1

Fundamentals

This introductory chapter uses the most appropriate terminology to give an overview of the history of the structure of telecommunications networks. For specialists in the domain, the chapter offers a recap on networking techniques, and the avenues which are open to companies are also touched upon.

1.1. Different kinds of network

1.1.1. *Classic definitions*

For simplicity's sake, the definitions given here take account of both technical considerations and regulatory aspects. They are accurate at the time of writing (2014). For further details on the official terminology used, readers may consult the ITU.[1]

When we speak of a "network", we mean a combination of various devices, management software packages and links which enable a certain number of terminals, distributed within a specific geographical area, to communicate with one another.

1 http://www.itu.int/ITU-R/index.asp?redirect=true&category=information&link=terminology-database&lang=en&adsearch=&SearchTerminology=&sector=&language=all&part=abbreviationterm&kind=anywhere.

A *local area network* is one whose coverage is restricted to the dimensions of a particular private space – e.g. the premises of a company (an area between 10 m and 1 km in diameter). The abbreviation LAN is used to speak of such networks). There are various types of LAN, including hardwired LANs (where the connections are formed by metal wires or optical fibers), wireless LANs (WLANs) and hybrid LANs. LANs are managed by their owners, and are often the responsibility of the technicians in a company's IT department. They may be completely independent of any external connection, or may be linked to another network. Small local networks are considered to be Personal Area Networks (PANs). Low energy-consumption wireless PANs are known as LoW PANs.

For greater distances – say, between 5 and 50 km, the expression "Metropolitan Area Network" (MAN) is used. An MAN belongs to several entities in cooperation with one another. It will be connected to one or more "Wide Area Networks" (WANs).

Thus, a WAN encompasses a number of MANs. Its coverage extends over diameters greater than that of a metropolitan area. WANs may be made up of numerous hardwired and wireless connections. Usually, they are managed by a number of competing companies. They are capable of handling communications to and from outside the LANs, including international connections. A WAN may be made up of hardwired, wireless and satellite connections.

In the medical field, we speak of Medical Body Area Networks (MBAN) for therapeutic applications or for clinical tests performed on the human body, using radio electric equipment exploiting the frequency bands authorized for that purpose. The terms BAN (Body Area Network) and BSN (Body Sensor Network) are often used to describe the use of portable low-consumption computerized devices, which function on, in or around the human body, for a wide range of applications – medical, consumer electronics, entertainment and more.

On a technical level, a large-scale network includes a "core network" (also known as a core network) and an access network. The core network handles the flow of traffic between network connection centers and intercity transfer centers. The core network is the junction between all the concentration points in the wired and radio access networks. In general, there tends to be one core network for each country, and one per network operator as well. The access network is the network which facilitates the receiving of calls and traffic hardwired or wireless subscribers. To define the interface between a wireless subscriber and the main network, we use the acronyms RAN (Radio Access Network) in 2G technology (2G means second generation in mobile telephony systems), UTRAN (Universal Terrestrial Radio Access Network) for 3G and *eUTRAN* for 4G.

Finally, we must mention private networks – i.e. those which are for the sole use of one company, and are made up of the equipment and resources in the general network of a particular operator. Real private networks (RPNs) are those which are physically in permanent existence, whilst Virtual Private Networks (VPNs) are those whose elements are added or removed on request by a computer. IVPRs are international virtual private networks.

A more recent vision represents the architecture of public communications networks as hierarchically-ranked set, hinged around three levels: the “backbone network” (or core network), the “backhaul network” and the “service network”; the latter two make up the “access network”. Backhaul networks, which are established at regional or municipal level, form the link between the backbone network and the subscribers, by carrying traffic between the service points where the operators’ distribution devices are installed.

1.1.2. *National networks and international connections*

Traditionally, every country has its own communications network, structured in accordance with the number of regions needing to be served and the density of subscribers to be connected. That national network is connected to the networks of the neighboring countries by way of international transit centers (or “nodes”). So as to avoid the demultiplication of operations when multiple transits take place, countries often agree to group together traffic with the same destination, depending on the affinity between the countries. There are bilateral international connections between the 193 UN member states (either direct or requiring transit operations), which form the basis of the global communications service. In classic network structures, financial viability is only guaranteed for around 10% of international connections, as there is insufficient traffic over the other connections.

Between a certain number of selected countries, it is possible to establish international networks which simply handle large volumes of business traffic: this is the function of IRCs (Internationally Recognized Carriers). Unlike RPOAs (Recognized Private Operating Agencies), which are public and private network operators recognized by the ITU (the International Telecommunications Union – the United Nations agency for telecoms), IRCs handle the business traffic of specialist companies. For example, SWIFT (Society for Worldwide Interbank Financial Telecommunication) is a cooperative which runs a private international messaging network linking over 10,000 banks. SITA (*Société internationale de télécommunications aéronautiques* – International Aeronautical Telecommunications Society) is an organization which provides computing and communications services to the aeronautics industry, through a vast international private network.

Although it does not have the status of an IRC, the activities of the Internet have been extended so that it now plays a very similar role in terms of international connections. The Internet is distributed in every country by network operators using Internet-connection application servers, which are also known as ISPs (Internet Service Providers). The Internet is distributed through access networks offered by different ISPs. The equivalent of the backbone network of the Internet is made up of high data rate connections between GIX (Global Internet eXchanges): switching and routing centers.

A GIX is a center housed in a physical infrastructure which interconnected networks use to accelerate and optimize their Internet traffic, thanks to what is known as “peering” – mutual agreements between the operators. GIX nodes are open to any and all network operators wishing to connect to them: Internet Service Providers, service companies, large accounts, local collectives, associations, etc. SOHOs (small offices), SMEs and individuals benefit from the use of GIXs by their ISP.

IPX (IP eXchange) is a model for the interconnection of telecommunications networks favored by the "GSM Association (GSMA)", for the exchange of different IP traffic from mobile and landline network operators and service providers, such as ISPs. The aim of this structure is not to compete with the Internet. It is an alternative for clerical application providers, and at all stages in the value chain, which is supported by Service-Level Agreements (SLAs), to guarantee performance, quality and security. Indeed, in today's world, it is necessary to minimize the number of conversions of voice signals between circuit-switching networks and packet-switching networks. The IPX architecture also includes inter-network packet exchange interfaces (peering points).

1.1.3. *Network exploiters and operators*

The policy of deregulation, which has been widely implemented in Europe and indeed the world over since the 1980s, has opened up the telecommunications markets to competition, and forced network administrations to become private commercial entities. Alongside the role of the network exploiter (*exploitant*), that of the network operator (*opérateur*) has come into being.

In the author's native French, this distinction is an important one: it relates to the different responsibilities attached to these two types of enterprise. The nuance is rooted in the legal obligations incumbent upon a "historical" network exploiter (closely related to the idea of a public service, with a duty to provide 24/7 coverage for the whole of a national territory, free emergency calls, rights of passage and obligations in cases of public good). An *opérateur*, on the other hand, is a purely commercial enterprise, free to engage in competition but also to collaborate with other operators (of which there may be several within a given country). An "operator" benefits from the skill and experience of the "network exploiter" providing the basic service – including for the maintenance of cables, for example. Unfortunately, in English, this distinction is difficult to preserve, as one tends simply to speak of a "network operator". Where the separation is of particular importance for the discussion, the word "network exploiter" will be used; otherwise, the term “operator” is systematically employed for both entities.

The distinction between the work done by network exploiters and network operators has become a tenuous one. In principle, whilst the network exploiters invest in the installation of infrastructures and carry out the exploitation and maintenance of complete and diverse networks, in addition to general service provision, network operators concentrate their efforts on one clearly-defined part of the range of tasks of a network exploiter. The service offered by operators is often original and innovative. This type of specialization of activity means that there is a dynamic aspect to the service provision which is both technical and commercial. Although strict terminology cannot yield a rational classification, the evolution of the professions leads us to distinguish a number of different types of actors or operators, including:

– Telco2.0 organizations, which are represented by actors who, thanks to the Internet, now harbor the ambition to take possession of value chains from the domain of conventional network exploiters, by controlling the distribution of value-added services (e.g. Amazon, Apple, Google, social networks, etc.);

– MVNOs (Mobile Virtual Network Operators), which do not have a dedicated radio frequency (RF) spectrum, or their own networking infrastructure. They sign agreements with mobile network exploiters, purchasing trafficking capacities or usage concessions from them, and selling services under their own brand names;

– BVNOs (Broadband Virtual Network Operators), which play the same role as MVNOs but with broadband;

– Infrastructure operators, who specialize in the design, construction, technical running and commercialization of very high data rate optical networks, under-roads, terrestrial and submarine, access to GIX (Global Internet eXchange, as discussed above), supply of “cloud computing” services (remote, Internet-based computing services), corporate telephony, and in hosting capability for the deployment of services to other operators or companies. They may also have the status of a regional not-for-profit organizations, or be partners in local collectives for public-initiative networks (PINs), and infrastructure operators;

– local operators, who cater for the communication needs of SOHOs, SMEs and administrations, in terms of Internet connections, corporate telephony, server hosting and network security, with computer applications hosted by a cloud computing service;

– an operator specializing in corporate-telephony and professional computing, oriented toward speech recognition and -synthesis technologies, who creates and markets tools which are essential for consumer relations for large enterprises and health establishments (university hospitals, clinics). Such an operator has developed software tools capable of handling telephone calls, irrespective of the language used, with virtual operators. When the call is connected, the called is asked to speak the name of the department or person he/she wishes to contact. The virtual operator responds to each demand by employing a number of scenarios. These new tools are able to extend the operating hours of the telephone answering service, reduce costs and improve a company's image by way of a personalized, efficient reception service;

– an operator who may specialize in the provision of communication services, e.g. for yacht owners, offering a value-added service by means of SIM cards, in partnership with the other operators, for varied bundles of services (GSM, Internet, television), playing the role of the single port of call from the Mediterranean to the Caribbean.

After Skype was bought by Microsoft, it began offering Internet telephony to companies. Thus, in March 2013, Skype was forced to declare itself to be a telecoms network exploiter in France. "The fact that Skype provides the services of an electronic communications operator, and in particular the fact of providing a public telephone service, also means it must meet certain obligations, including the handling of emergency calls and the use of the means necessary for legal interception of calls" (article L. 33-1 of the *Code des postes et des communications électroniques*, CPCE – Postal and electronic communications code). However, Skype maintains that it is not a true network operator or an MVNO, because in fact, Skype provides users with no hardware and no SIM cards. It does not require a paid subscription, it does not invest in the telephone network, and it does not install relay antennas or centers. Declaring itself to be an operator would require connection to a paying telephone network, keeping of a directory, and installation and maintenance of public phone booths. Ultimately, on a technical level, Skype, which does not use the SIP protocol, proves to be incompatible with the hardware and autoswitches used by other network operators.

1.1.4. *Economic role of MVNOs and VNO*

The introduction of MVNOs into a national mobile telephony market is supposed to stimulate the global market – either by price competition or by the provision of particularly attractive services and terminals. It does not necessarily require the redistribution of the frequencies between the beneficiaries, because MVNOs use the same frequencies as the mobile network operator with which they are associated. The entry of Apple into the Chinese market, or that of Google into many other mobile networks, can be achieved in this way, with the promise of investment as a result. The acceptance of this exchange – foreign investment for the creation of an MVNO – is often left up to the judgment of the regulatory services.

The introduction of VNOs into a national telephony market stimulates demand on target markets. It may facilitate the sale of original terminals or services. The introduction of new actors or new operators into the communications market reduces the market share held by the historical network exploiter, and drives down the price of its services. As the profit margins of the traditional network exploiters decrease, so too do their capacities to invest.

1.1.5. *Public and private networks*

The age-old notions of a public network and a private network have been revised (see the ARCEP Website for the most up-to-date information on this topic).

The “public network” used to be that which provided public communication services with constant (24/7) service requirements, total coverage of a country’s territory, handling of emergency calls, provision of directories, etc. The privatization of the historical network exploiters in most countries has caused this concept to change.

“Universal service” must be understood as a minimum set of services which operators have to provide their users in accordance with the legislation in force. An example of a universal service is the United States Postal Service.

A “private network”, often constructed using rented bandwidth for connections, may be built for the benefit of a particular company or a group of clients (e.g. SWIFT, HP, PMU [a betting network in France]). These networks, be they hardwired or radio electric, are specialized for particular services: banking messages, voice messages, still or moving images, fax, text or data-messaging, etc. They may be characterized, for example, by the process of leaving and returning of messages. PMR and PAMR are private radio electric networks with shared frequency resources:

– PMR – Private Mobile Radio communications: a mobile communication system using radio waves over a short or medium range, for use by professionals, security personnel, public works, industry, etc. Examples include the walkie-talkie from Motorola, TETRA, PMR446, RUBIS, etc. PMR facilitates the communication of messages to a particular group, with or without confidentiality;

– PAMR – Public Access Mobile Radio: radio electric communications systems for professional activities, which can be connected to the public network, divided into a number of categories defined by the regulations.

1.1.6. *Fixed and radio networks*

A fixed network is one wherein the connections between the devices are formed by terrestrial and submarine cables, selfsupporting cables or approved supports in the public or private domain. The communications terminals are not mobile.

A radio network uses radio links to establish the connections between the network centers and the users' mobile terminals.

1.1.7. *Main operators worldwide*

In view of economic globalization, the networking market covers the whole of the planet. Logically, in time, we expect to see only those with international stature survive. However, the system of competition in Europe has weakened European operators in favor of others, who are benefiting from the current favorable conditions. The current regulation system has led to the fracturing of the sector: there are 159 network operators in Europe, whereas in the United States there are only four. Network operators are also under pressure from Internet actors in terms of services (e.g. Google, Microsoft), and it is always possible that mergers or acquisitions will take place.

Operator	Turnover in billions of USD	Profit in billions of USD (2011)	Employees	Millions of subscribers
China Mobile	84 (2007)	20	175,000	650
Vodafone	79 (2007)	12	84,000	371
Telefonica	84 (2011)	7	291,000	310
NTT Corp	124	6	219,000	NC
América Móvil	47	6	72,000	256
France Télécom	60	5	172,000	226
AT&T	126	4	256,000	63
Telstra	27	3.5	36,000	9
KDDI	41	3	18,000	37
Singapore Telecom	14	3	23,000	426 (35)

Table 1.1. *Main telecoms network operators (2011)*

This selection of operators was constructed from data provided by BVD Info. However, it shows that there are no discernible recurring "laws" linking the number of subscribers, workforce size and financial results.

1.1.8. *Pan-European network project*

In January 2013, AT&T and Verizon, between them, controlled 75% of the American market (340 million users). The seemingly-demagogic European regulatory constraints have scared away investment. Tariffs in 2012 in France were nearly twice as low as in Germany, and three times lower than in the United States.

ETNO, the European Telecommunications Network Operators Association, which brings together 38 European telecoms companies from 35 Member States, stated at the start of 2013 that there were no projects in its then research program relating to the unification of mobile networks in Europe. However, the European authorities do want to put an end to the fragmentation of the European telecoms market, both for wired and wireless communication. In 2013, the project for pooling of infrastructures or simpler regulation of communications between limitrophe states was again brought up among the major European network operators, without the presence of European industrialists, who feel their business would be damaged by the splitting up of the European equipment market.

The European deregulation authorities, which actually caused the aforementioned fragmentation in order to encourage competition and drive down prices, now wish to unify the networks in 28 countries into a single entity using uniform technology and charging uniform rates. Whilst there is unanimity about the objectives to be attained, the way in which to do so is the subject of much debate. Is it best to begin by unifying the situation for cross-border transmissions, or is it more advisable to envisage the creation of a new company (a "newco") for telecommunications on a European scale?

1.1.9. *Single European hub for telecoms regulation*

The establishment of a European telecoms regulation office for all 28 EU Member States would pose numerous problems. The many differences between the situations in the different individual countries, as things currently stand, cannot easily be overcome (there are the issues of attribution of frequencies, differences between the various national telecoms infrastructures, etc.). The frequency spectrum, portions of which are currently auctioned off to national operators, would need to be transferred to the jurisdiction of a new regulatory entity, which would constitute a loss of revenue for each national government. In addition, all the different States are at different levels of advancement in terms of each of the national markets – e.g. in relation to the unbundling of optical fibers.

1.1.10. *Pooling of network infrastructures*

The pooling of a network infrastructure allows for shared use of that infrastructure by different operators, with regard to each of its physical elements (casing, fibers, active equipment, bandwidth, etc.). Such pooling caters for the requirements of geographical coverage and competition whilst sharing costs – particularly civil engineering costs – between the parties involved. The territorial collective, because of its position of responsibility for the public domain, or possibly as overseer of the network, can now build clauses on pooling into the formulation of its contracts and calls for tender. Notably, this practice leads to conventions between operators and syndicates authorizing interventions on the shared parts of the co-properties.

1.1.11. *Energy consumption of telecoms systems*

According to the Digital Power Group, over the course of a year, the balance of power consumption due to a smart phone is greater than that of a refrigerator. Obviously, telephones very frequently need to be recharged, but in addition to that, when a smart phone is turned on it causes the activation of dozens of other pieces of equipment, which begin functioning to provide service to the terminal. Making calls and sending SMS on a smart phone consumes less energy than using the device to watch videos, for example. 4G networks consume sixty times more energy than do 2G networks to provide the same level of coverage.

In total, the digital economy consumes around 10% of electricity produced worldwide. This phenomenal figure is arrived at by adding the electrical consumption of a number of activities: production of computer hardware, use of the terminals, use of the networks (both hardwired and wireless) and the energy used to power the data-processing centers. The proportion of electricity used for information and communication technologies has reached this level in the space of barely two decades. In years to come, this proportion is expected to remain stable. However, the amount of electricity consumed in terms of absolute value is expected to double within ten or twenty years. Although latest-generation terminals and networking equipment may offer better performances, they are extremely energy-hungry.

1.2. Financial aspects relating to networks

1.2.1. *Economic studies in telecommunications*

The telecommunications economy has really developed from the 1960s onwards. The former Directorate General for Telecommunications set up a service specializing in this domain in around 1965, thereby responding to a number of studies conducted on the topic by the OECD, by various US research groups and even by industrialists in the sector, in search of export markets (see the Jipp Curve, created by A. Jipp, a commercial engineer at Siemens). These comparative studies aimed to model the growth of markets in the future, the correlation between a country's GDP and the average number of telephones *per capita*, or between the growth of the telephone network, the fax network and data traffic, etc.

The International Telecommunications Union (ITU) is helping promote a coordinated definition of international pricing rules between the member states. The ITU proposes that the rates should be correlated with capital expenditure and operating expenditure.

1.2.2. *Cost price*

In the terminology typically employed in this domain, capital expenditure (CAPEX) for investment refers to the costs of development and supply of equipment. In addition, the operational expenditure (OPEX) for the network must be taken into account. The annual cost price of a network is generally deduced from an evaluation of the following five criteria:

– offsetting of the cost of the cabled connections used over a period of 30 years (or more);

– offsetting of the cost of the networking equipment and consumables over a period of five years;

– offsetting of the cost of the energy generation and storage equipment needed over five years;

– offsetting of the cost of the premises used over a period of fifty years (for example);

– contribution to the annual costs of human capital needed for the running of the network.

The sum of these five points then needs to be expressed in relation to the sum of the traffic channeled, evaluated using a given criterion (minutes of voice conversation, distance, volume of data, network resources, etc.). By the same principle as this method, provided a detailed billing system is available, it is possible to evaluate an actual cost price per minute of conversation per use 100km everywhere.

At present, for data traffic over the Internet, network operators prefer to use the method of flat fees for consumption per subscriber, whereby the total sum of revenue should, in principle, be greater than or equal to the total sum of outgoings.

The use of a “price cap” is a method which consists, for a given period, of setting respective limits on the increase or decrease of rates – particularly those for a universal service – and by extension, the price difference or percentage evolution is fixed.

The burgeoning volume of Internet traffic today should lead to pricing on the basis of the amount and type of data exchanges made by Internet users.

1.2.3. *Financial mechanisms involved*

Each of the industrial and commercial stages in the activity of telecommunications must generate sufficient revenue for that profit to be reinvested in the financing of new articles, and thereby support the requirements of the global market [BAT 02]. The economic spiral loops back on itself, as the communications services are supposed to compensate the investment in the equipment to support those services, and the operation of that equipment is supposed to contribute to the agreed payment for the manufacture of its components, and the sale of those components themselves must generate a sufficient profit to help finance fundamental research.

Any possible economic crisis aside, this financial loop is liable to be blocked by the sudden emergence of a technological barrier, or by the sudden saturation of the users' needs.

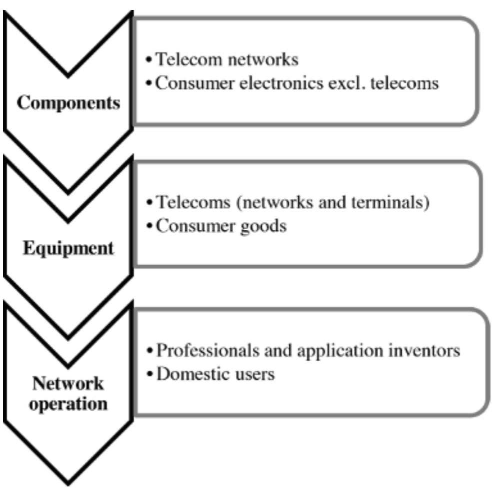

Figure 1.1. *Chain of activities linked to network sand to ICT*

1.2.4. *Cost of networks and operator charges*

It is not possible to constantly increase the charges incumbent upon network operators without forcing those companies into financial difficulty. Thus, the share value of the five main European mobile operators – Orange, Deutsche Telekom, Telefónica, Telecom Italia and KPM – which employ 600,000 people around the world and cater for nearly a billion customers, is not even half that of Apple, and slightly less than that of Google. Operators are giants with feet of clay. The third industrial revolution of the digital economy cannot take place unless adequate networks are available. However these networks require major investment, which only the operators themselves are capable of making, in these times of high public debt. “We need to create conditions favorable for investment”: (Stéphane Richard – CEO of Orange, July 2012).

Whilst operators in developed countries complain, the situation is by no means any better for communication network operators in developing countries, as the installation of Internet resources and provision of that service consumes a large portion of their financial resources, but they have not yet been able to reap the attendant rewards.

1.2.5. *The hidden income source for long-standing network operators*

For those operators of hardwired or mobile networks who have been able to invest in IP technology, two facts arise in spite of the massive pressure exerted by competition: one positive, and the other negative. Firstly, their OPEX has decreased because of the digitization of the interfaces. It is no longer necessary to plug patch cables into the distributors to change the orientation of the structures of circuits, because this task is performed directly by the routers, with a simple computer command. This may represent a quite considerable saving in terms of manpower; the same is true, of course, depending on the investment made, for the measuring of the circuits, the handling of the catalog of cables, etc.

On the other hand, the new IP equipment is much more compact than the old machines, which reduces the volume of racks of hardware needed for each transmission center or service center. Thus, the buildings owned by the traditional network operators are occupied to a far lesser extent than was previously so. Such is the case, for example, with AT&T, which is often cited as having unwillingly become the largest real-estate owner in New York. Unfortunately, the unused space often cannot be sold, because it is hemmed in between other surfaces which are used for other tasks that are essential to the survival of the network. Often, this vast property empire comprises rooms whose ceiling clearance is inadequate for the space to easily be used for another purpose. Therefore, on their balance sheets, a great many long-standing operators have a lot of money tied up in property which they cannot get rid of. This is a poisoned chalice from a tax point of view, which is much lamented by the shareholders!

1.3. Historical overview of the communications market

This brief recap of the past 120 years looks at the facts which have marked the evolution of the network in France (throughout this book, France is used as a case study), and also those relating to the equipment and component industry, and its means of financing, the organization of its infrastructures and their operation.

1.3.1. *Industry in France*

France accounts for only a small portion (1%) of the world's population, but its industrialists have long been extremely active and innovative, since the very dawn of the telecommunications market. Manual telephony was introduced to France in around 1879. It would remain essentially restricted to urban areas until 1923 (the founding of the first major telecommunications industries, with SELT, l'Alsacienne, etc.). In the 1930s the administration for PTT (post, telegraphy and telephony) founded the "*Service d'études et de recherches techniques*" (SERT – Technical Study and Research Service) and the *Laboratoire national de radioélectricité*

(LNR – National Radio electrics Lab), which was given responsibility for distributing the available radio frequencies between the different radio-broadcasting actors. The first regional cables (mainly paired and quad-wire copper cables) were laid before WWII, linking provincial towns to the capital. The first coaxial cable was laid between Paris, Bordeaux and Toulouse in 1939. It only became operational in 1952. In 1941, the *Direction générale des télécommunications* (DGT – Directorate General for Telecommuncations) and an "imperial" telecoms coordination committee (CCTI, from the French) were created to organize telecoms policies. In 1942, a telecommunications factory (SAT, the Anonymous Telecoms Society) was opened in Montluçon in the Free Zone.

CNET (France's National Telecoms Research Center), set up in 1944, brought together many of the inter-ministerial research services. It was responsible for the re-establishment of France's telecoms network (telephone and telegraph) with SRCT, the successor of SERT. The first of its actions which were visible to the public was in 1953: the transmission on terrestrial television of the coronation of Queen Elizabeth II. CNET was also responsible for innovative solutions – e.g. in the field of power-line communication in 1949, with the Tecnetron, designed by Stanislas Teszner – a precursor to the field-effect transistor; in space-based telecommunications, with the first televised intercontinental linkup in 1962, between Pleumeur-Bodou in Brittany and Andover; the manufacture of France's first space rocket, *Véronique*, in 1957; France's first scientific satellite FR-1; the incoherent scatter radar ionospheric model (ISRIM). In 1972, CNET created the temporal electronic switching system PLATON (*prototype lannionnais d'autocommutateur temporel à organisation numérique* – Lannionese Digital-Organization Temporal Auto switch Prototype); the Minitel in 1978; the public card phone. CNET played a pioneering role in the area of hyper frequency emission tubes and transmission systems using terrestrial and submarine cables. France's first submarine cable was laid by CNET in 1956. CNET developed original filtering techniques: electromechanical filtering, quartz filtering and surface acoustic wave filtering. The different transformations which occurred in the telecoms sector led CNET, after mergers with other departments, to become Orange Labs in 2007.

Around 1953, the French industrial sector was unified technically by the creation of mixed-finance companies for transmission (Sotelec) and switching (Socotel), by the adoption of common norms validated by CNET and the monitoring of prototypes made by the SRCT. At that time, France's industry was strong, with three cable manufacturers, three ferrite kiln production lines (for making coils and filters), and five large suppliers of components and equipment. This industrial independence became a considerable burden, and meant that exports were rather low. The period 1975-1985 marked the peak of French technology and innovation, and the end of State-run technical institutions. Techniques then turned in the direction of digital, and the market was flooded by foreign devices. By 1995, the globalization of the telecommunications sector was complete and undeniable.

1.3.2. *Components, past and present*

In France's PTT network, originally the components needed for telecommunications equipment were made in France, with this industrial activity having been constructed using a vertical model. The French Administration specially commissioned the making, for its network, of power-amplifying triode light bulbs, with an effective lifespan of over 22 years (up to 200,000 hours continuous operation for 202P bulbs), as well as highly specialized components (electromechanical filters, quartz filters, surface acoustic wave filters, hyper frequency tubes, equipment for submarine cables and for service provision to rural areas).

Swayed by economic pressure, equipment manufacturers increasingly began to source materials from abroad. In 1982, the creators of the Minitel had to make very significant effort to ensure that their terminal was made with at least 75% French-manufacturer components.

The dawn of digital techniques completely overthrew this vertical industrial setup, and in spite of numerous attempts to create a French system making integral components, foreign suppliers managed to penetrate the communications market, although the European Commission and the European industrialists were unable to coordinate amongst themselves to create a united front. In 2014, in Europe, there are a great many industrial players making components capable of supplying a great many types of equipment and digital terminals, but they do not have a unified strategy. Hence, France's communications network, like most networks today, is constructed from components and devices from all over the world.

International competition and research have led the designers of components and silicon smelters to integrate, into the components, functions of communication systems and spaces capable of hosting applications. Thus, "System on Chip" (SoC) processors raised component manufacturers to the status of designers of devices or of integral functions. This transformation of the discipline illustrates the progression of technologies, as the demands of a huge number of users are gradually being taken into account by system designers, and then by component manufacturers, so as to reduce costs and increase the ergonomic quality of the services provided.

It is possible to successfully acquire the Intellectual Property Rights (IPR) attached to a processor architecture or to an SoC, and an industrial advantage can be gained by taking that technology and adding an extra function to it – e.g. low power-consumption when the device is in standby mode. A good example is that of a mobile phone which has a camera function, for only a fractionally higher price. Yet the progression toward new performances of components is becoming increasingly costly. As demonstrated by Joseph Schumpeter [SCH 42], "technological innovations destroy the old structures, whilst creating new ones around themselves."

1.3.3. *Tomorrow's components*

The digital technology market requires the stable presence of industrial actors, capable of innovating and investing in the domain of components. However, component-manufacture factories are becoming increasingly expensive to build (several billion dollars per industrial site), and the longevity of these facilities is contingent upon the development of global markets. In actual fact, this industrial model is an unstable system, because it owes its survival entirely to the success of the ever-growing world markets for new technology. The eventuality of an interruption in the cycle of investment, a crisis in self-funding or a noticeable slowing of the rate of users' purchasing, threatens to cause the complete breakdown of this industry [DEG 12].

This situation is not unique to telecommunications. Very similar situations are to be found in other industrial sectors, because it stems from the globalization of the market. In order for manufacture to be financially viable, there must be a huge market for the product, and the cost price per unit must be very low indeed.

> *In comparison to the production of the earliest components of yesteryear, the manufacture of processors today appears to jeopardize the whole of the electronics industry, because no assurance can be made about the permanence of production of the most crucial elements. A shortage of crucial mineral resources, known as the "rare earth" elements, represents a serious threat for the West. China has developed a wise, well-founded industrial strategy, centered on local production and development of a value chain. In contrast, Europe and the United States have been shortsighted in their strategic vision.*

In reality, these so-called "rare" earth metals are rare only because Western countries are not prepared to accept the pollution inherent in the production of the elements needed for the manufacture of electronic components. It is likely that research will turn toward smarter, more viable metallurgy.

Producing components at minimum cost requires there to be a global market founded on a set of consistent standards. Anything which is not achieved by the components themselves can be handled by the software associated with those components. The evolution relating to the components needed for the communications of tomorrow can be summarized in the following two points:

– *in terms of research*, the strategy adopted by the semiconductor industry has been guided by the worldwide industrial association

SEMI, which supports the principle of innovative use of KETs (Key Enabling Technologies). Product lines (nanotechnologies, biotechnologies, photonics, product automation) can be used by a wide variety of industrial disciplines in both the public and private sectors. Whilst Europe is well-placed in terms of research, holding a third of patents, it is in less of a good position with regard to industrialization (10%). According to the survey group IC Insights, in 2012, 53 billion dollars were invested, worldwide, in the manufacture of components (i.e. around 17% of the total turnover for that industry). Between them, Samsung and Intel put in 12 billion dollars of that amount. As a component factory costs between six and ten billion dollars, the initiative to found new factories can only be taken by six to eight multinational corporations, for very specific objectives;

– *coordinated component research* may be taking place, but this does not stop the major investors from creating the chips needed for their own industrial strategy. In general, the major innovations lead to the temptation, for mass markets, to provide integral circuits offering multiple networking functions (e.g. Wi-Fi and Zig Bee), applications for future markets (Internet of Things, PLC), whilst also envisaging energy-saving functions (e.g. sleep mode), or integration of forty frequencies on the same component (as is the case for 3G). Also available are programmable components on 14-nanometer technology; 3D-structure components with seven billion transistors on low-consumption 22-nanometer technology; ten-core processors, where every core is associated with over three billion transistors designed for high data rate processing, etc. The mobile market is considered to be a very promising one. The increasing complexity of the onboard circuitry, and the quest for enhanced performance and miniaturization, necessitate ever-greater investment in innovation and research, and also in industrial equipment.

Globalization and the concentration of suppliers on components mean that new technologies are more fragile. In the case of electronic components, the choices made by industrialist have been guided by the amount of investment for large production capacities, and by the constant pressure for lower prices. The overconcentration of certain forms of production in particular geographical regions could prove catastrophic, where something to go wrong. A tsunami or a war in Asia could lead to a worldwide shortage of terminals, memory components, visual display units (VDUs) and the breakdown of the electronics industry for a period between six months and a year. According to Euler Hermes, the damage caused by a worldwide stoppage of production of electronic components is evaluated at 24,500 billion Euros (i.e. around half of the world's GDP), and would have a knock-on effect on all the continents and in numerous industrial sectors.

1.3.4. *History of network operators*

The role of network operators was inspired by the economic context. In 1878, the French State decided to supervise the handling of communications, creating the *Administration des postes et des telegraphes*, which became the PTT (mentioned above) in 1923. The urban telephone network in the 1900s expanded to offer intercity communication in 1924, with improved techniques for amplification along the cables. The next big step forward was Georges Pompidou's "*Téléphone pour tous*" (Phones for All) project, in 1965; the publication of the Nora Report in 1981 was the first to mention the "right of access to information" and the expression "information superhighway". On 1 January 1988, the PTT gave way to FT-Orange, and a regulatory body was set up (ART, and then ARCEP). Between 1991 and 2000, the Internet bubble grew. In 2004, France Télécom became a private company. In 2012, the networks of Europe were affected by the economic crisis.

> *The period of abundance of goods and services certainly appears to be over, and having become accustomed to limitless communication capacities, it is likely that everyone will have to learn to live with a smaller budget – both for hardware and for connection. The efforts of industrialists, along with application operators, to increase their market share at the expense of the dedicated network operators, e.g. in the unified communications sector, where value-creation is easier, is perfectly understandable.*

1.3.5. *Financing of networks*

Between 1880 and 1960, it was the French State which financed and managed the telephone network, through the *Direction de la Poste*. The telephone service was not considered to be a priority service, or a tool of indispensable importance for the economy. 1970 finally witnessed the creation of a number of telecoms financing groups, with “leases” of the equipment for a period of ten years (Finextel, Agritel, etc.). In 1986, in the context of the networks’ opening up for competition, French operators decided to create flat rates for communications consumption. In 1988, those network operators began investing with their own capital. The global economic crisis which struck in 2012 led to renewed debate over the governance of the networks and the Internet, and about the possibility of a merger between European operators (see section 1.1.8).

1.3.6. *National and international legislation*

In 2014, the legislation on communication in force in France services hinges around two principles: setting the acceptable rules for the adequate function of the services and transposing the European directives into French-law equivalents (this is the dedicated role of ARCEP).

On these bases, the regulation attempts to:

– set the rules for fair competition between “pure players” and network operators;

– ensure an acceptable service for users, which conforms to international standards;

– safeguard the protection of personal data and the neutrality of the networks;

– encourage “pure players” to make commitments to respect a sufficient quality of service, conforming to the “best effort” principle;

– favor access to communication and information for handicapped persons;

– and provide support for culture and education.

In 2013, the revelation of the espionage connected to the PRISM project made clear the necessity of taking specific measures in the area of security and of strengthening European legislation.

1.4. Networking techniques

1.4.1. *Analog vs. digital*

1924 saw the first analog transmission, using manually switched circuits.

The earliest networks used analog transmission, which reproduces the usable signal in an analog form in a different frequency range. The drawback to analog technology is that it is difficult to separate out the usable signal from the noise acquired over the course of the signal's journey through the connecting cables, and to use effective signal-compression techniques. In addition, the components are specialized and costly, and the capacity of the supports used is limited in terms of bandwidth.

It is the human operator who manually connects the circuits needed for the transmission, using instructions communicated to him/her over the course of the day, depending on the state of traffic.

In 1950, the world witnessed the birth of automated spatial switching, with remote control of the equipment in manual mode.

National and international communications use transmission functions, which are necessary for the amplification and regeneration of the usable signals, and switching functions, which ensure the messages are correctly routed.

Temporal circuit switching has been a reality since 1955 in France's network. With analog transmission and circuit switching, the network became intelligent enough to correctly route communications. The intelligence of the connections was ensured by the automated monitoring devices put in place. Gradually, computer technology worked its way into circuit switching and network management. It would be 1968 before digital transmission, increasingly associated with temporal switching, was implemented on a national scale. Between 1975 and 1980, this arrangement facilitated all-digital telephony (both for switching and transmission), with the creation of an "intelligent network" (IN). This smart network then facilitated the implementation of new services. IN is defined as a "network architecture which concentrates intelligence at certain points in order to better handle the complexity of the supply and demand in terms of connections and services" (see section 4.2.4).

Finally, transmissions were made in binary (0,1) series conforming to preset encoding rules. Today, digital processing of transmitted signals is used for voice signals, music, images and other data, with the encoding being different for each application.

> *"Signaling consists of a transfer of information exchanged between terminals or networking devices, to facilitate the establishment of communications on demand – i.e. on a call-by-call basis. This concept has been extended to any information relating to the provision of additional services (call transfers, call-waiting, busy tone, etc.)"[HAR 02]*

The development of multimedia services and information management are also based on digital techniques. Fiber-optic and all transmission supports have been adapted to digital. The various modifications which have affected the morphology of the networks have not been noticeable for users, either in terms of the transmission mode (analog or digital), or of the operation (circuit mode or packet mode).

From 2010 onwards, the entry of the Internet into wired and mobile digital networks led to the implementation of NGNs (New/Next

Generation Networks) in France and in all networks the world over. NGNs combine fixed and mobile networks and the Internet.

Operational	Switching	Transmission	Intelligence
1925-1950	Manual	Analog circuits	Human (operator and routing files)
1950-1970	Automatic circuit-switching	Analog circuits	Management of switch selectors Remote monitoring of the network
1970-1985	Automatic circuit-switching	Digital supports PCM	National supervisor and intelligent network
1990-2010	Circuit-switching [Data]-packet switching	Digital conduits Gbit/s Ethernet	IP routers SIP protocol
Since 2010	Circuits and packets	All digital	NGN and IMS

Table 1.2. *Evolution of networking technologies*

1.4.2. *Circuit-switching*

The circuits used in manual switching and automatic switching include a long-distance part (i.e. intercity or international range), made up of four wires (two for each direction of transmission). Their terminal part in the access network is often made up of two wires. This technological obligation means that, for the four-wire part of the circuit, one “there” pair and one “back” pair are needed, with each pair only being used at most 50% of the time, so as to facilitate the alternating exchange of requests and responses.

With automatic switching, the composition of the number of the desired subscriber (between eight and ten digits) by the caller guides the routing of the call through the network. The numbering guides the establishment of the necessary circuit connections. The signaling uses a specific channel, which is distinct from the operational traffic. These conditions are fulfilled regardless of the nature of the supports (analog or digital). The circuits are specialized to deal with the particular service being provided:

– for voice and fax signals (telephone circuits);

– for telex signals (telegraph circuits);

– for data signals (non-switched circuits, established on demand between points defined with the users).

Other circuits are specialized for one-directional transport of image and television signals.

1.4.3. *Data packet switching and the Internet*

After many experiments on both national and international scales, it became apparent that it was more economical to no longer systematically operate long-distance connections using the principles of four-wire circuit-switching. Indeed, with digital techniques, it is possible to transmit all types of messages (voice, texts, images), using the protocol IP. IP (which stands for "Internet Protocol") is the basic communication protocol used by the protocols of Internet networks, with the "Internet" itself being formed by the inter connection of networks (Inter Networks). After the information is divided into packets, those packets find their own destination on the IP network, using the IP address of the recipient, thanks to "packet routers" distributed throughout the network. The routing of the packets is linked to the instantaneous situation of the network, in accordance with the "best effort" concept. The signaling specific to the network uses the same transmission channel as the operational traffic.

The telephone switchboard operators of yesteryear have therefore been replaced by IP routers. It is no longer the network which directs calls to the correct destination. Instead, the packets of information themselves are capable of finding the right path to their destination using routing tables memorized in the internal network, routers, control platforms and software platforms.

> *Previously, the electronic telephone center drained traffic from subscribers within a 6km radius, and was capable of connecting between 40,000 and 100,000 subscribers maximum, at a cost of around 100 Euros per subscriber. Today, access technology, with DSLAM, is able to connect 500,000 subscribers on software switchboards (Softswitch), at a cost of one Euro per subscriber, over distances of more than 100km. The drop in prices to the consumer is attributable to these technological advances.*

IP packets are transferred either as a series of blocks of data, called "datagrams", which do not require acknowledgement of receipt, or as a temporary data session, with the network grouping together the packets used during each session. In data session mode, a signaling system is combined with the classical process of routing of the IP packets. The "signal boxes" are IP routers. Control platforms manage the data communication sessions requested by the clients' terminals. Their role is to direct the streams of signals associated with each session. They supervise the sessions established and manage contextual data associated with those sessions. In order to perform their tasks, the control platforms need to have access to the data describing the service to which a customer has subscribed, and in mobile networks, to the data specifying the subscriber's location. Finally, service platforms support software that is specific to the provision of certain services to the customers. The transporting of the information in the form of IP packets results in the complete separation of the transport functions and control functions. The users' terminals make an increasingly important contribution to the provision of the service, because IP technologies have tasks performed on the periphery of the network which, in traditional networks, used to be performed at the very heart.

The Internet is a system of interconnection of computer machines, of global scale, using a set of data transfer protocols. The Internet provides its subscribers, known as "internauts", with all sorts of information, and facilitates the delivery of communication applications, such as e-mail, messaging and access to the World Wide Web. Internet access is delivered by an Internet Service Provider

(ISP), by access to the low data rate switched telephone network, ADSL, fiber-optic, or through a radio electric system (WiMAX, satellite, 3 or 4G). The expression "World Wide Web", represented by the acronym "www", refers to the global computer network uniting the servers and their various protocols (HTTP, HTML, etc.). The Internet and the Web are two separate entities, although the terms are often incorrectly used synonymously. It is possible to use the Internet without using the Web: such is the case, for instance, when Skype is used. The Web is a service which uses the Internet.

1.4.4. *Intelligent networks and NGNs*

The equipment at the heart of the access network (either wired or radio electric) and the platforms are able to recognize the nature of the caller's terminal. Depending on the nature of the call, these devices direct it either to a circuit-switching digital network or to a packet-switching network using IP (an Internet network).

The whole of this polyvalent access network and the associated core network, which is able to handle different traffic streams from IP networks over cables or channeled via the various types of radio electric technologies, is called a "new/next generation *network*", or NGN. The NGN is capable of linking the traditional digital networks– both hardwired and mobile – to the Internet.

1.4.5. *Range and availability of networks*

The international standards define a chain of 27,500 km connections, taken as the reference maximum length of a global connection. What this means is that, placed end to end, WAN connections should be able to join any two points on the surface of the Earth, even if those two points are antipodal. It is obvious that such a connection would require the cooperation of networks with diverse structures, using terrestrial cables, submarine cables, and possibly also radio or satellite links. This maximum range is achievable with analog or digital networking technology, using circuit-switching. It is also achievable in NGNs, using packet-switching with IP. Whilst these various technologies are able to serve this criterion of quality relating to the maximum-length connection, it is not necessary to impose it in private networks, because the purpose of these networks is not to provide worldwide coverage and universal access.

The availability of a network or a device characterizes the prospect of its working properly and being accessible. The availability of a device is expressed by dividing the time for which that device is operational by the total duration in question. Thus, what is known as "five-nines" availability (99.999%) corresponds to a rate of failure limited to 5 minutes and 37 seconds over the course of a year (8,760 hours) of operation, or 26 seconds per month. In order to guarantee a good level of availability of the network for the customers, the network operator must put in place redundant equipment and organize preventive maintenance.

1.4.6. *Confidentiality*

Confidentiality is defined as the fact of preventing third parties from gaining access to the information transmitted to a specific recipient (definition given by the ISO). While the rules of professional deontology general respect the principle of confidentiality, the applications sometimes differ in reality, depending on the country in question. In practice, no technique can ensure total confidentiality, all the time. Infamous cases of espionage (such as the PRISM scandal) or recent conflicts demonstrate that it is always possible to penetrate the content of purportedly "secret" messages.

All communications networks exhibit significant fragility in terms of the reliability of the transmission of highly-important messages, which is manifested either by silent eavesdropping or by denial of service.

Silent eavesdropping (also known as "Man in the Middle") is carried out by a hidden device, which records exchanges between two people or between two devices, in order to make fraudulent use of the information. In principle, this intrusion is undetectable, except if an unexpected technical check is carried out. As it is rather common on radio electric links, today these links use techniques entailing the rapid and frequent switching of frequencies.

Denial of service (*DoS*) aims to cripple a service by overloading it with requests, in order to prevent legitimate users from using it. This may be caused by a maneuver to temporarily saturate a network to stop it from working, or by interference of the connections between two terminals, preventing access to a service. The existence of request-generation robots (or “bots”) makes this sort of disturbance easy to orchestrate; fortunately, they are also easy to detect. The only defense against DoS is to have access to two different networks, installed with discretion.

These aspects are touched on once again in Chapter 4.

1.5. Choices available to companies in a changing world

1.5.1. *SMEs faced with ICT*

Information and Communication Technologies (ICT) are gradually invading all domains of human activity. Telecommunications tools are found in remote diagnosis and treatment (e-health), in industry, in remote monitoring of livestock and crop farming, in traceability of goods, etc. It is becoming very difficult to stay on top of all of these developments – particularly for small and medium enterprises, in spite of all the efforts of the various training organizations set up for that purpose.

In the absence of any preliminary study, SMEs often find it very complex to make the right choices in terms of ICT. *A priori*, an SME may think that its activity is not affected by the development and burgeoning expansion of the different types of ICT, and that argument can be defended, wrongly or rightly: the scale factor and adaptation coefficients may come into play, as the SME may not have sufficient expertise to evaluate the financial viability of projects put to it. It may lack qualified personnel with appropriate skills, or appropriate network infrastructures. It may be uncertain about the costs of the project (in terms of hardware, networks, software, logistics, reorganization, recurring costs, etc.) and about its potential profitability [OCD 04].

Security or trust issues may arise – particularly in relation to the reliability of e-commerce systems, payment methods, or the legal aspects of the envisaged development.

In spite of the numerous possible stumbling blocks, it is clearly essential to help SMEs – which are the driving force behind the national economy – to grasp the possibilities for ICT in each of their sectors, and estimate the requirements of relations for each activity.

1.5.2. *SMEs faced with the choice of a connection*

In 2014, it seems that complete knowledge of networking techniques is the exclusive preserve of network operators – particularly long-standing, well-known operators.

The choice of connections available for SMEs is vast, and is essentially linked to the activity of each SME and the service available in their area, in terms both of quality and price. This choice is closely related to the prevailing geographic directions and to the appropriate available services.

The company needs to choose both an operator and a network structure. It is also possible for the company itself to become a service operator, and negotiate partnerships for its own sector of activity.

1.5.3. *Factors in choosing a connection for a company*

Companies must take into consideration all of the following decision-making criteria: types of communication services needed, frequency of use, cost price, level of security, guarantee of quality of service, constancy of the service, coverage of the sites in question by the desired services or applications, confidentiality, mean time to repair, choice of partners, upgradability, etc. Companies must also consider the factors of technical and regulatory change.

In 1985, a permanent 4-cable analog connection between two points was profitable if operational for four hours or more per working day. By the year 2000, this value had shrunk to 1½ hours of activity per working day, and in 2012, it was comparable to a constant 500-kbit/s Internet connection. Today, the costs of terminals depend on the decisions made in Brussels, which are “transposed” for application in individual states, and on the state of competitiveness in the countries in question.

1.6. Summary

The evolution of technologies and the globalization of commercial exchanges have led to the emergence, alongside the traditional network exploiters, of other partners or competitors, to provide business and domestic users with new digital communication services. A range of a great many digital services is now available, at cost levels and with a quality of service which companies must examine on the basis of their particular requirements. Thus, digital technology presents a variety of new opportunities for businesses.