, the electric telegraph could handle at least ten times more information than the optical telegraph could after half a century of improvements and refinements.[41]

Electric telegraphy had become attractive on the demand side as well. By the 1830s, as we have seen, governments and entrepreneurs were setting up optical telegraph lines in most European countries, in the United States, and in other parts of the world. The optical telegraph proved useful in building nationhood, in maintaining public order, in preventing revolution, and in transmitting commercial information.

Inventors like Morse naturally turned to their government for support. The first electric telegraph in the United States, the Baltimore-Washington line, was operated by the Post Office from 1845 to 1847. Yet governments were technologically conservative; their demand was limited and did not justify investing in an electric telegraph network. In the United States, telegraphy became a private enterprise by default when Congress lost interest.

In Britain, William Cooke realized that the speed and capacity of the new device required new customers. The telegraph had long been valuable to shippers and shipowners in announcing ships' arrivals. News services, pigeon post, and the various attempts to set up alternative optical systems in France showed that there was a demand for rapid information among financiers and stockbrokers. On the new railways, information about trains had to precede the trains themselves, to prevent crashes. Cooke and Wheatstone's first operating electric telegraph was strung along the Great Western Railway in England. In countries that permitted private enterprise in telegraphy, the results were astonishing. By 1848, telegraph lines crisscrossed the British Isles and linked all the United States east of the Mississippi, except Florida.

France, which had pioneered the optical telegraph, resisted the electric one for political reasons. In 1842, the Chamber of Deputies voted to subsidize experiments with nighttime transmission on the optical lines, even though the physicist François Arago protested that the Chappe system was obsolete. Two years later, a commission found that Britain, the United States, and the German states were all forging ahead with electric telegraphs. In response, the electrician Louis Breguet and Alphonse Foy, director of the government's optical network, devised a two-needle telegraph that reproduced, on a small scale, the movements of the Chappe machine. This was not so much a case of technological conservatism as a rational desire to continue using the skills of existing telegraph personnel. Though slower than its neighbors, France gradually acquired electric lines. It soon became apparent that, unlike the optical lines, the electric ones could handle all conceivable official messages and still remain unused nine-tenths of the time. In 1850, under pressure from progressive Saint-Simonians, the business community, and the new president Louis-Napoleon Bonaparte (soon to be Napoleon III), the National Assembly finally allowed public access to its telegraph lines.[42]

If the electric telegraph was indeed revolutionary, it is not just because it was a child of electricity, "the first science-based invention." Rather, it represented a quantum leap in capacity and flexibility and a radical decline in cost compared with its optical predecessor. It opened up real-time information to railways, stockbrokers, capitalists, and merchants, to newspapers, and finally to the general public.

Notes

1. George Dyson, *Darwin among the Machines: The Evolution of Global Intelligence* (Reading, Mass.: Addison-Wesley, 1997), 131–38.
2. Capt. L. S. Howeth, USN, *History of Communications—Electronics in the United States Navy* (Washington, D.C.: Office of Naval History, 1963), 3.