# THE CARRIER WAVE

New Information Technology
and the geography of innovation,
1846–2003

PETER HALL
PASCHAL PRESTON

London
UNWIN HYMAN
Boston Sydney Wellington

# 4

# The birth of new IT: telegraph and telephone

New IT was born in the 19th century, in the form of two electrical communications technologies invented 40 years apart: the telegraph (1837) and telephone (1876). It was thus firmly a creation of the second Kondratieff, though the subsequent development and impact of the telephone would constitute a major source of economic advance during the third long wave – and, indirectly, a potent influence during the fourth. So the earliest New IT, a child of the 19th century, was to produce children and grandchildren, forming an extended family of technologies which has vigorously reproduced itself throughout the 20th century.

True, in this long development other technologies have played a crucial rôle; late 20th-century semiconductors owe as much to 19th-century third-wave chemical technology as they do to second-wave electrical technology; the switching and printing functions in today's IT derive from early 20th-century printing technology. But there can be no doubt that the dominant line of development, which we now begin to trace, runs from the telegraph and the telephone to the extended electronics family of the late 20th century. It is thus important not only in itself but as the basis for the whole subsequent history.

The telegraph and telephone were in fact the first commercially useful electric technologies, that is, the first electrical innovations. The first came four decades before the major electrical advances we shall describe in Chapter 5, the second immediately in front of them. Yet they were very different from what followed: they depended on 'weak current' as distinguished from the high-voltage current necessary to light or heat cities or to drive electrical machinery. As we shall see in the next chapter, at first the new 'strong current' found little or no application in information technology, which developed between 1880 and 1930 as if electrical power still did not exist. That, in part, may have occurred just because the earliest New IT – dependent on weak current – was still growing and diffusing rapidly in these decades. For that reason, the following account starts at the beginning of the second Kondratieff and continues into the first years of the third.

## The first electrical innovations

It is not surprising that electricity played no rôle whatsoever in the Industrial Revolution, which ushered in the first Kondratieff. For the basic scientific discoveries were only just beginning. As an historian of electricity has put it:

> Until a moment ago in man's long history, electricity was wholly inconceivable. It was not merely that its vast modern usefulness had yet to be discovered. It was impossible for man to imagine something that was, yet was neither solid, liquid or gas; something having no weight, being invisible, occupying no space, moving at enormous speed; yet for all this, something that was a normal part of nature. (Canby 1962, 9)

True, even the ancients had observed natural manifestations like lightning, static electricity or magnetism. But for centuries there was little appreciation of their relationship, let alone an explanation. Although in many other scientific fields the first advances came in the 17th century, in electricity they had to await the 18th. Between 1700 and 1750, Gray discovered conduction; de Cisternay, Dufay and Nollet identified two distinct types of electricity, and discovered the law that like charges repel and unlike charges attract; von Kleist and van Musschenbroek discovered the Leyden Jar, the first electrical condenser; Franklin proposed the use of positive and negative designations; Watson instantaneously transmitted an electrical charge along a two-mile wire. In 1767, Joseph Priestley inferred that the attraction of electricity was subject to the same laws as those of gravitation and set out the basic laws of electrostatics; in the 1770s, Lesage installed the first primitive telegraph, and Alexander Volta invented the first real electrometer, as well as a plate form of condenser. By the time of the Industrial Revolution, in the 1780s, fundamental advances had been made – in the UK, France, the Netherlands and Germany, and in the American colonies. But they were not yet sufficient in themselves to form the basis for commercial exploitation.



Perhaps the key advance came in 1796 with Volta's creation of the 'Volta Pile', a battery that constituted the first source of direct electric current; though its current was weak compared with the improved Leyden Jars, it was self-charging and continuous. Its demonstration at the Royal Society in London, in 1800, triggered a new epoch in electrical development (Canby 1962). Now, there began 'a communal interchange among great minds and small . . . a veritable explosion of discovery', bringing the principles on which modern electrical science is based (ibid., 41–2). Volta's battery was subject to numerous improvements, including the precursors of the modern dry-cell and storage batteries, and remained the principal source of electrical power until a practical dynamo was developed in the 1860s. Its existence led Davy, Faraday and others to discover and explore electrochemistry, electrolysis and the arc lamp. It facilitated the discoveries and contributions of Ampère, Oersted, Arago and others in the field of electromagnetism.

These advances were systematized and brought together in the work of Joseph Henry in the USA and Michael Faraday in England who, independently, discovered the laws of induction in 1832. Faraday was the first to publish his discovery that just as electricity can produce magnetism, so also can magnetism produce electricity via motion, the basis of our modern electric motors and generators. Henry even went further than Faraday and discovered that a changing magnetic field around a conductor induces an opposing current in the same conductor, the principle of self-induction; he discovered the principle of the transformer, whereby the voltage of fluctuating currents may be stepped up or down via induction from one coil to another. Henry also found that a varying current with a continually changing magnetic force could induce a complementary image of itself: a principle underlying the discovery of alternating power in the 1880s, as well as the transmission of speech and music as varying currents, and many other electronic applications (Canby 1962). These fundamental advances had come by the mid-1830s. Their commercial exploitation, in some important applications, did not come for another half-century. But in one, the telegraph, it came almost immediately.

## The birth of the telegraph

We have seen that Lesage had developed a primitive electric telegraph in Geneva as early as 1774; and in 1812 came a wire telegraph based on battery power. But the modern electric telegraph depended not merely on the battery as a source of direct power but also on the electromagnet of 1825, Morse's relay, and an effective system for coding messages. In 1831 Joseph Henry of Albany, New York, after discovering the laws governing the design of coils of electromagnets, produced signals over a mile-long circuit by causing a horseshoe electromagnet to swing a pivoted permanent magnet and strike a bell: the first electromagnetic telegraph. In 1833, Gauss and Weber in Germany constructed a two-wire electric telegraph. The receiver was a compass-type device for detecting and indicating the flows of current, with each character represented by a certain set of movements of the needle. In 1837, Cooke and Wheatstone in England patented a six-wire, five-needle apparatus that could be read visually. The system was first installed on the railway between Paddington and West Drayton in July 1839 and was extended to Slough in 1843. In the 1840s, Cooke and Wheatstone developed a cheaper and more efficient single needle instrument, using equal-duration left and right deflections of the needle to denote characters in a code closely resembling that of the eventually more succesful chief rival system, that of Morse.

It was also in 1837 that Morse registered a patent for his system, five years after his first sketchbook ideas about the use of electromagnets in telegraphy made during a voyage home from Europe. At that time Morse was a landscape and portrait painter who knew nothing about even the most basic principles of electricity; but he was able to harness the technical knowledge of his friends and combine it with his own invention of the dot-dash code to produce the most widely used wire telegraph system.

These early innovators – Henry (Princeton University, Albany and the Smithsonian Institute), Wheatstone (King's College, London), Morse (a successful artist and professor of the arts of design in the university of the City of New York) – were keen inventors who were often academics. When Morse first successfully demonstrated his system at New York University in 1837 before Professor Gale and Alfred Vail, 'they appeared to be the only ones in this country at that time who had any appreciation of the great commercial possibilities of the telegraph . . . no private capitalist could be found who believed that this invisible and elusive electric fluid could possibly be put to any commercial use' (MacLaren 1943, 45). Morse had to wait until 1843 before the necessary $30 000 finance for his first practical system, over 43 miles between Washington and Baltimore, was provided by Congress. Only after the success of this initial endeavour, financed by the state, did the swarming process and rapid growth on the basis of private capital and entrepreneurship begin in the American telegraph industry. But then, quite quickly, demand came from railroads, the press, business and financial services; business, rather than private citizens, provided the basis for the industry's growth, in contrast to the position in Europe (Du Boff 1980).



Morse was thus able to found his own firm, the Magnetic Telegraph Company. From the very early years local telegraphy companies began to merge, partly in order to facilitate message transfer between various local systems and to avert telegraph chaos (Canby 1962). In 1856 the Western Union Telegraph Company was formed, unifying many small local telegraph firms, on the basis of Morse patents. Although Morse was initially barred from obtaining British patents, he did succeed in introducing his register as a competitor to Wheatstone's needles in many European countries commencing with France in 1845.

These growth decades of the telegraph saw many important improvement innovations, which considerably helped its functioning, reliability and cost–performance ratios. Morse replaced his embosser and inker registers with the much simpler sounder, which allowed skilled operators to transcribe messages more quickly and allowed average operating speeds of 20–25 words per minute. The demand for private wire systems that required no knowledge of code was met by Wheatstone's direct reading system and other similar systems developed in France and Germany. There were also many improvements in the types of distribution lines and wires and their insulation and more efficient utilization; one of the important innovations here was the duplex which made it possible for one wire to provide separate eastbound and westbound paths for simultaneous transmission, and in 1874 Edison invented a double duplex, called a quadruplex.

The innovatory origins of the telegraph thus came independently and simultaneously in the USA and in the UK. That makes the early challenge of Germany particularly interesting. For 30 years later, as we shall see in Chapter 6, the German electrical industry became (together with the American) the UK's chief competitor on the international stage; and its origins lay at this time, when, as an East German historian has put it, the infant electrical industry consisted exclusively of information technology (Barr 1966). These origins were curious ones. Werner Siemens, born near Hannover in 1816, enrolled in 1834 as an army officer because he had no other means of obtaining the scientific education he desired. In 1846, still a lieutenant posted to the Artillery Workshops in Berlin, he came into contact with the electric telegraph. It was a subject of great interest to the Prussian General Staff, who had been operating a semaphore telegraph since 1832 (Siemens 1957a, Weiher & Goetzeler 1981).

To develop and improve the telegraph, in October 1847 Siemens set up in partnership with a technician of the Physical Society (Physische Gesellschaft) of Berlin, Johann Halske, in a combined workshop and house in the Kreuzberg area of Berlin, close to the Anhalt railway station. The location was perhaps significant because it was close to the headquarters of the War Ministry. Here, for a time, he pursued an extraordinary treble life as army officer, official of the Prussian Telegraph Commission, and entrepreneur, a situation that came to an end only when he clashed with the Commission (Siemens 1957a, Kocka 1969, von Peschke 1981). His early home business was based almost exclusively on demand from the Prussian army, railways and the telegraph (Baar 1966, Siemens 1957a); in the 1860s, they expanded into long-distance telegraph cable ventures (Siemens 1957a).

Over in the UK, for some years immediately following Cooke and Wheatstone's initial system of 1837 the use of the telegraph was almost entirely confined to railways. The first British company formed to undertake the business of transmitting telegrams, the English Telegraph Company, was incorporated in 1846. For a time its activities were confined to the construction and maintenance of railway telegraphs and for some years it was regarded as a commercial failure. By the early 1850s many improvements had been made in the operation of the telegraph, a cable was laid from Dover to Calais, and the telegraph industry began to take off and make progress in the UK: 'numerous companies were formed, and keen competition led to considerable extensions of wires and reductions of tariffs, with the effect that the volume of business increased enormously' (*Garcke's manual of electrical undertakings* 1896, 2). Between 1857 and 1867 the Electric Telegraph Company's number of messages transmitted increased fourfold from 881 000 to 3 352 000 whilst the average cost per message fell from 4*s*. 1*d*. to 2*s*. 1*d*. (20.5p to 10.5p)

Throughout the 1860s there was much public dissatisfaction in Britain over the fact that the larger towns, where competition for the provision of telegraph services had been most keen, had unduly benefited at the expense of the smaller towns where the service was relatively less profitable. Telegraphy was becoming increasingly indispensable for industrial and commercial affairs. In February 1870, in response to political pressures, the government took over the telegraph companies, made a considerable reduction in the rates per message and a uniform tariff of 1*s*. (5p) per 20 words was established; this tariff remained in force until 1885 when it was further reduced to ½*d*. (0.2p) per word.

The nationalization of the British telegraph service companies arose from the fact that the growth and exploitation of the telegraph by private companies in the UK 'was not an unmixed blessing, as they were primarily concerned with making profit and not with catering for the varied needs of the public' (Fleming & Brocklehurst 1925, 16). Within a few years of the founding of the industry there was considerable agitation for the state to acquire the whole telegraph system. One of the leaders of this campaign was the Edinburgh Chamber of Commerce and it was followed by many other chambers; and most sections of the public press actively participated in the campaign. In response, the government ordered an inquiry into the running of the service in 1865. It found, among other things, that about 2800 towns were served by telegraphic service, a very small number of places compared with the 10 000 served by the postal service. Eventually a Bill came before Parliament seeking to remedy the defects of the service and nationalize it. The main arguments in favour of the Bill were set out by a Mr Scudmore, who in introducing the Bill argued that:

> the charges made by the telegraph companies were too high and tended to check the growth of telegraph; there were frequent delays of messages; that many important districts were not provided with facilities; that in many cases the telegraph office was inconveniently remote from the centre of business and was open for too small a portion of the day; that there was little or no improvement so long as the working of the telegraphs was conducted by commercial companies, striving to earn dividends and engaged in wasteful competition with each other. . . (quoted in Fleming & Brocklehurst 1925, 241–2).

It was also argued that the growth of telegraphy in Belgium and Switzerland had been greatly stimulated by the state ownership and control of the service and the consequent adoption of low charges; it was also argued that the association of the telegraph with the Post Office would benefit the public at large and eventually provide a substantial revenue to the state. The Bill was passed into law and the telegraph service was nationalized in 1870 on the basis of a 20 years' purchase of the profits of the year ending 30 June, 1868. The anticipated increase in the volume of business from the reduction of rates was realized when the number of messages relayed rose from 6.5 million in 1869, to 10.0 million in 1870 and 20.0 million in 1875. At the time of nationalization, there were about 30 different telegraph companies in the UK (apart from the railway companies) engaged in the transmission of telegrams and several different systems were utilized. In 1870, the total number of telegraph offices in the UK, including railway stations transacting telegraph business, was 2500. By 1896 it had increased to 9926 (*Garcke's manual* 1896).

The state monopoly did not extend to the colonies or to the international submarine telegraph business, in both of which private enterprises were the major actors. From the 1850s the growth of submarine telegraphy was considerable, with the total number of submarine cables approximating 1400 in 1896 and their length amounting to 161 385 nautical miles; of these, 1021 cables of 18 578 nautical miles were owned by various governments and 369 cables of 142 806 nautical miles by companies, most of whom were incorporated in the UK (*Garcke's manual* 1896).

Despite the invention of the telephone in the late 1870s, the telegraph continued to grow as a means of communication up until World War I, although it increasingly lost out to the telephone, as the data in Table 4.1 indicate; indeed, it remained the main form of long-distance international communication until well into the 20th century.

As with other later information technology systems based on electricity and electronics, the electrical telegraph technology and industry in turn facilitated the growth and development of other new sets of economic activities (product innovations). Together with the development of the railways, the telegraph was an important facilitating force in the development of mass-circulation newspapers and other media; the 'penny press' was able to feature

**Table 4.1** UK Post Office telegraph revenues and messages handled, 1856–1 and 1911–2.

| Year | | Number of messages | Gross revenue (£) |
|---|---|---|---|
| 1855 | | 1 017 529 | n.a. |
| 1868 | | 5 718 989 | n.a. |
| 1870–1 | | 9 850 177 | 801 262 |
| 1883–4 | | 32 843 120 | 1 789 223 |
| 1895–6 | | 78 839 610 | 2 879 794 |
| 1907–8: | telegraphs | n.a. | 3 100 940 |
| | (telephones | n.a. | 1 383 180) |
| 1911–2: | telegraphs | n.a. | 3 147 705 |
| | (telephones | n.a. | 2 962 736) |

Sources:
(1) *Garcke's manual of electrical undertakings* (1896, 1913–4).
(2) Fleming & Brocklehurst (1925).
*Note:* The government took over the British telegraph operating firms in 1870, so prior to this date the numbers of messages refers to those carried by all the telegraph firms in the UK.



domestic and foreign hot news in place of journalism's traditional fare of stale editorial comments and commentary on information and news received by mail. The press wire service, a growing information industry even to this day in its new digitized and often wireless form, originated in the UK in the work of Reuter, who from the late 1840s was supplementing incomplete telegraphic communications systems on the continent by using carrier pigeons to bridge the gaps; from the 1860s he was operating submarine cables owned either wholly or partly by his news agency. In the USA, Associated Press was established in 1848 to pool telegraphic expenses, and it set up the first inter-city leased-wire service in that country in 1875. The telegraph thus played an important rôle in lowering the cost of information relevant to business transactions by speeding the flow of business information, extending the effective spatial scale of markets, and thereby improving the efficiency of the market economy (Du Boff 1980).

## The emerging cable industry

From the 1840s on, a major part of the emerging telegraph industry was involved in the development, production, laying and maintenance of cables, wires and insulators capable of conveying messages via small electrical charges, across land and sea. The success and growth of the industry was dependent upon a whole set of novel inventions, innovations and literally 'heroic' entrepreneurship on the part of inventors, engineers and teams of workmen, especially in the case of submarine cables (Fleming & Brocklehurst 1925). Even in this very first, and rather primitive electrical industry, successful industrial innovation was systemic in character, depending upon advances in many aspects of electrical technology as well as those in chemicals and mechanical engineering, a point neglected in many accounts which focus on single product inventions or innovations in the apparatus concerned with sending and receiving the messages. Although these secondary innovations in the wire systems of conveying, transmission and distribution of telegraphic messages might be less dramatic and exciting, they were fundamental to the growth of the telegraph industry – and subsequently, since they constituted the first 'information highways', of telecommunications generally.

The early telegraph innovators were able to overcome a wide range of novel problems in this field. Morse's first telegraph line used glass doorknobs as insulators, but both British and American firms soon designed improved insulators of glass and porcelain which were used and improved upon by the later telephone and electrical power industries. The early telegraph industry also had to pioneer methods of laying and insulating underground cables to protect them from electrical failure due to moisture. The development of submarine transmission systems, from the late 1840s, presented a truly enormous set of technical and engineering challenges; these concerned not only the design of wire cables and electric insulation material with adequate mechanical strength and ability to withstand the rubbing action against rocks caused by the tides but also the development of new techniques of cable-laying from ships, based upon many expensive trial and error learning experiences and dogged determination (ibid.).

Indeed the problems of large-scale insulated wire and cable construction, the development of adequate insulators, lightning arresters, fuses and other components, which confronted the early telegraph industry, were entirely novel ones, requiring innovative solutions. They thus fed into and facilitated the subsequent growth of telephone communications systems, because telegraph lines were basically similar to early telephone lines, and almost invariably the same facilities were used for both. And they even greatly facilitated the development of the heavy duty transmission systems of the electric power and lighting industries which emerged after 1880.

London was the major communications node and centre for financing most of the international submarine cable business. In large part this arose from its position as the centre and metropolis of the hegemonic international industrial, trading and military power of the time. From the start, British-based cable and wire making firms had a strong international position, although one of the main companies was Siemens of Germany, which concentrated its submarine cable activities on its British branch. The British telegraphic wire and cable industry exported a high proportion of its total output (Scott 1958, Byatt 1979).

This strong innovative performance carried over into the manufacture of wire and cable for the electric lighting and power industries which developed from the 1880s. The heavier currents involved in the latter required new kinds of insulators and conductors compared to those used for telegraphy. The two main innovating firms in this respect in the early 1890s were not the established telegraph cable makers; one was Callenders, a road materials firm, which developed a system by which the conductors were laid in wooden troughs and covered with bitumen; the other



was the British Insulated Wire Company, which developed Ferranti's simple but ingenious idea of using paper as a dielectric that substantially reduced the cost of high voltage cables. Although some paper-insulated flexible cables had been used in the USA for telegraphs, the use of paper insulation for electric power cables was first made and patented by Ferranti in 1888 for use on rigid tubes. Atherton, who founded the British Insulated Wire Company in 1891, invited Ferranti to join the company board. Using a variety of US patents and Ferranti's patents, the firm produced 11 000 volt paper-insulated flexible cable that was relatively cheap and easy to lay (Byatt 1979).

The British cable and wire industry continued to have a strong international position down to World War I, with exports more than five times the level of imports between 1906 and 1913 (ibid.). Indeed, throughout the third Kondratieff the manufacture of cables remained 'one of the strongest and most consistently successful sections of the British electrical industry' (COIT 1928a, 302). Two noteworthy features were that it was subject to less technical change than the electrical machinery industries (Byatt 1979) and that it was generally dominated by a relatively small number of firms (COIT 1928a; Byatt 1979).

## The invention of the telephone

The telephone, as already seen, shared with the earlier telegraph a basis in weak electrical current. This second early electrical communications and information technology industry, however, differed from the telegraph in a number of respects. Firstly, the telephone permits the transmission of speech and other articulate sounds across great distances rather than signals that have to be interpreted by skilled operators or printed on paper via expensive equipment; it is thus not only an enhanced form of human electrical communication over space but one which can be more easily and efficiently operated by anyone with speech and hearing abilities. Secondly, although it may be an exaggeration to claim that 'the telephone is much more the product of a single inventive mind than the telegraph' (Fleming & Brocklehurst 1925, 249), it appears that 'only a few hardy pioneers had sufficient courage or imagination to undertake the much more difficult task of transmitting articulate speech over great distances, but their progress was comparatively swift' (MacLaren 1943, 50–1).

Thirdly, unlike the telegraph, there was a gap of almost 40 years between the initial scientific discoveries and their practical combination and application by Bell in 1876 (Finn 1985). One possible reason is that 'the social need was not great enough' at the time (ibid.); another may be a lack of 'innovation push', in that there were very few experiments and attempts at developing telephony between the 1830s and the 1870s. Perhaps this was because of the sheer novelty of the improvement in human communications represented by the telegraph system; the multi-faceted challenges posed by the telegraph system, and the improvement of its apparatus, wires, cables, insulators and other components, concentrated scarce inventive and innovative resources within this particular technological paradigm for four decades.

The principle of the telephone is based, like that of the telegraph, on magnetic induction: the human voice or other sound vibrates the air, which in turn vibrates a diaphragm; the movement of the diaphragm produces a corresponding vibration in an electric current. Thus the essential scientific discoveries necessary for the telephone were the concept of sound as a vibration which was known since the beginning of the 19th century, and the knowledge that vibration could be transferred to solid bodies (which Faraday had demonstrated in 1831 by showing how the vibrations of a piece of steel or iron could be converted into electrical impulses). Among the few to experiment seriously with sound transmission before Bell was Philip Reis, a German schoolteacher, who in the 1860s developed a crude device for the transmission of music; it was however ineffective for communicating speech (MacLaren 1943). In 1874 Elisha Gray, who was the chief electrician of the Western Electric Company of Chicago, invented a liquid form of transmitter which corrected the main defects of Reis's system. When Gray applied for a patent on 14 February 1876 he found that Alexander Graham Bell had filed an application for practically the same device a few hours earlier on the same day. The interference suit that followed was decided in favour of Bell (ibid.).

It was no accident that Bell's Scots grandfather was a professor of elocution; his father was a specialist in teaching the deaf and dumb, and he himself was a doctor who – after emigrating, first to Canada, then to the USA – became professor of vocal physiology in Boston, with a school for deaf mutes and others with defective speech (Birdsall & Cipolla 1980). He became interested in the analysis of sound waves and in methods of transmitting sound electrically by means of tuning forks; he was originally seeking to use this method to transmit several telegraphic messages simultaneously over the same wire, a problem that interested several telegraphic inventors at the time. Seeing a 'mechanical ear' at the



Massachusetts Institute of Technology – an early example of the serendipitous effect of urban agglomeration in innovation – he found that, by utilizing Faraday's discovery of electromagnetic induction, a miniature generator could be produced from a vibrating magnet placed close to a coil of wire giving rise to electrical waves which could be reproduced at a receiving instrument at the end of a line.

In pursuing this line of work in 1875, Bell was becoming discouraged despite his progress, for he felt that he was without adequate means for carrying out his ideas to the point of commercial success; but, in the summer of that year, he was strongly encouraged to continue his work by the 80-year-old Joseph Henry (MacLaren 1943, Birdsall & Cipolla 1980). In that same year he gained financial support from two Boston capitalists, his father-in-law Gardiner Greene Hubbard and Thomas Sanders, signing an agreement with them to form the Bell Telephone Company (Dummer 1983). He filed his patent for a 'speaking telegraph' on 14 February 1876, was granted it on 7 March, and successfully transmitted speech three days later; he spent the rest of that year preparing it for public use (Bruce 1973, Tucker 1978, Reich 1985).

It led to a huge battle with the Western Union company, who, rightly seeing the new instrument as a threat to their profits, commissioned Thomas Edison, then an employee, to develop an improved version using the rival patents of Elisha Grey. Edison developed a much improved transmitter, the weakest part of Bell's system, and a new type of receiver by 1878. The suit was eventually settled out of court by a compromise, whereby Bell was to have use of Edison's transmitter on payment of 20% of its profits on the rental of telephone instruments to Western Union and each company was to confine itself to its own particular field of activities.

Meanwhile, commercialization of the Bell system had begun in 1877 and a Boston electrical manufacturer, Charles Williams, was selected to make the first instruments. It was also decided at that time that the instrument would not be sold to the public but would remain the property of the telephone company. By the end of June there were 230 telephones in regular use throughout the USA, and two months later there were 1300 in use (MacLaren 1943). Soon it became evident that although the telephone derived technologically from the telegraph it demanded an entirely different system of organization. The telegraph had immediately been adopted as a communication and safety device by the railways, and a public message service developed as an ancillary to that primary purpose; consequently, the railway station became the public telegraph office (Birdsall & Cipolla 1980). But with the telephone many subscribers had to be interconnected, necessitating the principle of the central exchange; the first, at New Haven in Connecticut, opened in January 1878 (Tucker 1978). This was soon solved at a local level: by March 1880 there were 138 exchanges in operation in the USA, with 30 000 subscribers; by 1887, only a decade after the commercial introduction of the telephone, there were 743 main and 444 branch exchanges connecting over 150 000 subscribers with about 146 000 miles of wire (Finn 1985). But development of the telephone for long-distance communication was severely limited by both technical and, outside the USA, political constraints. It is a story that properly belongs to the third Kondratieff and will be treated in Chapter 6.

After settlement of the Western Union suit and a number of subsequent actions – a process that took until 1893 – a number of independent companies emerged in the USA. Yet the Bell system held such a predominant position 'that a great unified system was built up in which the smaller companies either disappeared or were granted exchange privileges which did not interfere with unrestricted communication throughout the country' (MacLaren 1943, 59). In Europe, however, politics intervened. By 1885, when the USA had 140 000 subscribers and 800 interurban connections, the UK – next in the world league – had a mere 10 000 and 80 respectively; the USA probably had twice as many telephones as the rest of the world combined, thus establishing a lead that was to last for many decades (Tucker 1978).

## The telephone in Europe

This was not entirely due to lack of technical innovation. In the UK, the first working telephones were exhibited at the British Association meeting in Plymouth in 1877. In the following year an important British contribution to telephony was made by Professor D.E. Hughes, who found that finely divided carbon was a particularly suitable material for a loose-contact transmitter and that under favourable conditions this type of transmitter could be used to magnify weak sounds; he called the instrument a microphone. Hughes said in his paper that he considered the principle of the microphone a discovery rather than an invention and he thought others should have the benefit of his discovery. Rather than patent it himself, he allowed at least three different inventors of instruments to follow his designs quite closely (MacLaren 1943). Edison was the first to design a transducer using



granules of carbonized hard coal, still used in present day microphones (Dummer 1983).

From the start, the rival Bell and Edison interests were not content with developing and expanding their telephone systems in the urban centres of the USA; they actively engaged in the transfer of their technology and systems to the cities of Europe (Hughes 1983). Bell himself came to Europe in 1877; Edison's telephone patents were promoted in England by Gourand, an American who often represented American banks in London and had valuable contacts among British capitalists. From 1878 Edison employed the services of Grosvenor Lowrey, whose associates, members of the great banking and investment house of Drexel, Morgan & Company, had the financial resources, the foreign contacts and the organizational wherewithal to move technology across national boundaries (ibid.), especially for major new systems and products such as telephones and electric lighting schemes, where such large financial resources were of the essence.

In 1878 the Telephone Company Limited was formed in London to acquire and work Bell's patent; in 1879 the Edison Telephone Company of London was formed, with plans to open telephone exchanges; in 1880 the two companies were amalgamated to form the United Telephone Company. But under the 1869 Telegraph Act, the British Post Office enjoyed a monopoly of all systems and devices for electrical communication; and it opposed the opening of public telephone exchanges, on the grounds that they infringed its exclusive rights, winning a High Court judgment to this effect. Thereupon the Post Office granted the telephone company licences to operate on payment of 10% of the gross revenues of the company. These licences were originally for specified areas; the companies had no power to make trunk lines between one town and another, or to open public call offices. In 1884 these restrictions were abolished.

The London and Globe Telephone Company was formed in 1882 and given a licence to compete with the existing exchanges, but in 1884 it was absorbed into the United Telephone Company. In 1889 the United Telephone Company amalgamated with some of the subsidiary companies to form the National Telephone Company. By 1896 this company had 'absorbed most of the companies holding Post Office licences, and is now the only company in the United Kingdom carrying on telephonic exchange business' (*Garcke's manual* 1896, 5). But a change in the law in 1899 allowed local authorities to operate municipal systems; and as late as 1912, there were at least three such systems (*Garcke's manual* 1912).

In 1896 the National Telephone Company had 654 exchanges and

88 093 subscribers' lines, handling about 350 000 000 messages per annum (*Garcke's manual* 1896). By this time there were also arrangements between the Post Office and the telephone company for sending telephone messages over the telegraph or via the postal services as express letters. By 1906 there were 10.15 telephones per 1000 population in the UK compared with 10.2 in Germany, the only other country, apart from the more advanced USA, that could then be compared with the UK in telephone development (Fleming & Brocklehurst 1925). The National Telephone Company continued to hold the monopoly until 1911, when it was taken over by the Post Office.

On the continent of Europe both the Bell and Edison companies moved quickly to introduce their new telephone systems. Late in 1877 Bell went to Germany and succeeded in obtaining the adoption of his system by the German postal service; several hundred telephones were ordered from Siemens Halske (MacLaren 1943). But many rival systems were also being developed in Europe at the time. Gower, a former Bell employee, developed one which met with considerable success in France and England. His enterprise became locked into a complicated set of patent suits with Bell and Edison companies and in 1880 the three interests united to form the Société Génerale des Téléphones in France and the United Telephone Company in the UK. Among the many other European devices were the Ader transmitter, which was quite popular in France, and the Crossley instrument; both of these and Gower's device were closely modelled on Hughes' discoveries (ibid.).

Many other competing systems and standards arose in Europe; 'The result of having so many companies starting up in a region where the field of activity was limited by national boundaries greatly retarded the creation of a universal intercommunicating system'; this was in sharp contrast to the USA, where a unified system was developed early under the Bell monopoly (ibid., 59). There, government supervision safeguarded the public against private monopoly power (ibid.); in many European countries the problem was later solved by direct government control.

## Conclusions

The telegraph and telephone were thus not merely the earliest New IT industries but the earliest electrical industries to emerge. This may be due in large part to the fact that they required relatively low supplies of electricity compared to those required for electrical



motors or lighting. Yet the telegraph industry emerged almost 40 years before the telephone, although the latter did not require any additional basic scientific discoveries for its development. The reasons for this time lag may be that the initial development of the telegraph itself constituted an extraordinary revolution in human communications potential; its systematic development and improvement may have presented a sufficient challenge to the prevailing technological (inventive and engineering) infrastructure. The telegraph's sheer novelty and revolutionary character is underlined by the fact that even in the heyday of *laissez-faire* capitalism, and even despite a burst of inventive activity attesting to its practicality, its early development everywhere demanded some state backing. Forty years later the telephone did not appear to suffer from any such hesitancy on the part of private entrepreneurs – at least in its birthplace, the USA. In contrast, the slow and relatively unsophisticated development in Britain led to demands for nationalization from the 1890s, finally realized in the 1911 Act (Clapham 1938).

One striking aspect of the development of the telegraph was the international character of the original scientific discoveries and resulting inventive activity, coupled with a level of international information exchange that is surprising in an era of poor transportation and communication facilities. Although Cooke and Wheatstone in the UK, and Siemens in Germany, developed a practical system at the same time as Morse in the USA, the latter is generally credited as the major founding father and innovator; even though his electrical knowledge was quite limited, his elegant solution to the problem of coding was a major contribution to the success of his system and its eventual dominance. In contrast, the telephone emerged from a relatively small group of inventors, and the credit for its initial innovation and development clearly lies with the work of Bell in the USA; Edison's pioneering development of an improved transmitter was also noteworthy, not only because it overcame the weak link in Bell's system, but also because the subsequent amalgamation of Bell and Edison telephone technologies ensured the rapid growth and dominance of this particular telephone technology both in the USA and internationally.

This distinction is important. At the onset of the second Kondratieff, in the mid-1830s, both inventive and innovative activity was finely balanced between the UK and the USA, with Germany in third place. Towards its end, in the mid-1870s, invention and innovation in New IT were firmly in American hands. As will emerge in Chapters 5 and 6, by this time the capacity for technological innovation generally was fading in the

UK; in the new electrical technologies of the period 1875–95 Germany and the USA shared the prize, whereas in the new mechanical information technologies the Americans took a clear world lead. One question to be asked, in Part Three, is how and why the locus of innovation should thus change.

PART THREE

# The electrical age

## New IT in the third Kondratieff, 1896–1947