TELECOMMUNICATION SYSTEMS AND TECHNOLOGIES

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Contents

Summary

This theme-level writing aims at introducing the reader audience to the multi-faceted world of telecommunication systems and technologies, which will be addressed in depth by the specific contributions of the following topics provided by the different excellent contributors taking part in the development of the theme. Our goal here is simply to offer a rapid and easy-to-read overview of what the telecommunications world includes in terms of technical issues, technologies, management models, organizational aspects, and even visionary perspectives of evolution for the years to come. After a very rapid outline of the telecommunication history, the chapter concisely presents the main technical elements behind telecom acts, by identifying primary models, technologies, and solutions. In particular, we would like to point out how, among all the different technical and organizational evolutions/revolutions of the dynamic telecom world, two primary guidelines have clearly emerged: the success of wireless technologies

(especially for last-meter connectivity) and the convergence between the telecom and the Internet infrastructures. These two telecom trends answer a more general tendency towards an envisioned world centered on communications, where possibly mobile users are willing to be immersed in a pervasive, ubiquitous, and always-connected environment fully supporting information/service sharing based on community belonging.

1. Telecommunications: Connecting the World

"I'll give you a ring". As easy as that!

Today, at the beginning of the 21st century sentences like this are uttered at any instant all around the world. Fifty years ago nobody would have pronounced it. The telephone was restricted to a minority of people in the so called developed world and it was barely existent in most parts of the world.

In the last fifty years, the International Telecommunications Union (ITU) has reported, on a yearly basis, the penetration of telephones in the various countries of the world. The USA progressed from less than 20% to close to 50% of the population and almost 100% of households. Europe has been lagging behind but has been a close follower, with higher penetration in the Nordic Countries and less in the Mediterranean region, till the 1980s. From that moment on, huge focused investment took place in many southern European countries and that filled the gap with the North. By the 1990s it was difficult to find a household without a phone in Europe, North America, Japan, Korea, Singapore, Hong Kong and Australia.

For the other parts of the world, in 1990, it was a quite different story. Cambodia and a number of Centro African countries had few percentage points of penetration, well below 10%. A significant number of countries were around 10% and others between 10% and 20%. At that time, being below 30% was meant to be "out of reach" for most people. It is significant to remember that India in the 1990s launched an ambitious plan, India 2000 that called for the availability of a phone for every citizen within a 20 km radius. That seemed, and for the technology that was available at that time, a daunting task.

According to the ITU progressing from 1% penetration to 10% would take a country close to 19 years, 14 years to move from 10% to 20% and just 8 years to reach 30% from 20%. These figures were issued in 1990 and were based on statistical data collected over the previous decades. Because of the shortening time required to increase of 10% the penetration as more and more diffuse was the telecommunication infrastructure, the gap between poor and rich countries tended to increase over time.

The distance between poor and rich countries in the 1990s was not only measured by the penetration factor but also by the quality of the telecommunication infrastructures (hence of the service available). The general rule was that pervasive infrastructures, like those to be found in Europe and North America, were also providing much better quality. They usually were the result of a continuous investment, the operation costs

(OPEX) could be split over millions of users, together leading to better resources and maintenance. Poor countries had outdated infrastructures, poorly maintained equipment (also because of technical skill shortage) and even new investments were submerged by the existing low grade equipment (a network is as good as its worst component).

The availability of a finely disseminated telecom infrastructure offering good quality became a pivotal element of progress from the 1950s on. Business started to rely on telecommunications in supply and distribution chain, leading to cutting cost and increasing productivity resulting in the economic miracle. The European Commission started specific actions (RACE, ACTS) in the 1980s and 1990s to fund cooperative research in telecommunications with the express objective of stimulating the creation of a top-notch infrastructure that can foster the development of business in Europe. In the 1990s the telecom biz (calculated in terms of capital costs -CAPEX-, OPEX, and services provided) amounted to 8% of the overall European turnover. European Union officials used to say that the only reason to invest in telecommunications was to stimulate the remaining 92% of the European biz: investment in better telecommunications would increase the competitiveness of many business sectors.

It is therefore obvious that in the beginning of the 1990s the ITU and the United Nations in their various Agencies (ITU is one of those, although it specifically focuses on telecommunications, standards and international regulations) were trying to address the issue of bettering telecom infrastructures in developing countries by rising awareness at political level.

1.1. The Wireless and the Internet Discontinuities: 10 Years to Change Telecommunications

In the next section we will consider a brief history of telecommunications. Here we only need to look at an amazing change, still in effect, that altered the way the telecommunication game is played.

Telecommunication services have been provided till the 1990s through fixed, copper lines. Their deployment was costly and took a lot of planning and time. The maintenance of the network was also very expensive and, in most situations, there was no economic sense in developing such an infrastructure; too few users, too dispersed geographically and with very little economic spending capacity to sustain a return on investment. Obviously that was the chicken and egg situation. If there is no infrastructure there is no way of stimulating business but, if no business is willing to pay for the infrastructure services, no one is willing to invest on its construction. Here comes the wireless revolution whose effects are even more important in the developing world than in developed countries.

A wireless infrastructure has a completely different cost sharing model. Whilst in a fixed line infrastructure close to 100% of the investment is burdening the network operator and has to be made “before” the infrastructure becomes available, in the wireless infrastructure only 30% of the cost is from operators’ pockets. The other 70% comes from investment in terminals, usually sustained by users. Additionally the wireless infrastructure can be deployed in an incremental way with respect to traffic, not to geography (covered areas). We can place a single antenna and cover a very wide area just by increasing the power. Once the traffic grows, it saturates the capacity of that antenna (of that cell) and a new cell will need to be deployed. The extra investment required for that new cell is justified by the existing traffic and, therefore, the return on investment is guaranteed.

Deployment in poor areas with limited spending capabilities becomes economically viable. Additionally, wireless equipment provides high quality everywhere, digital systems either work or they do not, hence a uniform quality level is assured. It may be curious to note that in India the poor quality provided by the fixed network led to a regulation that asked the operator not to charge for the first 30s of conversation to give time to the calling party to verify that the call indeed reached the intended party. With the deployment of the wireless digital network quality was no longer an issue but the regulation still applied with the result that Indians started to make very short calls, under 30s each, to avoid paying. The wireless operator went bankrupt. Eventually the regulation was changed…

In the new century, starting with 2001, the greatest ratio of development shifted from the developed to the developing world. By 2005 the absolute value of investment in wireless infrastructure sees in the top ranking China and India, with sub African countries also showing a tremendous increase in wireless coverage. If in the 1990s the newest equipment would be found in Europe, East Asia and North America, in 2005 one has to look at developing countries. Manufacturers used to develop new products for developed countries and sell outdated models to developing countries. In 2005 new developments target the needs of China and India; whoever wants to upgrade its network need to ask what manufacturers are developing for China.

The uptake of the wireless market (in 2005 there were 2.2 billion cell phones versus 1.6 billion fixed line) created another major shift: it is no longer the network manufacturers that lead the innovation but the cell-phone manufacturers. As more powerful electronics has become available, there is less and less need for network equipment. Where hundreds of units of equipment were required to route a telephone call, now a single equipment can handle millions of calls. In Italy at the beginning of the 1980s there were 11,000 switches in the network; in the 1990s their number shrunk to less than 6,000; a new infrastructure based on optical switches and fiber may require less than 100 switches. The whole market for network equipment is shrinking.

At the same time the electronic progress pushes the evolution of feature-rich terminals (cell-phones with ever more powerful digital cameras, better screens, increased storage capacity…) that stimulate the market to dispose of older models for new ones. The market for cell phones in 2005 has exceeded 800 million pieces, many of these being a replacement of out-of-fashion ones. This trend will continue in the coming years shifting the innovation from the network to the terminals, again placing on very similar footing markets in both developed and developing countries.

The short life cycle of terminals, measured in months rather than years (as it is the case for network equipment), creates a continuously evolving platform that can be exploited by the business both in terms of new service offering and as a tool to increase the effectiveness of the biz itself. This latter aspect is just starting to develop.

Practically at the same time that the wireless revolutionized the telecommunication world reshaping its actors and the biz models, Internet and the Web started to create opportunities to fixed-line operators by stimulating bandwidth offer and demand.

The Internet uptake, particularly by the mass market, is driving the demand for broadband connectivity. The availability of alternatives (connection via ADSL on copper lines, fiber, cable television, or satellite) stimulated a quite competitive market resulting in price decrease and increased bandwidth.

Korea (and Singapore but, given its limited area, it is usually disregarded) is the country that has the highest penetration of broadband lines, over 75% of households, with a bandwidth of several Mbps (usually 3-4 Mbps are required for viewing television over the Internet). Japan has also a significant penetration and in 2004-2005 has started a significant deployment of optical fiber that has been met by an increasing demand (bandwidth of 100 Mbps are easily delivered on fiber). USA has a mixed situation with cable companies competing head to head with operators' companies, these latter providing broadband via ADSL. Initiatives have started in 2005 to deploy optical fiber to increase bandwidth. In Europe the majority of broadband connection is provided via ADSL, even though in some areas cable (mostly) and satellite have a significant share of the market. The uptake of broadband in Europe will continue for a while being still much lower than saturation.

Internet and wireless are quite different markets in terms of biz. While Internet is either “free” with connectivity provided at a flat rate (by far, and increasingly so), the wireless market is basically using a pay per use model (although there is a shift towards flat rate in some areas). Wireless till the end of the 1990s has been for voice; wireless data transmission (if we disregard instant messaging and SMS) was basically nil. At the turn of the century the dissemination of technologies like Bluetooth and Wi-Fi started to change the scenario: in 2005 a growing portion of data traffic in the last “meter” goes wireless bringing in flexibility and low cost.

Conversely, Internet was traditionally about data communications. At the turn of the century, Voice over IP (VoIP) moved from being a technology to become a viable technology. In 2005 Skype exceeded the threshold of 50 million users of its VoIP service. Clearly the dissemination of broadband connections made this possible. Skype is just one of many service providers offering VoIP. The main motivation to use VoIP has been the much lower price associated to this communication, in many cases completely free (in a PC-to-PC voice call). Over time, this motivation will fade away as more and more operators are moving towards an “all you can eat” subscription model including unlimited calls (hence the price of the call drops to zero). This will not signify the demise of VoIP as a service (VoIP as a technology is something that will become a generalized reality but it will not be perceived by the users who cannot care less about “how” their calls are managed and routed as long as their quality is acceptable and their price is low).

In fact, people using Skype (or any other service provider of this kind, our mentioning of Skype here should not be considered as an endorsement to that particular provider or an indication of ranking) have learnt that a new communication paradigm becomes possible. Skype is not about connecting two people, it is about creating a multitude of squares, one for each subscriber. In that square the subscriber finds all her acquaintances and perceive at a glance their availability in terms of connectivity. As one logs in on Skype, the contact list immediately shows tiny icons indicating if that person is on line available to talk or just to chat, or if she is on line but engaged in other business and cannot be disturbed, or if she has set up a voice mail to take messages. It is really like being on the village square, seeing all people we know and perceive at a glance who we can get in touch with at that particular moment. Welcome to the concept of community communications. This is important from a biz viewpoint because communities are the "monads" of the market, the fulfilled dream of market segmentation.

Telecommunication services are moving in this first part of the century to provide a means to become the fabric of millions, billions of communities. Any person can be at the same time involved in tens/hundreds of communities: the one of people sharing her political ideas, the one sharing her hobbies, the one whose children go to the same school, the one of people suffering from the same ailments, the one of people interested in buying a certain product along with others selling that product (e-Bay docet).

The fulfillment of this marketers' dream, which corresponds to the basic need of people to cluster together, requires a strong fabric of communications, a ubiquitous infrastructure reaching all places and invisible to users. We are not thinking about the roads although we are always on them as we walk or drive from one place to the other. Same will go for telecommunications. Today we no longer have to search for a phone booth to make a call, getting out the cell phone from the purse or the jacket pocket, a few key strokes and that's it. Tomorrow even these easy gestures may be forgotten as we will walk around with wearable devices able to intercept our "let's call John", set up the call and conveying sounds as if we were talking face to face with John. This is the amazing, and invisible transformation, that telecommunications are bringing about. How did it happen?

2. 150 Years in a Blink of an Eye: a Very Short History of Telecommunications

Google and you can get as many histories of telecommunications as you wish. The point here is not to provide yet another controversial telecom history but look at its evolution in terms of achievements, the whole in a very few pages. The bibliography will guide you to in-depth discoveries of this broad area.

2.1 The Birth of the Idea of Voice Telecommunications

It is very difficult to trace the birth of the idea of sending voice over space beyond the capability of "shouting". Possibly the very first engineering feats were accomplished in the first palaces in Mesopotamia and Egypt were special conduits allowed the voice uttered in a room to be heard in a distant place in a different part of the palace.

It might seem a very long shot to make reference to these far away epochs but it is actually that idea that moved Meucci, an Italian born in Florence in 1808 working at the Teatro La Pergola as assistant chief mechanics, to set up in 1834 an acoustic-pipe telephone to communicate from the stage to the maneuver trellis-work. To avoid rioting in Florence, he moved with his wife to Havana and started to work on experimenting with electricity to relieve some kind of pains. In one such experiment, in 1849 he placed a oral electrode in patient suffering from a severe migraine and moved to another room were he had all his apparatus to graduate the level of current applied to the electrode. To evaluate the intensity he had no amperometre but used a similar electrode in his mouth. Through a rheostat, of his own invention, he could increase the current flowing to the two electrodes and have a feeling in his mouth of the level to make sure he did not exceed the “cure”. His patient in the other room, however, was much more sensitive to pain than he was and started to scream when the first electrical current hit his mouth. Surprisingly, Meucci heard his screaming through his own mouth, because of the variation of the electrical current flowing in the electrode he had in his mouth matching the variations produced by the screaming of his patient in his own electrode. Serendipitously he had discovered the electrophonic effect: an electrical current can be used to transport voice. For the record, his patient migraine was not cured but science made a step forward.

Meucci continued his experiments on what he started to call the “speaking telegraph” in the USA where he moved in 1850 taking a home in Staten Island, N.Y. There, in 1854 and 1855 he started to use a sort of proto-telephone to connect his wife’s bedroom (where she was confined because of a worsening arthritis) with the laboratory where he worked.

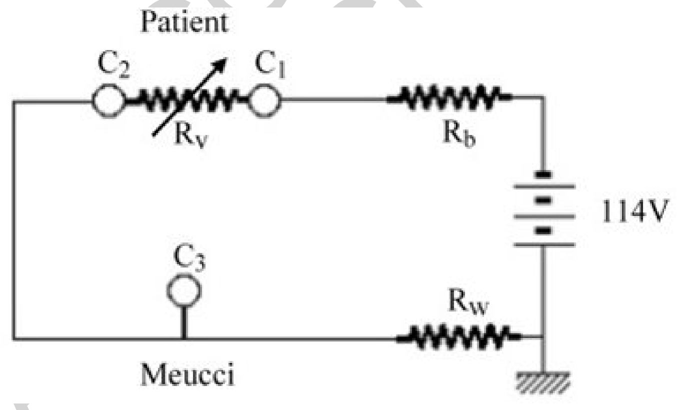

Figure 1: Electrical scheme of the equipment used by Meucci, which resulted in the electrophonic effect in 1849

A quite different approach was followed by Alexander Graham Bell, who has come to be known as the inventor of the telephone, and Elisha Gray who submitted a patent for their invention within few hours of each other, which led to a legal battle over priority in the invention, won by Bell. Bell’s background was on the physics of sound and music and he looked at the existing telegraph to extend its capability that at that time were limited to exchange only one message at a time. He proposed the idea of a “harmonic telegraph” able to send several messages at the same time on the same wire if each message, as a note, was sent using a different pitch. He “sold” his idea to his father in law, Greene Hubbard, a rich attorney in Boston, who gave him the financial backing to further his research. Bell used that money to create, with his assistant Thomas Watson, a device that would transmit speech electrically. He had discovered in June 1875, while experimenting with his harmonic telegraph, that an electric current may be used to transmit voice and that was what he was really interested in.

On March 10th, 1876, he called: “Mr. Watson, come here. I want to see you”. This sentence transmitted from one room to the next one marked for many historians the first phone call. That was indeed a small step for a man, a giant one for mankind, as somebody else said in 1969 on a quite more spectacular occasion in front of a whole humankind watching.

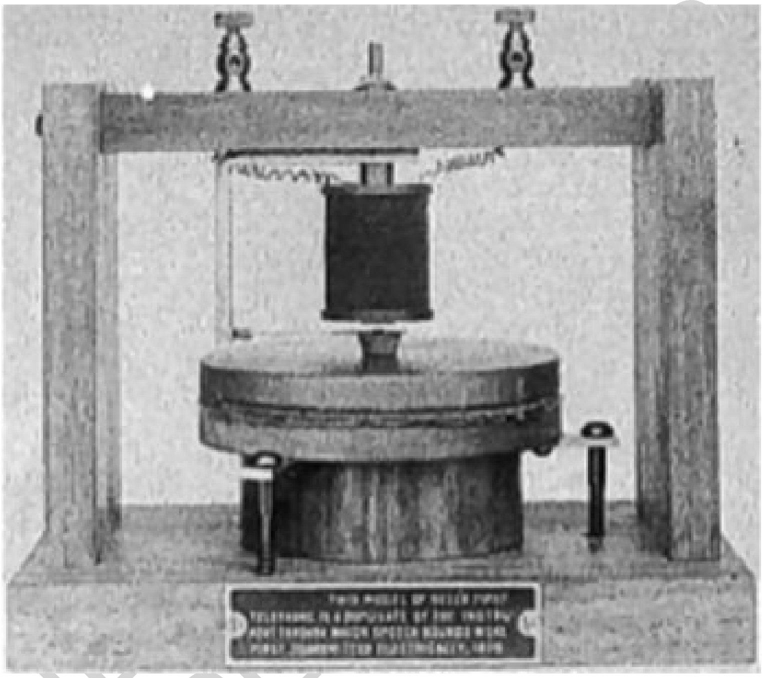

Figure 2: Reproduction of the first telephone developed by Bell and used for the very first call

There is another man who has to be remembered looking at the first steps of telephone history: Guglielmo Marconi. He did not invented any telephone although with his first experiments back in 1895 over the Bologna hills in central Italy, he demonstrated the possibility of using electromagnetic transmission over air to send signals. For the very first experiment the 20-years-old Marconi got one of his servants to wave a handkerchief to signal the reception of the signal sent over radio waves and later, once he was able to transmit farther away the signal in spite of a hill standing in between, by firing a gun.

Curiously Marconi is quoted to have said: "A pity that this signal can be received by anyone". He would have liked to have invented the telephone, while he paved the way to radio and television where a signal is broadcasted to be received by many. Conversely Bell in one of his interviews declared that a good application of his phone would be to let people in a village square to listen a concert being played somewhere else. He did invent the telephone but he wished he had invented the radio. Today we can say that this difference has faded away. Radio communications is at the bases of cell phone communications, 2.2 billion terminals say thanks to Marconi invention every day. Right in these first years of the new century we have seen the explosion of radio stations and television programs being brought by fixed telephone lines, through the Internet, thus fulfilling the dream of Bell.

There are over hundred years in between those first experiments and the pervasive multimedia communications we take for granted today and of course many people contributed to make this happen. As said at the very beginning, the purpose of this part is not to mention all of them, not even the most important ones (it would anyhow be debatable who was most important), rather to get a feeling of the overall evolution. Let's start.

2.2 The Conquest of Distance

Sending an electrical signal over a wire has the same effect of sending a wave over a stretch of water. After a while the signal fades away. The same happens, just sooner, if there are several contiguous wires carrying signals: they tend to interfere one another making their detection more and more difficult, as it happens if we create waves in a pond by throwing pebbles in the water. Each one creates a wave that gets mixed with the other one and makes it impossible to our eyes to single out one from the other.

The first problem facing the pioneers of telecommunications was, how to conquer distance, making it possible for voice to reach the furthest corner of the world, thousands of kilometers away. Actually in the first years making the signal detectable beyond a few kilometers was already a challenge. Part of this challenge lay in the terminals transforming voice into an electrical signal and then the electrical signal back into voice. A first breakthrough came with the carbon microphone. By compressing the carbon powder contained in a capsule at the end of the handset, actually a sort of horn conveying the sound ways right to the membrane, one could vary its resistance and therefore modulate a signal. The modulation was not what we would call today "hi-fi": the best response was in the 3,000 KHz, approximately the fundamental frequency of women voice; that is why switchboard operators were women: their voice was the one that could be best heard over the line. At the other end a spire activated a membrane attached to an iron cylinder when current flew through it recreating the sound waves.

To increase the length of the transmission, engineers had to cancel out the interference created by the signals they were transmitting. At the end of the XIX century Pupin, a Serbian born educated in the USA, UK, and Germany and at that time serving as professor at the Columbia University, invented a way to do so by placing special coils (condenser) every few kilometers, a method that has come to be known as "pupinisation" of the line, patented in 1900. That work was stemmed by regulation issued in the USA asking the operating companies to lay telephone cables underground, rather than on poles. That made transmission even more sensitive to attenuation. Using this method in 1914 AT&T established the longest transmission line connecting New York with Boston, a span of over 500 miles. Another way to tackle attenuation was of course finding a way to amplify the signal when it degraded below a certain threshold.

The invention of the vacuum tube by Lee de Forest in 1906 (that was basically an ingenious evolution of the Edison bulb lamp with an additional third wire, the grid) provided that capability.

By 1920s one could say that the major battle to conquest distance was over. However the war against distance was won much later in the 1960s with the advent of digitalization, the satellites and later on, in the 1980s with the deployment of optical fiber (we will talk about fiber in the next sub-section focused on capacity). But that is more the icing on the cake created in the first 20 years of the last century.

2.3 The Conquest of Capacity

The telegraph, as we saw, was plagued by the limitation of being able to transmit only one message at a time on any given line. The telephone system, although making much better use of the line, was still hampered by the same limitation. To increase capacity in the system you had to increase the number of available wires. Obviously the single customer would make use of just one communication at a time, so one could use one single line per customer and then provide within the network a multiplicity of lines to manage the thousands, millions of people that can be talking at any given time.

This is basically what has been done in telecommunications by network engineers that have struggled to provide architectures able to minimize cost (every single line has a cost) and to carry as many conversations as possible. The first trick to implement was the connection of the line reaching the home of a customer to the bunch of lines leading from the central office in the area of that customer to other central offices. The first switching device was a human being, a woman in general. She sat at a console, received the request for a connection from a customer with the information of who she/he wanted to call, and manually inserted a cord to connect the customer line with the one leading to the called party (or to another central office where that customer line was terminated). The speed of dissemination of the telephone was such that in the 1920s it was forecasted that, given a continuous expansion of the telephone service at the rate of those years, by the 1960s every single person in the USA would have had to work as a switch operator to serve all the demands.

As soon as the first telephone lines were deployed, the means to interconnect them one another attracted the attention of engineers. Strange enough, one of the contributors to implementing an automatic switch was no engineer at all (Almon Strowger, a Kansas City undertaker): he invented a system that could connect one line to one line out of a set of 100. That system was so successful that more than one hundred years later there were still many of them working to connect people through the world. We will see more about ways to connect one line to the next in order to create an end to end communication path in the next part of the theme-level writing. The point here is that switching was the first step on the way to increase effectively the availability of capacity that was made possible by the deployment of more and more wires beginning to criss-cross the world.

A second significant step in the conquest of capacity was the invention of ways to use the very same wire (or channel/spectrum in a wireless system) to carry several communications at the same time. Clearly such a capability would immediately multiply the capacity of the infrastructure. The first successful example (there are many more today but here we will consider just three of them) was Pulse Code Modulation (PCM). PCM was invented by the British engineer Alec Reeves in 1937 while working for the International Telephone and Telegraph in France. The idea with PCM is to sample the voice repeatedly and transform these samples into a set of numbers, each one representing a specific pattern in a timed succession. Provided the samples are taken in a sufficient number and at regularly spaced interval it is possible to reconstruct the voice at the end of the line by converting this numbers sequence into the analogue signal. This way of transporting the voice requires a coding function. Coding has become one of the most important aspects of telecommunications and we will dedicate a full chapter to that. The first transmission of speech by PCM was the SIGSALY voice encryption equipment used for high-level Allied communications during World War II. The sampling and the signal reconstruction was a complex feat that became economically viable only in the 1950s with the advent of transistors in the market.

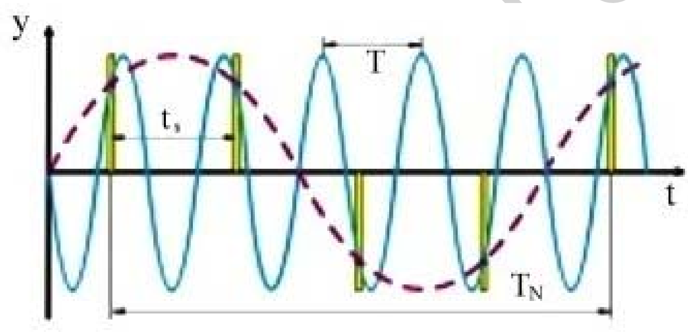

Figure 3: Sampling of a signal and its reconstruction based on samples

Transistors were looked suspiciously by telecommunication people because they were a very young technology still to be proved in terms of durability in the field. There was therefore a significant resistance to their introduction in operation. By the middle of the 1950s the increase of telecom traffic in New York City required more capacity of the infrastructure and the deployment of more wires. The municipality objected because of the disruption to (vehicular) traffic that the digging of streets, required to lay new cables, would have caused. Engineers decided to go for PCM, thus multiplying the capacity of their infrastructure over 20 folds (24 communications can be carried on a single line using PCM according to the American Standard, 30, if the European standard is used).

Two other major steps in the conquest of capacity need to be recorded: the conquest of capacity over radio and the one over fiber. We have seen how Marconi regretted the fact that a radio signal can be received by anybody, thus making it unsuitable for person-to-person communications. Technology circumvented the problem by inventing ways of coding signals over radio in such a way that only authorized receivers can decrypt it. The evolution of electronics has opened up more and more radio spectrum by increasing the frequency million of times from those first Marconi's experiment and by increasing the sensitivity of receivers thus allowing for a much more efficient utilization of the spectrum. Today, hundreds of communications can be managed within a 5 MHz spectrum coded on a 2 GHz bearer frequency (see *Fundamentals of Communication Systems*, *Fundamentals of Telecommunications*, and *Analog and Digital Transmission of Data* for a detailed description of coding techniques).

The optical fiber at the turn of the century, by the end of the 1990s, changed the rules of the telecommunications game by creating an explosion of capacity in the infrastructure. The first idea of using a fiber to transmit a telecommunication signal dates back to the 1960s with the first experiment at Bell Labs in the USA. The possibility to transmit a signal over a fiber became possible by the invention of the laser and the discovery of ways to make the fiber transparent to the frequencies emitted by the laser. Glass, that's what fibers are made of, is not transparent at all as soon as there is a lot of it. Think how that transparent glass turns to green and than to black as its thickness increases. A one meter thick glass pane is basically as dark as a brick. In a fiber we are talking about sending a signal, a light beam, across kilometers of thickness. Discovering and creating industrial processes to produce fibers with some windows of transparency in certain frequency ranges was a challenge that took forty years to conquest. By the end of the 1990s electronics and optics were ready and so were the economic conditions of offer and demand. Operators started to deploy massively optical infrastructures multiplying thousand of times the overall capacity of the networks in the span of few years. Today's infrastructure capacity in the backbone is so great that any estimate of traffic increase for the next ten years is well below the capacity we already have available. Only twenty years ago the capacity of a single subscriber line could be measured in terms of tens of Kbps; in 2005 the Hong Kong Operator started to offer 1 Gbps to its subscribers.

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Roberto Saracco is a computer science graduate and has a university degree in mathematics. He has been working in the telecommunications field since 1971 at the Telecom Italia Labs (formerly Telecom Italia Group Research Center, CSELT). He was involved in designing the first electronic exchange and data network in Italy (1980s). He became responsible for network management research, contributing to the international standardization of the Telecommunications Management Network (TMN) and led the team that developed the first Italian NM center.

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