THE TELEGRAPH OF CLAUDE CHAPPE -AN OPTICAL TELECOMMUNICATION NETWORK FOR THE XVIIITH CENTURY

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ABSTRACT

Claude Chappe (1763-1805) invented a semaphore visual telegraph. The lines between cities were composed by a series of towers (stations), 10-15 km apart, equipped with a pair of telescopes and a semaphore which beams were permitted discrete angular positions. These positions were assigned to numeric symbols in connection with a code book. Where the transmission of a message took days, it only needed tens of minutes with Chappe telegraph (individual symbols may be transmitted at a speed over 500 km/h!).

Started during the French Revolution, the network grew to 556 stations covering 3000 miles of lines (5000 km), most of them in France. However, cities like Amsterdam, Brussels, Mainz, Milan, Turin, Venice were also connected. Small networks were also deployed in Algeria and Morocco, while a mobile network was used during the Crimea war. In 1855, it was finally replaced by electric telegraph.

The purpose of the presentation is first to present the technology of this optical telegraph, and to demonstrate the modernity of its principles. Nevertheless, political and social implications will be described to show their strong similarities with the (supposed) implications of the World Wide Web. More precisely, such issues as source coding, error detection and signal restoration, control and data signals, routing, regulation and fraud, dissemination of new social behaviours, will be addressed.

INTRODUCTION

10th of April 1814, Easter Day, 6 o' clock in the morning, the battle of Toulouse is waged between the French troops (41000 men) of Marshal Soult and the coalition (Portuguese, Spanish and British) troops (52000) of the Marquess of Wellington. There will be no real winner: Soult will be forced to leave Toulouse with his troops the night of the 11th, but he will organize an excellent withdrawal like an exercise out of Sandhurst" [1]. Wellington will enter the town the 12th, but the British losses are greater than those of the French, and Soult is about to join the army of general Suchet, maintaining a high fighting potential. Therefore useless, about 320 French soldiers and 650 coalition soldiers were killed. Moreover, because communications took a long time, the battle of Toulouse took place four days after the abdication (6th April) of Emperor Napoleon I!

Wellington and Soult were of course aware of the imminence of Napoleon's abdication. Messengers (an English colonel and a French colonel) arrived in Toulouse the 12th of April with the great news: the war was over! The messengers had left Paris the 7th of April in the evening. Because of the state of war, they needed nearly five days to reach Toulouse. In normal circumstances, mail from Paris was delivered by postal coach (four days of travel) or mounted couriers (best travel time: three days). In both cases, communications would have been too slow for a cease fire before the battle.

However, since August 1794 (20 years ago!), a new communication means had been established in France. It permitted the transmission of information at a speed over 500 km/h, when a postal coach mean speed was around 10 km/h. This new communication means was the optical telegraph of Claude Chappe. Unfortunately, at the fall of the First Empire, the line between Paris and Toulouse was not established yet.

The purpose of this paper is to present the technology of this optical telegraph, and to demonstrate the modernity of its principles.

Before going into the technical details, it is worth mentioning that the battle of Toulouse could have been the last battle of the First Empire if Napoleon had not decided to return from Elba island. Later will come the episodes of the Hundred Days and of course Waterloo.

OPTICAL TELEGRAPHS BEFORE CHAPPE

In this paragraph, we will only briefly consider permanent ground systems, operating over a large area, allowing two-way transmission of letters, words or phrases with a single sign. A more comprehensive description of communication systems using messengers, pigeons, mirrors, flags, simple protocol fire beacons etc... used before Chappe telegraph can be found in [2]. The above methods dominated until the advent of Chappe' s invention.

The first developments of a telegraph, for which written records exist, is due to Aeneas (350 BC) and Polybius (150 BC). The latter system was able to transmit more sophisticated messages than a simple alarm signal, by encoding the 24 letters of the Greek alphabet into signals using a torch telegraph. Like Chappe's design, transmission of a letter was done in two steps, by transmitting two numbers between 1 and 5. The first number was used to indicate which tablet of a set of five was to be used. Each tablet was labelled with five (or four) letters. The second number was used to indicate which letter was to be read on the selected tablet. Of course, relays forming a chain were used.

Surprisingly, it will take nearly twenty centuries before some of these principles would be rediscovered. From Charlemagne to George Washington, the main features of long distance (ground) communications were the same [3]. The invention of the telescope at dawn of the XVIIth century will foster new designs for telegraphic schemes [2] and will allow day time operation (on the contrary Chappe telegraph will never be operated at night). But the first documented large-scale use will be that of Chappe's, starting a continuous era, with no more gap like the above 2000 year period during which all previous progress was forgotten. This new era started with a period of nearly 60 years corresponding to optical telegraphs dominating long-distance communications.

THE INVENTOR

Claude Chappe d'Auteroche was born in Brulon, France, in 1763. Claude Chappe initially planned on a career as a member of the clergy, but the French Revolution changed his projects. He then concentrated on scientific work, including long-distance transmission of messages. Most of his work was done with his brothers.

They soon rediscovered that complicated messages could be sent using combinations of simple signals. In 1791 a first version of an optical semaphore was devised and successfully used.

However, a few more years will be needed to improve the semaphore design and the coding procedure, while efforts were made by the brothers to gain support from the new authorities. In 1794 Claude Chappe was finally put on a government salary.

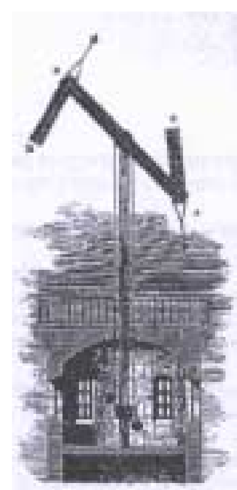
At this stage it is worth remembering that the word telegraph (telegraph, n.- means of sending messages; v.- send a message) comes from French télégraphe. At first, Claude Chappe wanted to call his invention tachygraphe from the Greek for "fast writer", but he was counselled to decide in favour of télégraphe (from "far writer τηλεγραφω")

Claude Chappe committed suicide in 1805, at a time his invention was already a success, to avoid "life's worries" such as criticism and claims from other inventors and competitors. After his death, his brothers Abraham, Ignace and Pierre will be commissioned to organize and chair the telegraph administration.

THE TELEGRAPH

The mechanical design

After early designs using synchronized clocks, and a failed trial to use electricity as a medium for transmission (because no efficient insulator could be found for the electric wires [6]), Chappe devised a semaphore. Preliminary experiments, conducted in 1792, made Claude Chappe and his three brothers convinced that linear arms were more visible in a distance than a shutter semaphore [6] like the one Abraham Edelcrantz was about to built in Sweden in 1794 [2]. Therefore, the final design consisted of a long (4 m x 30 cm) rotating bar (the regulator) with two smaller rotating arms (the indicators) on its ends, counterbalanced with metallic weights. While the regulator could be oriented horizontally, obliquely or vertically, the indicators could be independently oriented in one of seven positions 45 degrees apart, giving a total of 98 combinations.



Regulator and indicators were black painted to increase contrast against the sky.

Abraham-Louis Breguet, a famous clock maker, designed and built a control mechanism allowing an operator, using a scaled-down model of the semaphore to remotely align the full-scaled one from the inside of a building, using pulleys and ropes. The figure on the right shows an example of semaphore design. It is reproduced from [8].
The identical positions of the semaphore and of the scaled-down model are visible. The two telescopes, each aiming at nearby stations. are not shown.

The code

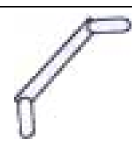
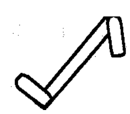
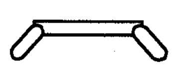
It was soon discovered that it was impossible to transmit without using control signals and an efficient coding procedure, because errors were inevitable in the process of transmission.

After 1795 and a first use of a signalling code which appeared to need improvements [6], transmissions were done by using 92 combinations of the regulator and indicators. In brief, the regulator could be positioned only vertically or horizontally, and the regulators could be set at angles in increments of 45 degrees, excluding the position where an indicator was extending the regulator. This gave 7 x 7 x 2 = 98 positions, reduced to 92 signals by reserving six signals for special indications. The 92 positions were used to identify in one step a first set (division) of 92 symbols (the alphabet, numbers from zero to nine, some frequently used syllables), or in two steps, first the page number of another 92 page code book (also called a division), and then one symbol (syllables, words, phrases) among the 92 symbols listed on each page. 92 pages time 92 numbered signs, or 8464, means 8464 signs to be transmitted by positioning the semaphore arms twice, transmitting a code pair. After 1799 extra divisions were added giving a total of five.

The above six signals reserved for special applications were used to identify the division. The purpose of this system was to save time, by using as few semaphore positions (or symbols) possible to transmit information. It would correspond today to source coding.

Basically the formation of a signal was done in two steps and three movements (the French expression "en deux temps et trois mouvements" still meaning today "rapidly done" comes from it). A signal was meaningless as long as the regulator was oblique (left or right), first with the indicators folded in, and then turned to their position (first step consisting of two movements). The left oblique was used for message signals (today the payload) and the right oblique for control signals (today the overhead). The operator had then to verify that the next station was correctly reproducing the signal (corresponding today to restoration at the bit level). This was considered as one of the most important rule to which the operators had to conform. The same error checking was to be made after the second step below. The regulator was then turned to an horizontal or vertical position (second step and third movement). Two examples (from a code table preserved at the Postal Museum in Paris and reproduced in [2]) of the formation of control signals are given in the next table.

Each received signal had to be recorded in a book. Additionally, time (hour and minute) was to be recorded for control signals.

	urgence Paris	1/2 h suspension of activity
step 1/first movement the regulators are folders in only if the following station has correctly copied the previous signal third movement		
step 1/second movement the indicators are set in position by copying the signal of the preceding station		
set 2/third movement the regulator is set in position only if the preceding station has done so, confirming that the copied signal is correct, and if the following station has correctly copied the second movement		

Performances

From various sources it appears that the duration of transmission was at best about 20 to 30 s per symbol per station for good weather conditions. The symbol propagation speed over long distances is more difficult to assess, data are not always consistent. From [7] it appears that at Paris, signals were received from Lille in two minutes, from Brest in six minutes, and from Toulon in twelve minutes. These are very probably the best results obtained with a fine weather. Routine transmissions were probably slower. During the transmission of a dispatch, with the exception of very short ones, all stations of a line were simultaneously in activity.

However, it is worth saying that these signals were travelling faster than ever before, and that these high speeds allowed a time synchronisation of the network, with obviously an accuracy of the order of a few minutes, at a time where local solar time only was officially used, and was therefore different from one city to another (nearly one hour difference between Strasbourg and Brest).

THE NETWORK

The line of about 230 km between Paris and Lille was the first of its kind. It was completed in seven months and started operation in May 1794. The second line, from Paris to Strasbourg, was completed in 1798. In 1799 Napoleon Bonaparte seized power, and soon ordered the extension of the network, including a line across the Channel (using larger semaphores) in preparation of a later forgotten invasion of England.

A line consisted of stations roughly 10 to 15 km apart, either using belfries or church towers to place the telegraphs, or necessitating newly erected buildings. In each station, two operators ("stationnaires") were operating the telegraph. Operators did only know the control code. Long lines were divided into shorter divisions at the ends of which messages were decoded, recorded in books, purged of transmission errors if that was necessary and possible, and then coded and transmitted again. This corresponds to what is done today at terminal equipment performing error detection and correction.

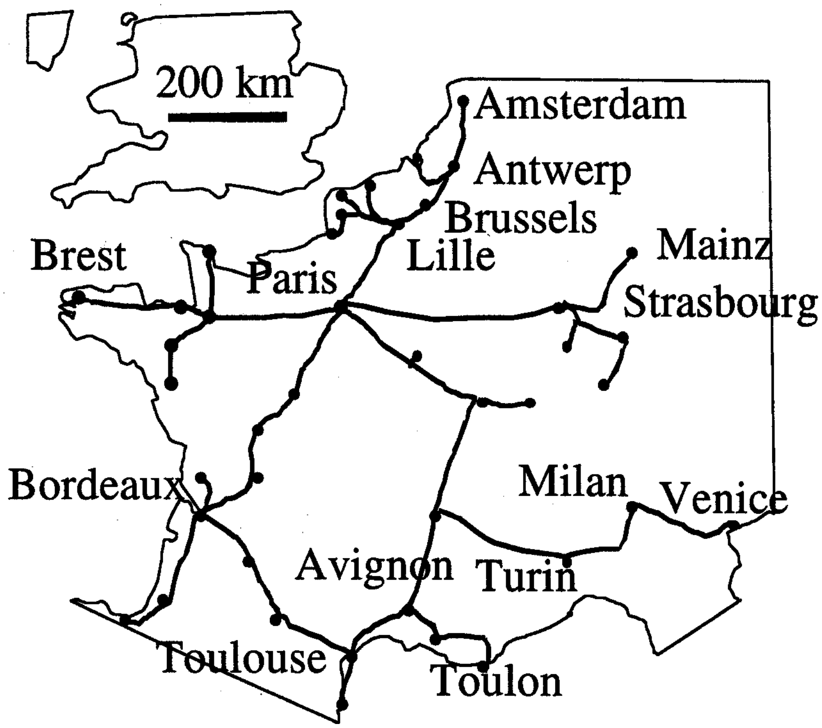
Around the years 1800's, four lines were connecting Paris to major cities: that was the beginning of a real network. New lines will be constructed until 1846 [2].

The figure below shows the telegraph network full extension. It is worth mentioning that all these lines have not been operated simultaneously, such as the lines in Italy, Belgium, Germany and Holland which disappeared after Napoleon's fall.

Some division stations were network nodes with more than two lines meeting. Each line terminated at a separate telegraph, and the messages were decoded before being passed on "manually". Moreover, the network was essentially exhibiting a star topology, and the necessity to build a partially meshed network finally appeared. That was incompletely done by the building of the Bordeaux Avignon line, a few years before the end of the network.

A capability for two way communication was of course compulsory, and control signals were used to indicate a degree of priority, to deal with messages travelling in opposite directions. Two levels of priority were used: "activity" ("activité") and "priority" ("urgence"), given the fact that messages from Paris had precedence over that of other origin of equivalent priority level. Rate control methods and codes asking for garbled information to be sent again correctly, were also used [2].

During the reign of Louis-Philippe (1830-1848) a simplified version (the indicators only were rotated and the heavy regulator beam was fixed in a horizontal position) of Chappe telegraph was installed in Algeria (three lines) and Morocco which were ruled by France at that time [5].



THE END

The first news transmitted by Chappe telegraph was the victory of French troops at Quesnoy (1794); the last one is supposed to be that of another victory, the fall of Sebastopol (1855). Indeed, during the Crimea war, the mobility of specially designed Chappe semaphores was very appreciated: a station was built in 20 minutes [7], much faster than long distance electric telegraph lines which were also used for more permanent links during that war.

Claude Chappe telegraph was in use for 61 years. It has been the first and largest network using optical telegraph, in continuous operation over more than sixty years.

However, the success of the optical telegraph was limited because it was difficult, and therefore expensive, to run, limited to government use, ignored by most of the public, unable to operate at night, vulnerable to fog, mist, and operator misbehaviour, and above all less efficient than the electric telegraph. Nevertheless, optical telegraphs had proven that simple signs could be used to send complex messages, therefore paving the way for electrical communication means.

In France, the decision was made in 1846 to replace the optical telegraph by the electric one (installed between Paris and Lille). As a comparison, the first installation of an electric telegraph was done in 1837 in England. The superiority of novel methods, such as the electric telegraph, is often difficult to establish. In this case, the new telegraph needed a physical connection between stations that appeared to be a drawback considering sabotage, and France was reluctant to abandon the old technology in the field of which she was leading. Surprisingly, at first, the electric telegraph in France will consist of a small electrically activated replica of Chappe semaphore, the codes being transmitted using electricity! They will be replaced by Morse telegraph in 1855.

All contemporary authors [5, 7, 8] agree that when semaphores were superseded by electrical wires, they were rapidly forgotten. The reasons for that are detailed below.

OPTICAL TELEGRAPH AND THE INTERNET

Surprisingly, optical telegraph has much in common with the most recent means of communication, in which there are echoes of primitive semaphore network.

Tom Standage wrote [3] that Chappe telegraph was "the mother of all networks" and that, at the end, the lines of optical telegraph formed a "sort of mechanical Internet." Indeed, there are a lot of similarities between the two, the first analogy being the supposed ability to disseminate new political concepts such as, in Chappe's case, the ideas of the French Revolution. The scientist Joseph Lakanal, member of the National Convention, wrote about the potential of the telegraph [3] "What brilliant destiny do science and the arts not reserve for a republic which, by the genius of its inhabitants, is called to become the nation to instruct Europe."

The telegraph was also considered a great achievement with implications in Geopolitics [4]: "The capital of distant nations might be united by chains of posts, and the settling of those disputes which at present take up months or years might then be accomplished in as many hours.. Sixty years later, the electric telegraph global network was similarly expected to result in world peace [3]. Today again "cyber gurus" consider Internet as a means for "computer-aided peace" [3]. Unfortunately "the potential of new technologies to change things for the better is invariably overstated, while the ways in which they will make things worse are usually unforeseen" [3].

On another topic, and like Internet outstripping the lawmakers, optical telegraph asked for new laws and regulations: a fraud related to the introduction, into regular messages, of information about the stock market, was discovered in 1836. The telegraph operators involved were using steganography (a specific pattern of errors added to the message) to transmit the stock market data to Bordeaux. In 1837, they were tried but acquitted, having not violated any explicit law. The criminals were one step ahead.

However, considering the regulation issue, there is a great difference between optical telegraph and Internet as explained below. Chappe wanted to extend the use of its telegraph to private and business use, or at least general interest purposes such as meteorology but, with the exception of the weekly transmission of national lottery numbers, its use was initially limited by Napoleon to military and administrative use. Nevertheless, it was later utilized to transmit stock market information. However, fearing a proliferation of private telegraphs, the French government passed a bill in 1837 banning private networks. This law will remain virtually unchanged until the end of the XXth century. These last points make a great difference between Internet and electric telegraph on one side, and optical telegraph on the other: the impact of the latter on everyday life of most of

French people was more than weak. Only a few officials were implicated. This explains why such an important topic as the use of codes for private messages, and the limits imposed by many governments on the complexity of the encryption, was not an issue for Chappe telegraph, as it will soon be with the electric telegraph and still is with Internet.

CONCLUSION

Technically speaking, in retrospect, the system may look simple, but it was a highly sophisticated technical tool using, as already said, source coding, control signals, synchronisation, flow control protocols, i.e. principles used in modern communication networks. Today, we are told that we are in the midst of a communication revolution (this is termed chronocentricity by some authors [3]) but optical telegraph, for those involved, was much more revolutionary. Let us consider for instance the case of civil or military officials, in remote provinces of France, who found their relative independence from Paris undermined by the optical telegraph, in a way no other telecommunication means will reproduce.

What is left today of the optical telegraphs? As already said, once they were superseded by electric telegraphs, their history was forgotten as most people's life had not been directly affected, while materials soon disappeared. All that is left today is a few street-names (like "rue du télégraphe"). However, it is worth saying that even if modern data telecommunication networks are faster, bigger, more flexible and reliable, they are not intrinsically very different. They still use basic methods developed by men born and educated in the XVIIth century.

The optical telegraph arrived in Toulouse in 1834, 20 years after the battle!

BIBLIOGRAPHY

A detailed information in English about optical telegraphs is available in [2]. This comprehensive work has been a very valuable source for the writing of this paper. The first chapter of [3] is a good summary of the above, but most of the book deals with electrical telegraph.

The most important contemporary information is contained in Ignace Chappe's book reprinted by Abraham Chappe [6]. Ignace and Abraham are of course two of Claude Chappe's brothers. Some others interesting sources [7, 8] are available on line from the Bibliothèque Nationale de France (BNF) at `http://gallica.bnf.fr`, ref. [8] containing some errors. On another topic, documents and materials on Chappe telegraph may be seen in Paris at the Postal Museum (Musée de la Poste) and at Musée des Arts et Métiers, also in Paris.

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