Telefónica since 1924

IP Networks

Pedro Flórez Miñambres

1. IP network (or rather networks)

The evolution of networks towards IP, and their architectures, is a chapter in the history of Telefónica in each of the countries in which it operates, which has its origin in the late nineties, and continues to this day. IP (Internet Protocol) networks have become the platform for transporting traffic for all services in the last 25 years of Telefónica's century.

In this history, the evolution of Telefónica's IP networks in Spain plays a prominent role, due to its undisputed leadership in the creation and use of these, leveraged on the success of the Internet and fixed and mobile broadband. It should be noted, in fact, that Telefónica de España was the first European operator (the United States was ahead, as it was the epicenter of the Internet) to deploy a national IP network of great capillarity and capacity, the RIMA network, and the first to build, not without intense internal debate, the new television on copper (IMAGENIO). using a solution over an IP network (IPTV), when other operators did it with ATM (Asynchronous Transfer Mode).

At Telefónica, it was soon foreseen that IP technology was going to end up being used to implement all services: the new Internet access services and the new television over the copper loop, and also those of the company's data networks and telephony itself, which had been the sustenance of the business in the first 75 years of the company's life.

After a first stage, in which separate IP networks were created, dedicated by service (Internet and IPTV) and by segment (B2C/B2B), and once confidence was gained in the exploitation of these (it was a matter of being able to minimize risks and ensure services), steps were taken to integrate segments and services into the same infrastructure. Unlike other operators, who, faced with the challenge, created specialized divisions; at Telefónica, it was understood that the way forward was to transform the entire company and all the means were decisively put in place to achieve this.

All of Telefónica's national operations have had to face the adoption of these technologies and develop projects to unify multiple networks and optimize their topologies as they advanced in the development of broadband, business integration, the bundling of offers and the explosion in customers and data traffic (video) occurred.

In general, for the operators of the Telefónica Group that have the copper access telephone network, their evolution has largely followed that of the Telefónica networks in Spain: Argentina, Brazil TELESP, Colombia; while mobile operations have experienced a development of their IP networks, later in time, and linked to the efficient growth of the voice-over-IP network and that of mobile broadband (3G-2008): O2UK, O2 Germany, VIVO in Brazil, which, as will be seen, also took place in Telefónica in Spain, with a demand for capacity and capillarity lower than that of fixed operations.

1.1 The prehistory of IP networks

Before going into the projects for the evolution of IP Networks at Telefónica, in Spain, it is worth briefly introducing the emergence of these networks worldwide, linked to the birth of the Internet; as well as the world's leading project in the creation of the first commercial parcel network developed by Telefónica de España with Telefónica I+D.

Leonard Kleinrock published the first paper on packet switching in July 1961, as a result of his doctoral thesis at MIT. It was a theoretical analysis that sought to demonstrate that, in a computer network, information can be transmitted in small blocks (called packets), without the need for a permanent connection. It was he who convinced Lawrence G. Roberts (also an engineer at MIT) of the theoretical feasibility of communications using packets rather than circuits. The other major step he took was to get computers to talk to each other. To explore this field, in October 1965 he connected a computer in Massachusetts to a computer in California over a low-speed telephone line, creating the first, albeit small, wide-area network.

Leonard Kleinrock

The results of this experiment demonstrated that multiple-access (or time-sharing) computers could work well with each other and that the circuit-switched telephone system was totally inadequate for such uses. Thus the conviction of the need for packet switching was confirmed empirically.

Historical Note: October 1965 the first remote connection of two computers via Packet Switching is made: the idea works!

In the 60s, large computers were a scarce and expensive resource and there was a tendency to use them in shared mode in the data centers where they were installed and from remote locations, in what is known as teleprocessing. It is in this optimization of the use of processing capacity from remote locations that the need for computer connection arises. The first experiences of data transmission between computers date back to the early part of the decade. Signal modulation and demodulation equipment (modems) and telephony links (voice circuits) were used.

The use of links via telephony circuits and digital point-to-point links had several limitations:

1.- The speed and quality of these media were low in the growth panorama of this type of communications.

2.- The cost, especially for the dedicated, better quality lines, was prohibitive in cases where there were a large number of remote terminals accessing a central system.

3.- Data traffic is different from voice traffic. The first occurs in bursts with intervals of silence, while the second is continuous and in synchronous sequence. Using voice systems to transmit data wastes resources on these systems.

Faced with this situation, initiatives are proposed, in two different environments, aimed at resolving these limitations:

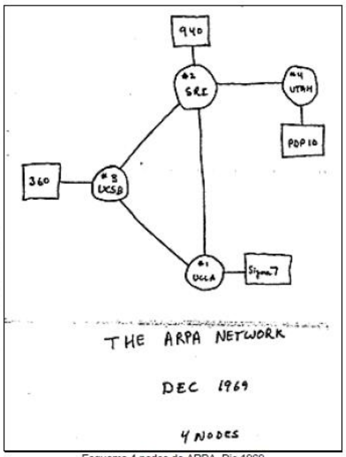
In the **non-commercial environment**[1] (academic and military), the ARPANET (Advanced Research Projects Agency Network) emerged, which would later end up configuring the world's public data network: the Internet. ARPANET relied on using computers as switching nodes, and fragmenting information into data packets that are sent across the network in various paths and then sorted and regrouped at the destination node. This scheme made it possible to optimize and make the use of the network more flexible for data communications traffic patterns.

In 1968 DARPA (Defense Advanced Research Projects Agency) on a list of requirements specifications launched a request for bids from suppliers to develop the key element, the packet switch.

The American company BB&Newman won) with the IMP (Interface Message Processor).

BBN team with the IMP

First versión IMP



Esquema 4 nodos de ARPA, Dic 1969

The first packet switch, the IMP, was installed at UCLA (University of California, Los Angeles) on September 2, 1969. A second node was installed at this university and the NIC (Nekwork Information Center) was created in which the tables that related the names of the computers with their network addresses were manually maintained.

Soon after, additional nodes were added at UCSB (University of California Santa Barbara) and at the University of Utah. By the end of 1969 there were already 4 mainframes connected to the initial ARPANET network.

The number of internet-connected devices reached 22 billion worldwide at the end of 2018, according to the latest research from Strategy Analytics.

The initial communications protocol in this network was the NCP (Network Control Protocol) in which significant limitations were soon identified:

- It did not allow communication to be maintained against interference (in radio-based transmission medium) or outages.
- It did not allow for correction of errors in communication; So, if there was a loss of packages, it stopped ("hung").
- It did not allow machines to be routed outside the ARPANET network and there were two other networks in this environment that were to be interconnected to

[1] Images, boxes and excerpts of contents from: The pre-history of the Internet. Dissertation. Andreu Veà Baró- May 2022.

ARPANET: PRNET (radio-based network) and SATNET (SATnet (SATelite-based network).

- It could not be modified.

These limitations prompted the decision to develop a new protocol to solve them, the IP protocol, the genesis of which is summarized below.

In the **commercial environment**[2], in the sixties, private data networks began to proliferate based on specific protocols of equipment manufacturers and oriented to specific needs.

Companies had communications networks to connect their IT computer systems, connections between Mainframe equipment, in Data Processing Centers, and access terminals distributed in offices nationally and even internationally. To mention the most implemented: IBM'S SNA, DEC-NET from the old Digital, Xerox's XNS, etc. These private networks were initially connected between locations hundreds of kilometres away using dedicated circuits, until the first public data networks managed by telecommunications operators appeared to optimally respond to this need.

Figure 3-1. Opening ceremony of the RETD

Source: '25 years of Data Transformation' [Rodríguez et al., 98]

On July 30, 1971, with the inauguration of Telefónica de España's first commercial data network in the world based on packet switching, with the inauguration of Telefónica de España's Velázquez headquarters in Madrid, which was built fundamentally to respond to the demand for connection of the computer systems of Spanish banks.

Other telcos in Europe and the United States chose to use circuit switches and lagged behind in adopting these technologies.

Telefónica's network was baptized as RETD (Special Data Transmission Network). Initially, UNIVAC 418 III computers and RSAN protocols developed by Telefónica I+D and inspired by the work of ARPANET were used for packet switching nodes. Subsequently, the standard x.25 protocol (x.75 for international interconnections) was created at the ITU (International Telecommunication Union) for these communications. With its adoption, the RETD was renamed IBERPAC.

[2] Images and historical information extracted from: "The development of the public IP data network in Spain (1971-1991): a case of technological progress in adverse conditions". Jorge Infante. Professor of Telec. Pompeu Fabra University.

The RETD was a significant success, with a spectacular growth in the number of connections in the first years of operation, as it welcomed the vast majority of Spanish banks and other institutions that made use of teleprocessing and real-time systems.

It is also a historical reference that, at that time, around 1978, Telefónica I+D together with SECOINSA designed and built a packet switching node for the RETD, the equipment known as TESYS, which was not consolidated, among other things, due to its shortcomings in being able to take it to the world market as a commercial product.

	RED DE CONMUTACIÓN DE PAQUETES	AÑO DE ENTRADA EN SERVICIO	RED DE CONMUTACIÓN DE CIRCUITOS
España	RETD/ RSAN	1972	NO
	IBERPAC X.25	1985	NO
Alemania	DATEX-P	1981	DATEX-L
Austria	DATEX-P	1983	DATEX-L
Bélgica	DCS	1982	NO
Dinamarca	DATAPAK	1984	DATEX
Finlandia	DATAPAK	1984	DATEX
Francia	TRANSPAC	1978	CADUCEE
Holanda	DN-1	1981	NO
Irlanda	EIRPAC	1984	NO
Italia	ITAPAC	1985	RFD
Luxemburgo	LUXPAC	1983	NO
Noruega	DATAPAK	1984	NPDN
Portugal	TELEPAC	1984	NO
Reino Unido	PSS	1981	NO
Suecia	DATAPAK	1985	NPDN
Suiza	TELEPAC	1983	NO
EEUU	TYMNET/TELENET	1975	Sin Datos
Canadá	GLOBEDAT	1977	Sin Datos

Table 1: Dates of data switching network roll-out around the world

Source: Ministry of Transport, Tourism and Communications, 1987 [MTTC, 87]

The next evolution of enterprise data networking was dubbed Network UNO (1990-2015) and was built with Nortel Passport nodes. It used FR (Frame Relay) technologies, an improvement on X.25 and ATM (Asynchronous Traffic Mode) both under the ITU standardization umbrella. ATM was a protocol that was conceived, like IP, to be able to transport voice, video and data optimally, but unlike the IP protocol it maintained the characteristic of defining fixed paths for the entire flow of a communication, as in telephony.

In this business environment and with the beginning of the Internet in Spain, the UNO IP Network was created to give Internet access to the ISPs that emerged with Infovia and Infovia+. As Javier Gonzalez Vela recalls in his article "Twenty-five years of Internet at Telefónica":

"The first (and for several months, the only one) Internet outing was a Frame Relay connection with a 256 Kb DLCI with Tipnet, the network of the Swedish operator Telia, through a line that passed through Zurich. At that time Telefónica was in a consortium formed by Swiss Telecom, Telia and KPN, in what not long afterwards became Unisource (and in which the new subsidiary Telefónica Transmisión de Datos TTD, which had been born in November 1995, would be integrated). I think it was in October when we gave more security to the Internet exit, constituting the first point-to-point circuit of 2 Mb capacity with the United States, with AlterNet, which had the Autonomous System number 701 (AS701)".

Later, in the years 1999 to 2000, within Telefónica Data in Spain, an IP/MPLS network was defined and built, the network initially called NURIA, and which was later renamed the RUMBA network, to offer virtual private data networks of companies with the IP VPN (MPLS) standard and serve xDSL broadband access and Internet access service.

1.2 The birth of the Internet IP protocol[3]

The IP protocol, already mentioned, emerged in ARPANET to solve the limitations of the NCP protocol and to achieve the goal of interconnecting data networks. It began to be developed in the spring of 1973 by Vinton Cerf (Stanford University) and Robert Khan (BBN, ARPANET,) who in September of that year presented at the INWG (International Networking Group), held at the English University of Sussex, the basic ideas for the new protocol.

These ideas were later embodied in the landmark article "A protocol for packet network interconnection", published in May 1974 by the two. It described a protocol called TCP (Transport Control Protocol), which provided all the services of transport and forwarding of packets in a network.

<u>A very simple idea would lead to an unimaginable result:</u>

Let's assume that every computer connected to a network has a well-defined address (a number we know today as an IP Address). If we want to transmit information from a computer on one network to a computer on another, all we have to do is split the information into small pieces or packets. Each packet is given the address of the recipient and the sender, assigned a packet number and handed over to the system for delivery. It is exactly like a simple postal system, the only difference being that both the users and the postmen are computers and can therefore carry out the process billions of times faster. This is the simple idea behind Cerf and Khan's TCP protocol.

The tests with the first implementations of the protocol were ideal for the transfer of data files; however, when transmitting voice in packets ("packaged") it was revealed that packet losses should not be corrected by the TCP protocol, due to the delay it introduced in a communication that should be synchronous, but that it should be the application of "voice over IP" that corrects these losses.

The inventors, to solve this limitation, reorganized the protocol into two, the TCP over IP protocol, which provided the correction of errors in communications and the UDP over IP protocol, which only made use of the IP protocol, dedicated to the correct addressing of packets, without the correction of errors, which were in charge of the applications that made use of the network.

[3] Note 1 applies to this sub-paragraph as well.

A key concept:

The Internet was NOT designed for a specific application, but as an infrastructure on which new applications could be developed. Thus we see how the WWW did not appear until almost a quarter of a century later or applications such as real-time chat (ICQ) in the exchange of music between two client programs, guided by a server (Napster). This is due to the generalist nature of the purpose for which the services provided by the TCP and IP protocols respectively were designed.

They thus created a basic open platform for voice, video and data communication, which through interconnection of networks and universal addressing, covers the entire planet; and on which, applications of all kinds and nature were created and continue to be created, which have constituted the success of the Internet and IP networks to this day.

Not even the creators of the protocol were able to imagine the growth of interconnected networks and computers, and later other devices, that were going to connect to the Internet. That is why the maximum number of connectable computers was limited to those provided by the 32 bits that were assigned for the IPv4 address tag (2 EXP (32); and that it was necessary to create in 1998, a new version of the IP protocol, IPv6, in which the numbering for universal addressing was extended to 128 bit (2 EXP (128).

The implementation and generalization of IPv6 is a challenge that is still being worked on around the world, and it is not easy, and it is very expensive, to replace IPv4 networks with IPv6 networks.

1.3 Address and domain name management[4]

As the Internet grew, the devices that connected began to be named, instead of the IP numerical address that identified them in the network for the purpose of routing packets. This is analogous to what happened in telephone networks, where there were Guides that identified users or businesses for the different telephone numbers. For example, to access the contents of the Telefónica S.A. website, users use www.telefónica.com without having to know the IP addresses of the computers that serve them.

At first, a simple table was created, where all the machines were reflected with their names and associated addresses, which were saved in a "host.txt" file, which could be accessed universally to have an updated guide. The management of this file was carried out by volunteers at the Network Information Center (NIC) in Menlo Park (California)

The spectacular growth in the number of independently managed networks and, consequently, in the number of machines and public IP addresses, led to the development of a system that would allow the work of constantly updating and consulting names and addresses, in a distributed way. This system, which is known as **DNS**

[4] Note 1 applies to this sub-paragraph as well.

(Domain Name System), allows by standard query to resolve the IP addresses for named machines following a hierarchical nomenclature. The term domino is used, associated with groups of machines that use it, usually within the same entity, company and organization.

Historical Note:

Paul Mockapetris of the Information Science Institute (ISI) at the University of Southern California (US), develops the Domain Name System: DNS. First documented in November 1983.

The management of the DNS system, the domain name space, and the assignment of public IP addresses has been adapted with the universalization of the Internet and today national networks have DNS servers to resolve the space of addresses connected to them locally.

1.4 The routing system

Packet switches, known as routers, route packets based on the IP address they are addressed. They use dynamic routing tables, and protocols to update them, depending on variations in the network topology and available paths.

As the number of interconnected networks and the total number of connected computers increased, router routing tables grew, and router routing tables became so frequent that they resulted in an unstable system.

To solve this problem, which is critical to the growth of the Internet, a hierarchical system for routing was created. To this end, the different networks, typically nationwide and managed by the same operator, were constituted as autonomous systems, and within them, the routing was solved with a protocol like the original one (IGP- Internal Gaetway Protocol), which dealt with local routing to and from the devices connected to them.

For communications between devices located in different networks, or autonomous systems, the BGP (Border Gateway Protocol) protocol was created, which is spoken by networks when interconnected between them, and which allows us to know the available paths based on ranges or aggregations of addresses accessible in or through each network.

Thus, when a device in a network or autonomous system communicates with another located in another external network, since there is no path within the source network (by the IGP), the exit is sought through one of the interconnected networks, which does offer a path to reach the desired destination (by BGP).

The destination tables (or route tables) are thus smaller in size and the reconfigurations in the different networks become internal variations, or local phenomena in routing, which, in the vast majority of cases, do not affect the rest of the Internet networks.

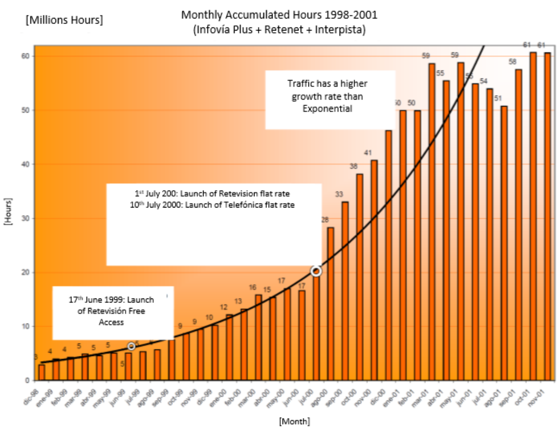
1.5 With massive access to the internet comes the need for national IP networks[5]

In the period from 1995 to 2001, narrowband Internet access was created and developed, under regulatory tutelage, in Spain. From the home computer and by making a call via modem, with a speed of around 33 kbit/s, the ISPs (Internet Service Providers) were accessed, using the telephone circuit network, which had the interconnection of their IP routers to the international Internet network.

Telefónica de España, as the "incumbent" provider of the telephone network, was obliged to provide these accesses, first with Infovía and later with Infovia+, which opened the possibility of access through networks of alternative telephone providers.

As already mentioned, the circuit network was neither in terms of capacity/quality nor in terms of what it represented in terms of circuit occupancy and suitability for data transport, nor ultimately in terms of cost, the appropriate network for Internet communications. He supposed; however, a quick way to popularize Internet access, since it facilitated it in every corner of the country with telephone access.

The following figure shows the traffic in millions of connection hours, from January 1999 to November 2001, carried by the telephone networks of Telefónica de España (Infovía Plus), Retevision (Retenet) and BT (InerPista).



The Retevision and BT networks used Telefónica's network for access, to which they were interconnected at regulated prices.

In the competition for customers, there was an evolution to models of free telephone access and flat rates, so that, in 1998, more than 1,200,000 Internet users were already registered.

Teleline first and Terra later were Telefónica's ISPs in Spain. The latter, famous for the acquisition of Lycos and its subsequent IPO, which ended with the so-called .com crisis, and its subsequent withdrawal from the stock market by Telefónica.

1.6 UNO IP Network: first IP network to connect ISPs to the Internet

[5] The following sections come from the book: "Chronicles and Testimonies of Spanish Telecommunications" (2005-2020) Volume 3 with the edition of the narrowband period (1990-2000) and some modifications of the original.

The interconnection of ISPs to the Internet, as already mentioned, began to be offered by Telefónica Transmisión de Datos, in its UNO IP network, with a deployment without much footprint or capacity, focused on Madrid. However, for the mass access of Infovía and Infovía Plus, it was Telefónica de España that took over the management of the international IP network. Telefónica de España already had transatlantic submarine cables (Columbus), which were and continue to be a key factor in the international Internet interconnection environment. This is how the Flexnet IP network was born, with a 34 Mb connection, in Alcobendas, at that time a very large capacity, and its own autonomous system: the AS6813.

Based on this success of the Internet in Spain, a reflection of what was taking place around the world, a model of Internet access with ADSL on the telephone copper pair was created and regulated in 1999. By using the copper spectrum above that used by voice, the access pair could be used to deliver voice and data simultaneously without interruption. With this regulation, the way was opened for the development of broadband over copper, an alternative to the one that cable operators had already started with their regional coaxial cable networks to the home.

In order for this access over copper to be offered in competition, a loop rental model was enabled with transport included up to 109 national demarcations, which the regulator defined with the industry, with a regulated price.

From the exchanges with ADSL to the delivery in the 109 demarcations, the data traffic of each subscriber loop was carried in ATM circuits, first in ATM circuits, and then Ethernet channels, to be delivered to the Offering Operator. This led to the construction of networks known as metropolitan aggregation networks.

As already mentioned; initially, that section was built on ATM, circuit-oriented technology, which was seen, as ISDN (Digital Network of Integrated Services) had previously seen, as the multi-service broadband network to absorb all traffic. GigADSL, as these disjoint networks were called, carried Internet access traffic.

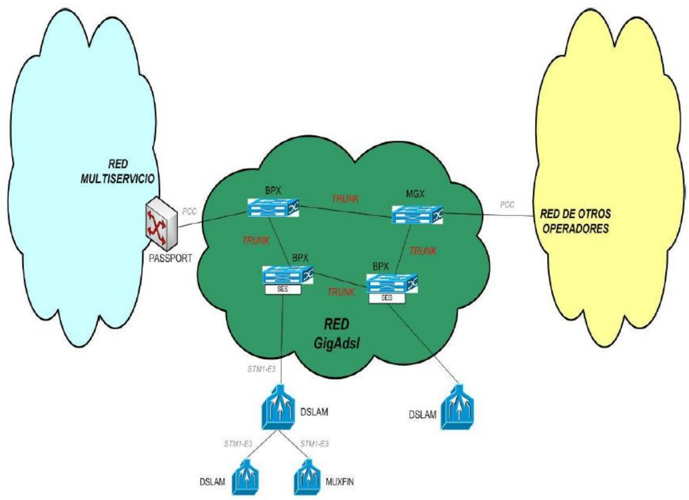


Fig.: ATM aggregation network of Telefónica de España. Indirect loop access. Source: J Ruiz.

Switched ATM circuits (PVCs) carried traffic from customer accesses to each operator's delivery points (PCCs). The GigAdsl network was initially built with nodes from the US company GDC, which was acquired by Cisco. In the next step, Lucent Technologies' MGX nodes were introduced, capable of interoperating with GDCs and with much greater switching capacity.

Soon these networks had to be replaced by packet networks, in that section based on Ethernet, making use of VLAN(s) (Virtual Logical Area Networks) to "emulate circuits" and thus separate traffic from operators and services.

The much more competitive costs, and above all the capabilities to aggregate traffic, led to this evolution, also fostered by the regulation that defined xDSL indirect access, by volume of traffic, to be delivered on GE and 10 GE interfaces. Telefónica built its Alejandra network in this transformation. It was curious to see the industry speculate about the reason for this name. Naming our sector is an art. In this case it was clear: A for Alcatel, L for Lucent, E for Ericsson, J for Juniper and having ALEJ then the normal thing is to complete it: ALEJANDRA. Years later, this explanation was given by a GOA from Telefónica (their knowledge and skills were incredible, Telefónica's GEO) during one of their visits. He was surprised when he received a much simpler explanation, as things usually are: it was the name of a beautiful girl who is now training as a Psychiatrist in Motril

On the Alejandra network, traffic from Internet accesses, IMAGENIO accesses and regulated wholesale accesses were added.

The regulated ADSL access speeds in the network-to-user direction were **256 Kbit/s, 512 kbit/s and 2 Mbit/s** and in the user-to-network direction **128 kbit/s** for the first two and **300 kbit/s** for the third

It was then identified that, for this retail Internet access service, taking into account the volume of Internet users that had occurred with narrowband, and the increase in traffic that ADSL was going to entail, it was necessary to create a distributed national IP network of high capacity that would connect to the Internet via Telefónica's international exits.

In the field of data services for companies, ADSL also represented a revolution in terms of access capacity and capillarity, compared to that of IBERPAC, with accesses based on digital circuits with speeds of nx64 kbit/s (up to 2 Mbit/s maximum). The appropriate network to offer these services was a nationwide IP network with implementation of the standards of RPVs (Virtual Private Networks) on MPLS (Multi-Protocol Label Switching), which as already mentioned was built by Telefonica Data, the NURIA network.

1.7 RIMA project, the first IP network in search of the five nines

The regulation of indirect access to the copper pair of the Telefónica de España (TdE) network with ADSL technology, in 1999, changed the course and dynamics of a company that had been focused since its origins on the fixed telephony business, which seemed to be going into decline in the last decade of the twentieth century. The narrowband internet business and internet content was centered on Terra. The company data was a matter of Telefónica Data. All these companies were new, with tight staffs and a careful selection of talent.

For historical reasons, TdE, like the rest of the important Telcos around the world, had a large workforce at the time, as a result of the fact that the fixed telephony business was, especially in the access loop, tremendously labour-intensive (registrations, cancellations and modifications of services, in addition to interventions for breakdowns and vandalism). And at that time, the implementation of companies specialising in external plants was in its infancy. The fixed telephony business, in monopoly or near-monopoly configurations, had been a very good business for more than half a century; In fact, telephone companies were considered among the strongest and most stable companies in all countries. The liberalisation of the fixed telephony market (as was carried out in Spain), added to the massification of mobile telephony, and Internet-based services, marked the end of a historical era and it was necessary to open new horizons

ADSL, and the strategic decision to implement a new IP infrastructure, on a large scale and in support of all services, was the beginning of a new stage for TdE. This new IP network (RIMA), initially designed to support massive ADSL accesses at 256 kbps, has evolved to the present day, with support for retail and wholesale fibre optic accesses, voice and video over IP, and mobile broadband connectivity (3G/4G/5G).

At that stage of the late nineties, as we have seen so far, the knowledge and responsibility for IP networks was in Telefónica Data. After a strategic debate, in which Telefónica identified that Internet IP technologies were going to support all traffic; as it has been, it was decided that Telefónica's offer of retail and wholesale Internet access was the responsibility of Telefónica de España, also seeking to achieve maximum efficiency in the provision of these new services, from access and aggregation to the exit of Internet interconnection.

Telefónica Data was specialized in offering data services for companies. Since the decision was made, Telefónica Data assumed and carried out a transfer of responsibilities to Telefónica de España, which is a reference of exemplary behavior in the history of Telefónica.

A new IP network, developed in the organization that had been responsible for telephony, was designed, as it could not be otherwise, with a quality objective of 99,999. Avoiding service losses or unavailability were in the DNA of Telefónica de España at all levels. The idea that IP networks are "Best Effort", which they are, did not fit very well with that culture and way of understanding traditional services. An example, always commented on, is the availability of telephone service in the event of electricity cuts in homes and businesses. This meant that network security was prioritized in the design. To avoid loss of service: redundant switching equipment, load sharing, and redundant IP links or paths were used, and the transmission circuits that carried these links were also redundant.

It must be said that the quality of the network that was built was very close to those five nines; although, as will be seen later, there were crashes and slow navigation, which in some cases affected the entire country, although they were not of long duration. Also, with the passage of time, there has been a change in culture towards acceptance, there is no other remedy, of the unavailability in the field of communications that the Internet has brought.

The start (December 2000) of the new IP Network project (RIMA) took place in Buitrago de Lozoya, in the facilities where you can still see today the satellite dishes that once connected Spain with the world by satellite. It brought together the best IP network experts from Telefónica Data, and the infrastructure organization of Telefónica de España. From it, a plan came to create a new IP network and migrate all narrowband accesses and first ADSLs, which were transported in Telefónica Data's IP networks. The objectives are to have the new network built with its provision and management systems and operational accesses to it in 8 months, and from that milestone, to reach 1 million ADSL accesses in one year.

With the collaboration of Telefónica Data, Cisco, Telefónica I+D, and HP, a management structure was created by projects and subprojects, with its weekly committee, which from the beginning chose to create an end-to-end model of the IP network and its management systems, connected to the ADSL access models, and equipped with Internet output. that would allow defining and testing all aspects of network and management, including migrations from the actual deployment that had to be done on site. As was done with NURIA, this new IP-MPLS TdE (RIMA) network emerged as a 100% Cisco network, on the network side, simplifying in this phase the need to solve the interoperability between equipment from multiple manufacturers.

The model was built in what is known as the Technology Building of Telefónica de España, on Calle Emilio Vargas in Madrid, interconnected to other access and service models, which made it possible to recreate the individual and the ensemble operation end to end, prior to its actual deployment.

This type of environment is essential in a large operator that works with a multi-manufacturer environment because:

- It is neutral ground. Nowhere else would they agree to co-locate their teams and technicians so naturally.
- It is the best possible training for the Operator's (and also the manufacturer's) professionals. Here the teams are stressed, and their real limits are known (far from the marketing pamphlets) in service and operation
- Here HW/SW failures are identified that, if detected in the field, would have led to problems with the most valuable thing: customers.

When those responsible for Technology and Planning formalized a certification of equipment, architecture, deployment procedure or migration, the Network Construction process was triggered under the responsibility of the areas of I+M (Installation and

Maintenance at the customer's site), Network Creation, and O+M (Operation and Maintenance) that could register thousands of customers in a week. If something went wrong, it was thousands of unhappy customers.

The network baptized as the RIMA network (Open Interactive Multimedia Network), which also gave its name to the project, was conceived in a hierarchical structure on three levels: access centers (97), transit centers (12), and interconnection centers (3). The hierarchical design was very suitable for Internet traffic since the interconnection traffic component, national (via Puntos Neutro) and international, was exchanged in Madrid and traffic between customers on access was negligible. The network was built with redundancy of equipment and links to achieve availability of five nines.

Management was first created at the same time as the network. It contemplated the systems of provisioning, inventory management, fault management, performance management, and security management. These systems used leading market products at the time, such as HP Openview (Netcool) for fault management, Infovista for performance management, with HP acting as an integrator. For inventory management and to provide services to customers, Internet access and MPLS RPVs, two tools developed by Telefónica I+D, SPCI and GesADSL were used. Security management, also under the responsibility of Telefónica I+D, included the security bastioning of the network equipment and multiple servers at all levels, the segmentation of service and management traffic, the installation and configuration of Firewalls and tools such as PeakFlow in the interconnections for detection and mitigation of denial of service attacks. The following two figures outline RIMA's management and security architecture

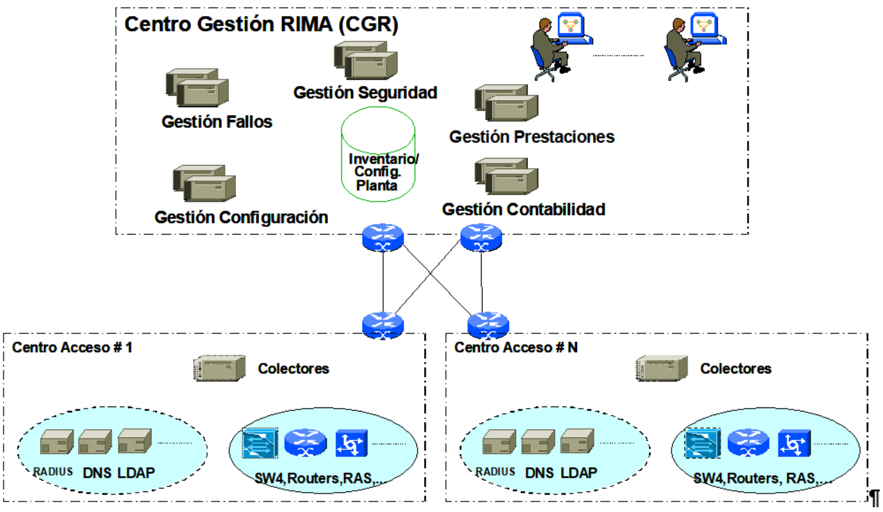


Fig.: RIMA management architecture. Telephone source

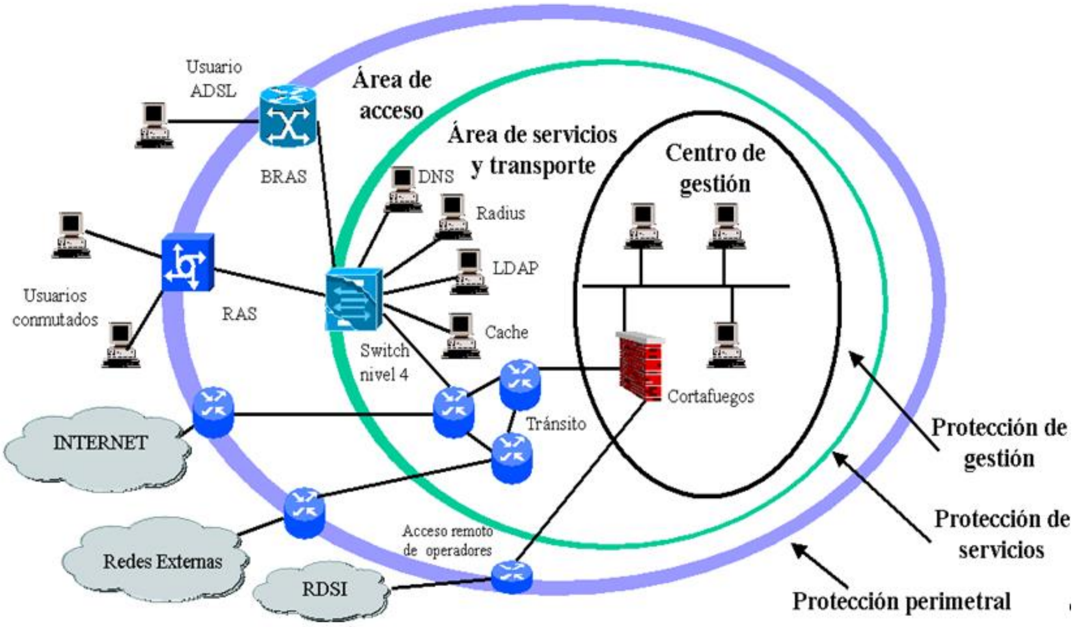


Fig.: Security Architecture: RIMA Protection Levels. Telephone source

As users and traffic grew, it was necessary to pay attention to the new network's DNS service, necessary and critical on any IP network, to translate domain names to IP addresses. Initially, the free software (shareware) BIND was used for the DNS service, which soon began to suffer from congestion, leading to slow browsing and complete unavailability of the service, with the corresponding associated media impact. The solution was not only to add more and more servers, it was also to use much more efficient software and above all without security vulnerabilities, such as those that BIND had. It was soon decided to change BIND for the software of the US company, Nominum, reusing the existing servers. A redundant architecture was also created with load sharing at the national level (Madrid/Barcelona), which made it possible to overcome the first crisis in this area.

Within the crisis section, in the origins of RIMA, there was one that kept many at all levels of the organization awake at night. It was the crisis of the balancers. These traffic balancing elements in the access centers, to which the caches and also the DNS servers were connected, had been purchased from the company Arrowpoint, acquired by Cisco, for their sophistication and innovative nature. Soon the balancers, which in the model did not present problems, began to fail trying to traffic from a network of those dimensions. The origin of the problem was due to the combination of two factors: 1) the volume of traffic, and 2) the peculiarity of the Caches that required the outgoing and incoming traffic of each client to pass through the same interfaces and ports in the balancers.

On many occasions, when there is a major failure in the Network, the origin is that several anomalous situations occur simultaneously. Each of them in isolation would not have caused the fall. This makes it very complex to isolate the root causes, although once found, their explanation seems obvious, especially to those who do not participate in their management.

The successive software versions (patches) for the Arrowpoints (Level 4 switches) always ended up failing in Madrid Norte; which is why Cisco was forced to change all the equipment for the less sophisticated, but more robust, Catalyst 6500, which also worked well with caches. A large operation given that each access center equipped two of these pieces of equipment for redundancy and load sharing.

Another essential characteristic of the management of the Networks of the time: the migration without impact on the service of complete networks, the one described here was one of the greatest. The days of preparing these processes down to the last detail were endless. The areas of Technology, Engineering and Operation working in unison. Again, everything was debugged in a mock-up in a simulated environment so as not to impact the customer, another advantage of this type of environment.

Other problems, mostly arising from the totally innovative nature of an IP network of this size, were related to the scalability of the network equipment, which, in some cases, did not manage to support all the load indicated by the provider. These were foreseeable and even normal problems under the circumstances, and were usually solved by adding more equipment and cards than initially planned with the consequent associated cost overrun, which was passed on to the supplier. Of this type of problem, it is worth mentioning the case of the NPR4 cards in the Cisco 6400 access BNGs (Border Network Gateways), which supported half of the intended users, and the Engine 2 cards, in the interconnect routers, which were not able to move the 2.5 Gigabit/s of their nominal capacity when the network protection rules were applied. in those gateways to other networks.

The RIMA project, with all its centralized management systems in the CNSO (National Center for Supervision and Operation) of Aravaca, began to traffic in August 2001, 8 months after the start of the project in December (2000) after the Buitrago meeting. The FOA (First Office Application – First implementation with real customer traffic, all departments present on-site) had started at the end of May 2001, following the Project schedule.

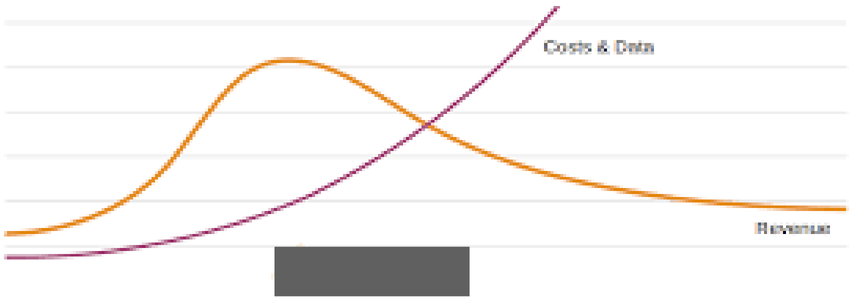
The migration of all narrowband accesses and first ADSL from the UNO IP and NURIA Network was addressed, nothing similar had ever been done, in the fourth quarter, and would be completed in December of the same year 2001. For the following year, 2002, the TdE Management Committee set the goal of reaching 1 million ADSL (a huge figure at that time, and which meant the beginning of the generalization of Broadband in Spain, not only for companies but also for individuals). The figure of one million ADSLs was reached at the end of 2002.

It was a project of enormous dimensions in all aspects (at that time, there was no precedent of similar characteristics, among the most cutting-edge Telcos in the world): participation of people from multiple companies, investment in models and network and systems equipment, working hours from morning to night and some weekends, and a dose of motivation and demand to meet the dates, which has left the participants with an indelible memory.

2. The big data flood: network optimization

The rapid increase in customers and bandwidth of the Internet access service and also in IPTV offers for the residential market, not to mention the use of P2P "Peer to Peer"), produced an increase in traffic on IP networks that carried them at a much higher rate than that generated by the growth of lines. It should not be forgotten that in this first decade of the 2000s, companies such as Napster (music and archives 1999), BitTorrent or Emule (2000) and Skype (2003) emerged, which would be true catalysts for the increase in traffic and changes in the nature of traffic.

The growth in traffic meant a constant increase in costs: investments to evolve accesses, including spectrum auctions, and growth of networks, with an added continuous unproductive expense, that of the constant realization of customer portability between operators. Revenues, on the other hand, were reduced as a result of regulation-driven competition. At that time, the graph was popular, with the growing evolution of capacity and its costs in the face of the fall in operators' revenues.



Typical graph of the evolution of costs and revenues. Source internet

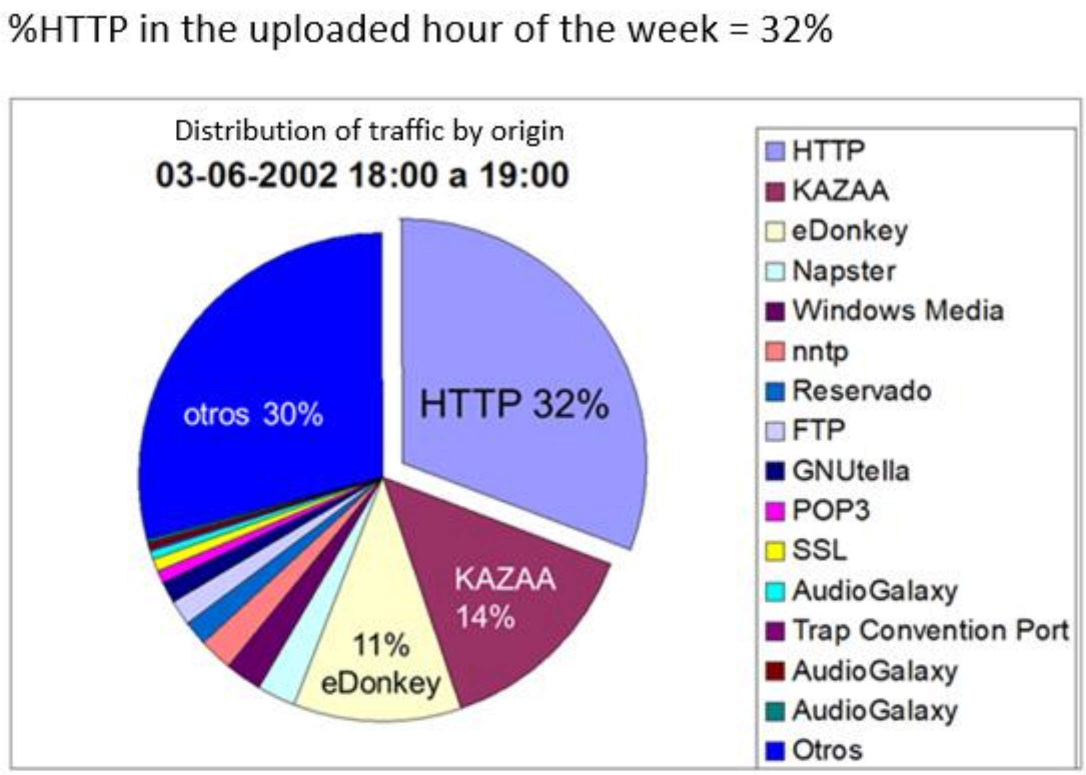
The technologies and market of network equipment evolved to offer solutions that allowed to carry the growing traffic. Network routers had to grow in switching capacity and the number and capacity of their interfaces so that operators could create network topologies capable of responding to demand. From Gigabit/s switching capabilities, they went to Terabit/s, from interfaces at 2.5Gbit/s they went to 10, 40 and 100 Gbit/s.

Traffic optimisation solutions **have also appeared** that have been providing an improvement in the quality offered to customers at each stage while achieving cost efficiencies.

In this section, the following are noteworthy: i) cache deployments in the early years of narrowband and low-speed broadband, ii) P2P solutions such as distribution networks that made use of the customers' own local PCs, until affordable and quality video streaming services emerged, iii) CDNs to optimally distribute one-to-one (Unicast) streaming video streams of OTT (Over The Top) solutions, which had their explosion in the second decade of the two thousand and; finally, iv) multicast (one-to-many replication) that was applied to make IPTV solutions viable in access (IP DSLAMs), and to optimize distribution within CDNs, but that was not implemented at the IP network level, despite having defined the standards for it.

The issue of efficiencies due to this type of optimization is always controversial for network designers: investments in solutions that optimize certain traffics versus investments in increasing the overall capacities of the network. To give the example in this situation: investing in caches for http and P2P traffic thinking that investments in IP transport and switching are delayed and that they provide a better response to customers.

The nature of traffic in the first stage of broadband shows that the dominant and fastest-growing traffic was P2P, from the eDonkey and KAZAA applications, which distributed multimedia content (movies, music and videos, above all). This traffic could be measured from the classification of traffic by port that could be identified by sampling traffic flows on network routers. To avoid the possible filtering of these traffics, users began to send them through non-standard ports (See figure xx).



Classification of traffic by port using Netflow in the RIMA network of Telefónica de España in 2003. Telephone source

2.1 Traffic optimization: caches, CDN perlude, and the P2P phenomenon

Between 2003 and 2006, some operators in the world deployed http browsing traffic caches in their networks, mainly to speed up the loading of content in customers' browsers, while reducing the amount of traffic that had to be brought from remote places, with longer loading time and higher associated costs. The loading time of pages on an Internet in which the speeds of 2003 of the narrowband (30 kbit/s) and the 256 Kbit/s of the first wave of ADSL was very high. If you wanted to load many images and some videos, the wait for page loading exceeded the time of "loss of patience" of those who accessed them. Many users had to disable the loading of images in their browser in order to load web pages and make use of the information.

There was the possibility of caching in the browsers of the time (Mosaic and Netscape) but this caching was individual, with much less effectiveness and efficiency, than that which shared caches could provide.

Together with the deployment of the RIMA network (Telefónica's IP network) and distributed in quasi-provincial points of presence, Telefónica activated between 2003 and 2006 the cache solution of the market leader of the time, Inktomi, deployed among others by AOL (American Online), the largest Internet provider in the US at the time, Microsoft, Amazon, eBay, etc. The cache was very controversial among Spanish Internet users because it was argued that it could be used to access private content and because it could return obsolete content.

When proposing the capillary deployment of caches by Telefónica, priority was given to achieving the best response in time, by reducing latency in content delivery due to its proximity to the end user, although its efficiency decreased by reducing the probability of content reuse due to fewer users sharing each server. This reuse was measured systematically and the measured efficiency data obtained were greater than 30% (see the figure below). Latency, especially for serving international content, was reduced to that of ADSL access or the switched network, with the consequent reduction in page load time, which was also reduced thanks to the capacity of the cache to reduce the size and quality of the images it served.

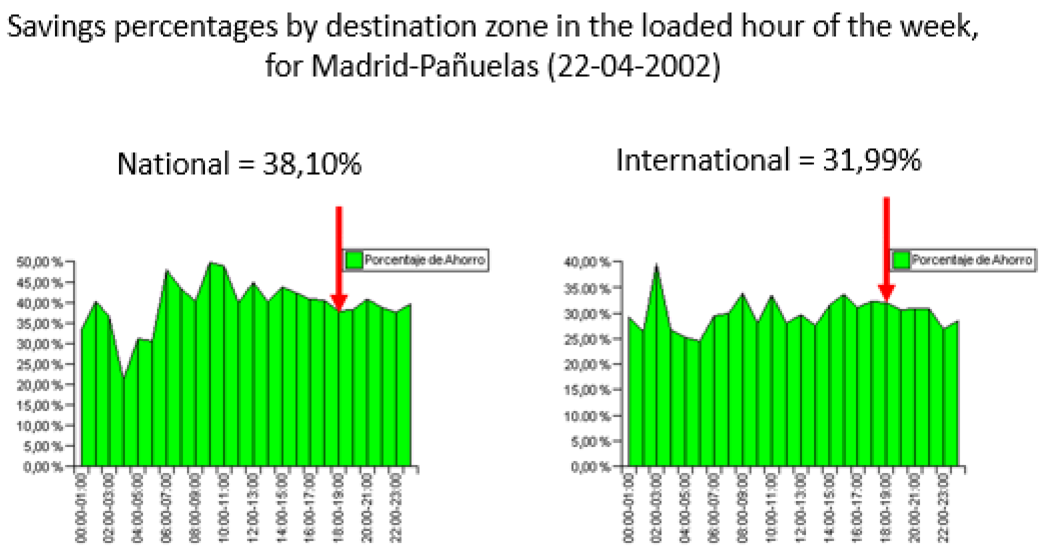


Fig. Percentage of traffic savings due to caches in hours loaded in the RIMA network in 2003. Telephone Source.

The same cache servers, from the beginning, were used to offer, in addition to content caching, value-added services for customers. Perhaps the greatest exponent was the Kangaroo Net service (parental control), which filters access to inappropriate content for minors, and plans the time slots for the use of the service, which could be controlled by parents. Other security and protection services from the network were added to this service, such as antiphishing, etc. The service was widely accepted at the time and remained alive without advertising for almost a decade.

Also on these caches, the first generation of CDN based on preloading music and video streaming content was implemented, which supported the streaming of Windows Media and the then popular Real Media of Real Networks. Based on this solution, Telefónica de España went so far as to deploy an OTT subscription music streaming service, which included online listening and downloading. The service was not successful in its commercialization, first because of the existence of P2P and second, because of the success of Apple's offer with its IPods and iTunes.

In 2006, after the second ADSL upgrade, the page load acceleration effect was no longer so necessary. In addition, the growth of non-http traffic (port 80) in the network complicated the specific management of this traffic, which led Telefónica de España to close this network facility, maintaining Kangaroo Net's security services in a two-center retreat.

Days before the acquisition and commissioning of the caching solution by Telefónica de España, Inktomi, the company that had created and marketed the streaming caching and CDN solution, was acquired by Yahoo. Inktomi CEO David Peterschmidt, a former fighter pilot in Vietnam, traveled to Madrid to explain the operation, according to which Yahoo acquired Inktomi because of its interest in Inktomi's search software in order to better compete with Google's search engine. Neither Terra with Lycos, nor the sale of Inktomi could overshadow Google (founded in 1998) in the essential ease of Internet searches that became the "only" search engine.

David Peterschmidt on that visit stated that the CDN solution already available was still premature for the Internet market and predicted, as it happened, that in a few years streaming CDNs would become a technology of high use and deployment.

Indeed, video streaming CDNs would have to wait a few years to become a massive solution on the Internet, linked to the success of YouTube and the OTT content offerings led by Netflix.

As already mentioned, the P2P that appeared with Napster and evolved into a distributed model, became in the years 2003 to 2008 the most important component of Internet traffic in broadband in Spain, and also in the rest of the world. As a traffic distribution technology, it can be considered a first-rate innovative invention. It is based on chopping up the content and replicating it and serving it from the PCs of the customers who download it, turning them, de facto, into servers of a content distribution network, which optimized the use of bandwidth and download speed by proximity.

Customers with xDSL accesses with a higher speed in the user-direction network, through which they became greater distributors, were favored when it came to obtaining the pieces of content they needed to complete their download. In the second speed doubling of ADSL, in 2006, which included the doubling to 300 kbit/s of the user-network channel of the basic modality, there was a high increase in total traffic in IP networks, due to the increase in P2P, greater than that which had occurred in the first duplication that did not affect the user-network channel.

The P2P stage would end years later with the increase in access speeds and the appearance of competitive offers of content distributed via CDNs (Netflix) that allowed the viewing of films and series on TV screens, in real time and on demand, without having to wait and manage downloads. There were also strong international campaigns for the protection of the intellectual property of content and increased persecution and closure of illegal content distributors, as was the famous case of Mega.

2.2 Anomalous traffic that caused significant degradation of customer services: Spam, attacks with DNS, DOS and DDOS, 3G signaling

The proliferation of anonymous free email offers and the ease of creating domains regulated by ICANN (Internet Corporation for Assigned Names and Numbers), led to the appearance and growth of spam, or junk mail, which began to be used as a tool to penetrate the networks of customers, especially companies, for illicit purposes. At that time, DoS (Denial of Service) attacks appeared, which consisted of sending excessive traffic or signaling to a customer's address from a malicious source that ended up causing the loss of service.

In some cases, spam and/or DoS traffic saturated the broadband links of the companies causing unavailability of Internet access. Also at the level of interconnected networks, some administrators of these networks on the Internet began to implement policies to filter traffic from domains that generated too much spam. Anti-spam solutions appeared to mitigate this problem, implemented in mail solutions and network solutions.

The DNS - Domain Name Server - due to its central role in Internet communications and since the facility of creating domains automatically and anonymously was opened, became an even more critical infrastructure, which was subject to attacks that sometimes created massive unavailability of Internet access for hours.

In the second half of the 2000s, the DNS began to be used as a sophisticated vector of attacks on customers, through the dissemination and control of what are known as "botnets" or "malware networks" that allowed the creation of distributed DDoS (Distributed Denial of Service) attacks. which, unlike the first DoS attacks, came from millions of distributed sources: the users' own PCs and in some cases the operators' broadband access routers. The detection and mitigation of these attacks has required sophisticated networked solutions with globally coordinated deployment.

Another scenario of anomalous traffic, which caused a crisis of unavailability of access to Internet service, occurred at the end of the decade and the beginning of the boom in mobile broadband access. These were the signalling storms caused by some mobile terminals connected to 3G networks permanently. The applications on smartphones, which periodically generated heartbeat traffic with their remote servers, caused signals of network state changes, between the base stations and their controllers, which came to saturate their processing capacities and the consequent massive loss of access to the service. Those were times of adjustment between the world of voice and the world of applications and mobile terminals.

2.3 Network consolidation projects: centrifugal and centripetal forces at work

At cruising speed, the new network had to respond to the constant growth in traffic, due to the increase in customers, access capacity, and the greater use that each of these customers made of it. In the latter, it is worth highlighting after the phenomenon of P2P downloads, experienced in the first decade of the century, that of streaming video, which was progressively growing to become the main source of traffic until today.

This growth meant a constant investment in new equipment and cards and network links in order to grow with demand, leading to very short amortization periods (4/5 years), unknown in traditional telecommunications networks. It was also a challenge for equipment manufacturers, who had to constantly innovate to increase the capabilities of their equipment by pushing the latest processing and memory capacities of Silicon Valley to the limit. The operators, as always in these situations, sought to have more than one supplier and the alternative to Cisco also came from Santa Clara in California, and is called Juniper. At Telefónica Data, still operating in services for companies as an independent company, they worked on and resolved the interoperability of the BNGs and Terarouters of this supplier with those of Cisco.

Two suppliers, for a network that serves the whole of Spain, implies an effort to integrate with their cost, especially in systems, but competition in purchasing processes ended up making the sum of 1+1 <2 of the term TCO-Total Cost Of Ownership fit.

The other great efficiency had to be sought in the unification of networks. Economic cycles in the stock market oscillated between concentration and the disaggregation of businesses to raise the stock market price of large groups. Telefónica de España, Telefónica Cable, Telefónica Data, Telefónica Móviles, Terra, TWIS (Telefónica Wholesale Services), etc., operated as independent companies, in some cases forced by regulation.

At the end of the concentration cycle, with the permission of the regulator, Telefónica Data was first integrated with Telefónica de España, around 2005, and in 2007 the operational integration of Telefónica de España and Telefónica Móviles. These integrations brought with them operational synergies, including network consolidation and operation.

The integration of Telefónica Data nurtured excellent knowledge of IP network engineering and planning and provided the integration solution of Juniper with Cisco. Telefónica Data, which provided local transit in Madrid for the delivery of national and international traffic, ceased to be an intermediary in this segment and its network was no longer necessary. It was a case of efficiencies, clear, based on the elimination of redundant concepts.

In addition, IP networks are beginning to be controlled with greater security by professionals who, however, with good judgment, do not dare to provide the "Multiservice" feature to a network that brings together diverse needs.

When in 2007, the Telefónica group anticipated the same fate for mobile voice as that followed by the voice on the landline, it proceeded to operationally unify Telefónica Móviles with Telefónica de España.

In IP networks, the unification began with a first meeting at the offices of Telefónica Móviles, at the door of Alcalá, of the technical teams of both companies. The project was baptized as the UNICA Network. The actors, the heads of infrastructures of Telefónica Móviles and Telefónica de España. The objective for IP networks is to unify in a single network the IP network (RIMA) of Telefónica de España and the IP network RUD of Telefónica Móviles. Objectives: to capitalize on the operational synergies of network consolidation and operation and to enable the platform for the creation of convergent fixed-mobile services.

In 2007 mobile voice was still in a cycle of growth in terminals and traffic, and data would begin to grow in the short term with the appearance of SmartPhones. The iPhone appeared in 2007 and Android terminals in 2008. The world's mobile voice exchange providers, Ericsson, Alcatel, Lucent, Nortel, had already gone through their forced thinning phase and had begun the transformation of their classic switching solutions to solutions in which signalling and voice were carried out over IP networks and general-purpose servers. At Telefónica Móviles, the transformation from voice to IP was already being developed and the first thing that had to be solved when merging RUD and RIMA was the transport of mobile telephony into IP. It must be said that the degree of automation in the provision and management of RUD was minimal, and that it was a matter of provisioning many signaling and voice flows, through numerous layers of firewalls, in different VPNs, according to the complex architecture that 3GPP had conceived. In traffic, however, the volumes were not remotely comparable to those of fixed broadband.

It was around 2008 when the debate took place about whether to one or two networks. Centripetal forces in search of efficiencies pushed toward total unification, centrifugal forces, in favor of network specialization, argued against such integration. IP voice required a low-traffic, highly secure, latency-optimized, mesh network. The Internet network was hierarchical with a lot of traffic and an almost frenetic pace of updating equipment, cards and software. At the most executive level, the question was: What happens if the UNICA network goes down? Are all customers left without voice, business communications, and the Internet?

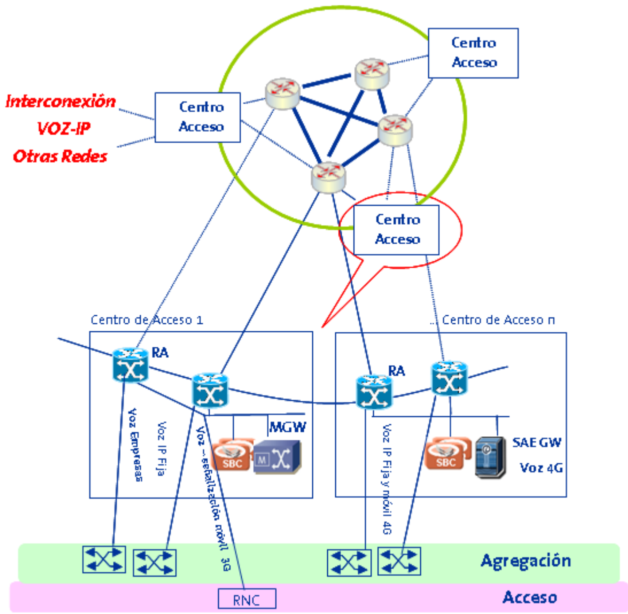
As already pointed out, there had been massive occasional outages on the Internet, for example, linked to the unavailability of the DNS. There were also outages due to "route injections", from international networks, which caused routing failures in the network core, and with it the complete loss of service for all customers. Although there were architectural solutions to solve these cases: for example, the use of logically segmented networks (RPVs), or the use of IP routing protocols only in interconnection routers and the use of MPLS tagging in the core, the final solution was agreed upon around the creation of two separate networks, since there was no total certainty regarding the impact of software problems on the critical elements of the network. The mesh network dedicated to voice traffic was baptized as the Critical Ring.

The UNICA network project was tremendously laborious, but the great knowledge and dedication of the entire network organization with experts from landline, mobile and data working integrated, led it to a successful conclusion.

Meanwhile, the IPTV network, from Movistar's TV and Video on Demand solution, operated as a separate network from the previous ones within Telefónica de España. Telefónica Cable was in charge of the content header. This network carried the signals of the TV channels through optical transmission rings, from the headend, in Ciudad de la Imagen, to the 23 national access centers, where they already entered IP routers, which connected with the xDSL (IP) access equipment first and OLTs (IP) later via the Alejandra network. In the section of client access there was total separation of the Internet, voice, and IPTV with the use of multicast for channel broadcasting. The plans for the integration of the IPTV IP network with the UNICA network were never finalized.

2.4 Connectivity, video and concentration and distribution debates

Although mobile voice traffic changed trend, as happened with fixed voice, the project to transform voice to IP over the Critical Ring continued to demand a continuous effort of structural actions associated with the evolution of the successive generations of mobile radio (2G/3G/4G). The connectivity, with manual provision, required elaborate planning of the work and a careful review of IP addresses to be used to avoid making use of those already in service. The multiple firewall layers of the RUD 3GPP network no longer appear in this architecture.



IP network structure in Telefónica. Fountain. Telephone

Internet traffic grew, with a very sharp increase in the video component, especially with the appearance of OTT streaming services, Youtube, Facebook, Netflix, HBO, Disney, Yomvi, Movistar+, etc. The traffic of IPTV and operator solutions also grew significantly, especially since the creation of the recording service and the U7D modality (last seven days) that were delivered in unicast streaming.

At the beginning of the second decade of the 2000s, with a Cisco/Juniper IP network, actions were carried out as a result of the recurrent debates of distribution versus concentration, in the number of centers, for the different levels of the IP network.

In 2011, in the interconnection, new centres were opened in Barcelona to exchange national and international traffic from the entire north-west region, without the need to transport them to Madrid. Although there were much more aggressive approaches based on transmission savings, it was there, taking into account that it is highly advisable to be able to control the entrances and exits of the network for perimeter security protection.

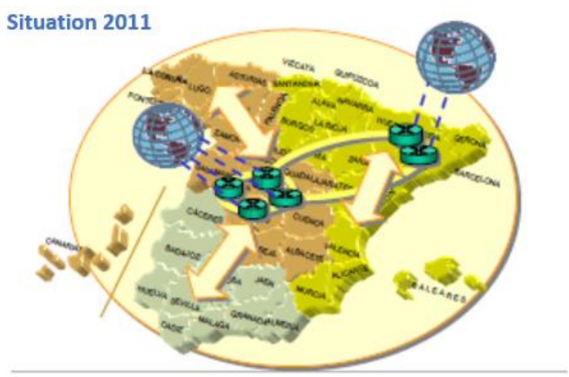


Fig.: Interconnections of the UNICA network year 2011. Telephone source

In transit, where Juniper took the lead in switching capacity with its generation of Juniper T1600 (1.6 Tbit/s) and T4000 (4 Tbit/s) Terarouters, a concentration of transit centers was carried out that allowed savings by optimization in the number of links and equipment. The operation to eliminate transit centres was a complex and risky process, which was ultimately carried out successfully.

The concentration and reduction of the number of access centers was another constant debate, almost from the beginning of the establishment of the network. The pressure to achieve savings in IP switching equipment by expanding the metro Ethernet network and reducing the IP footprint arose periodically, each time marking a more or less aggressive reduction of access centers. The concentration reference, set by the 23 centers of the IP network for IPTV, marked the highest degree of concentration that was proposed. This debate ended up being resolved towards the concept of maximum distribution of the MPLS IP network, which was expanded to the most remote nodes of the metro network. But this deserves its own account below.

2.5 Explosion of CDNs and their progressive capillarization

During the last decade of the twentieth century, the prominence of OTT video led to the explosion of CDNs from large video providers installed nationwide, in private or public colocation centers, where access operators, and Telefónica (through TWIS (Telefonica Wholesale International Services) in particular, began to interconnect directly to them. It is worth highlighting here the CDNs of Google, Facebook, Netflix, and Akamai as an aggregator of content from small and medium-sized providers. Telefónica de España's IP network was connected to Google in Madrid in 2012. The traffic served by direct connection to these CDNs soon surpassed that served by international IP (remote) interconnection in Spain.

Around 2015, Telefónica de España's IP network reached 1 Tbit/sec of maximum traffic per remote Internet interconnection.

By then, the traffic served from the CDNs installed in Spain and connected directly to Telefónica's IP network had far exceeded that Terabit/s of uncached traffic. Only Google's CDN in 2015 was interconnected at 1.27 Terabit/s to the Telefónica de España network, Akamai's CDN did so at 675 Gbit/s and Netflix's CDN, which, having just entered Spain, did so with 200 Gbit/s. All three already required expansion. In round numbers, in 2015 CDNs served 2 Terabit/s of traffic, compared to 1 Tbit/s served by classic IP interconnections.

Fig.: Installed interconnection capacity of Telefónica's IP network in Google, Akamai and Netflix CDNs in September 2015. Telephone Source.

The never-ending debate over the payment model between content and network operators began to take shape in favour of network operators, who began to receive some compensation for traffic delivered to customers of their networks nationwide. The political debate on net neutrality and the negotiating power of these giants has made these amounts minimal, from the point of view of network operators, who face large investments in the growth of accesses and networks, with revenues from their services in constant erosion.

The next move in the advancement of these CDNs, and their desired monetization by network operators, will be the interconnection of these in centers of the operators' own network, at a level and with capacities adapted to the demand for local traffic at all times.

2.6 A great project for the single grid

The word FUSION in Spain, in the context of ICTs (Information and Communication Technologies), is associated with Movistar and its fixed-mobile bundling offers that include fibre to the home. In the installation of fibre to the home, network operators' contractors make use of fibre fusion to connect homes to the network with sophisticated machines, given the level of precision required for this operation.

The engineers of Telefónica de España chose for their latest major IP network transformation project, the term FUSION, which in the network is associated with the combination of the metro ethernet network and the IP network to merge into a single network.

In 2007, Telefónica de España's strategic network plan had already set out the IP network architecture of the FUSION project, with an even greater degree of integration for access equipment, which included, in addition to the L3/L2 accesses of the fixed and mobile network for residential and business, the IP access function of the IPTV network.

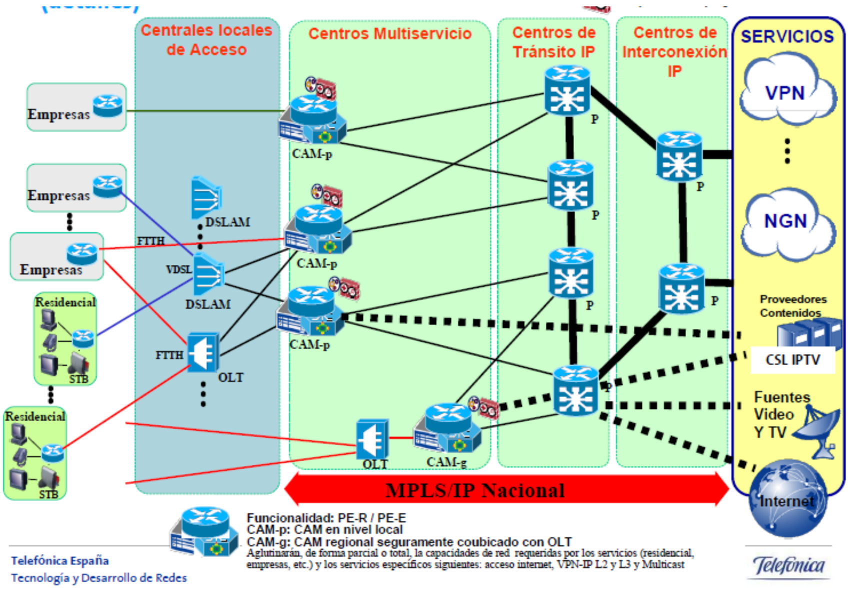


Fig.: Distributed IP network model in 2007. Telephone source

In 2017, with a very elaborate business case and a memorable purchase negotiation, the IP access distribution project was started. The FUSION project was awarded to two suppliers: Nokia, whose presence was very significant in the Metro Ethernet network, following the acquisition of Alcatel-Lucent; and Juniper, which has managed to take its IP solutions to the metropolitan level with this project.

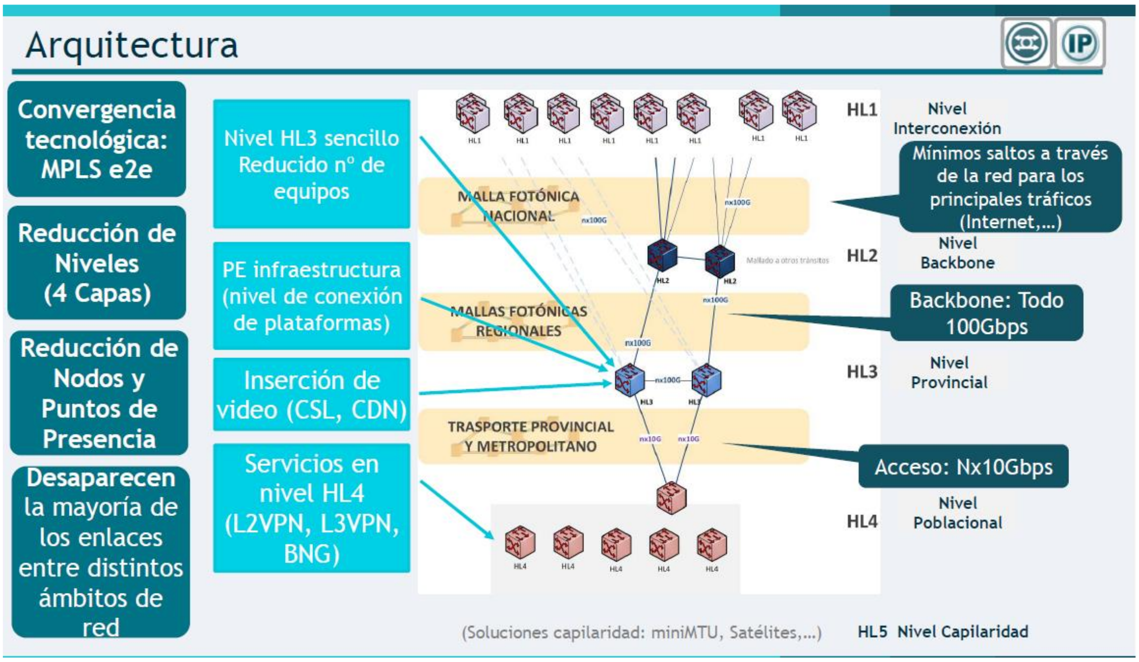


Fig. FUSION network architecture of Telefónica de España (2017). Telephone source

With the reduction in the number of layers and nodes, a significant reduction in the number of underlying optical transmission links was also achieved. The latter, structured in photonic meshes, with automatic signaling and restoration capabilities, using what is known as a GMPLS control plane, at the national, regional, and provincial or metropolitan levels.

In 2019, at the end of the first phase of the FUSION project, the increase in traffic demand that occurred in the period 2015/2019 was 250%, far exceeding the initial forecast.

With this distribution, the network has been simplified, provision automation has been gained, as it is not necessary to provision VLANS nested in the metro network, and very importantly**, IP and ethernet connectivity are available at 1 and 2 hops from the customer's equipment.** This enables an option for maximum capillarization of the CDNs, and for connection in general of content servers, which allows latencies of a few milliseconds in access to them. This architecture serves both fixed fibre access and broadband access based on 4G and especially 5G where the operator will enable shared and segmented Cloud environments, with the highest level of capillarity.

"The phase that begins now will focus on continuing to deepen this network virtualization but also on the automation, provision and maintenance of the service, as well as on adaptation to address new services (streaming, cloud computing, etc.). In fact, one of the pillars of this Fusion Network will be the high-level lines direct to digital content providers and cloud platforms, in order to improve the end-user experience when using these functionalities".

In the meantime, work continues on the introduction and use of the IPv6 protocol to overcome the well-known IPv4 addressing limitations. In 2023, Telefónica de España has enabled this protocol for mobile access terminals, which is a remarkable milestone in this global transformation effort that began in 1994 with the decision of the Internet engineering bodies to develop the new protocol. This confirms the complexity of replacing an infrastructure in a network of networks the size of the Internet, which has not prevented its growth, using non-optimal IPv4 address sharing solutions in the meantime.

3. The journey towards the quantum internet

3.1 From J.C.R. Licklider's galactic network (MIT) in 1962 to Benett and Brassard's quantum network in 1993[6]

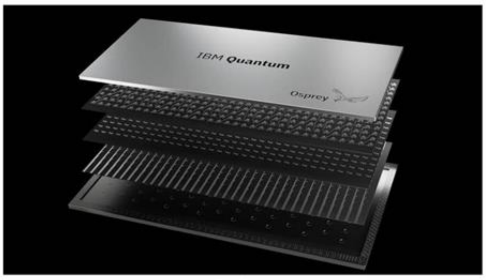
The Internet that has given rise to the revolution known to all, was "dreamed" for the first time in 1962 by J.C.R. Licklider (MIT) who coined the term galactic network to refer to "*a set of interconnected computers through which data and programs could be accessed anywhere*".


Joseph Licklider 1915-1990

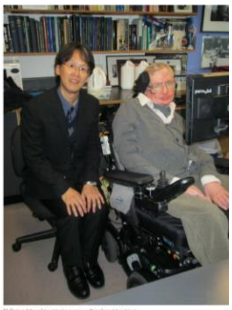
What is the next "dream" that another revolution like the one experienced with the Internet can bring?

In January 2023, articles appeared in the press that echoed the experimental success of energy transport instantaneously and without using cables or waves. Specifically, see article published in El Confidencial by Jesús Díaz (20/01/2023, updated 26/01/2023)

These are the experiments carried out by the Japanese **Kazuki Ikeda** on one of the quantum computers that IBM makes available to companies and educational institutions. From his labs at Stony Brook University, N.Y., Ikeda says he has managed to teleport energy using a pair of entangled quantum particles inside one of IBM's quantum chips.

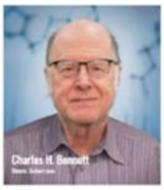


El chip cuántico IBM Osprey de 433 cubits. (IBM)


El físico Masahiro Hotta junto a Stephen Hawking

Ikeda wrote an algorithm for that machine following Hotta's theory, which states that "the measurement of a quantum system injects energy into the system and that this energy can be extracted from the same system at a different location without the energy having to traverse any distance or use a physical channel." The energy is always the same, teleporting without any loss or gain. It simply disappears in one place and appears in the other thanks to the fluctuations of quantum systems.

The possibility of **teleporting energy** without any distance limit was first formulated in 2010, when a team of Japanese scientists led by **Masahiro Hotta** published a scientific paper detailing the calculations that proved it.

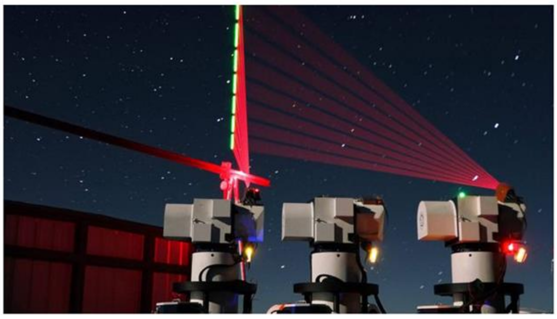


His work was based on the work that **Charlie Bennett** developed in 1993, when he demonstrated for the first time that **teleportation of information** at the quantum level was possible at IBM's Watson Research Center in New York.

[6] Figures and content from the article in the digital press: "They discover how to transport energy instantly without using cables or waves". Jesús Díaz, El Confidencial (20/01/2023).

Physicist **Masahiro Hotta** concluded that the fundamentals of that experiment, with information, could be applied to the teleportation of energy over unlimited distances and without reduction in the energy level, something that the Massachusetts Institute of Technology's Technology Review magazine described at the time as "a technique that would have profound consequences for the future of physics.

Instantaneous teleportation of information using quantum particles entangled over large distances has been possible for decades. The most notable experience was teleportation to 1,400 kilometers using the Micius satellite, part of the Chinese-European Quess program. That was the record for the longest distance ever achieved.



Parte del sistema Quess para la teleportación cuántica de información.

The power teleportation demonstration works in a similar way and will have no limitation on teleportation distance, at least according to the pending *peer-review study published on the Arxiv server.*

Ikeda says that "the realization of a long-range QET (quantum energy teleportation) will have important implications beyond the development of information and communication technology and quantum physics. Information and energy are physical, but they also have an economic dimension."

The latter is important: no one yet knows the implications that this discovery and the establishment of a quantum internet network may have. The network is expected to consolidate and become global in the 2030s, but no one can imagine what the consequences of this type of communications and transactions will be beyond achieving instantaneous communications that are impossible to intercept.

3.2 The Quantum Teleportation Race

But, despite not knowing the ramifications and applications of this new technology now in development, world powers are running a new race to dominate the sector, something that experts say is vital to achieve future global hegemony.

At the moment we know that China is in the lead, leaving the United States behind for now. The Chinese have been building such networks for years and, according to experts, their impressive progress in the last six years will have strategic consequences at the commercial and military levels. This is what Arthur Herman, historian, expert in quantum computing, artificial intelligence and director of the Quantum Alliance Initiative at the Hudson Institute, tells us.

Herman also says that, in the face of China's success, Europe has accelerated with three public-private initiatives aimed at establishing satellite-supported quantum communication networks. Surprisingly, the U.S. is right now out of this new technological race that they themselves started in 2003, when DARPA — the advanced research arm of the Pentagon that developed the Internet and GPS, among many other key technologies — launched the first quantum communication network. There is still a long way to go, but, if confirmed, this experiment would have accelerated one more in a race whose end is still unpredictable.

3.3 Onwards and Upwards

Whatever the next revolution, it has always been very difficult to predict what the future will bring without being wrong, it is clear that IP networks, linked to the Internet, have tended and continue to have a major development and growth that has exceeded what the most dreamers could imagine. They have also contributed to improving people's lives, as became so evident during the COVID pandemic. The use of communications, entertainment and remote work greatly mitigated the problems caused by forced isolation, and IP networks withstood with honor the great pull of traffic demand that occurred without degradation or loss of service.

As we celebrate the centenary of Telefónica's life, IP networks are still there, carrying the traffic of all services silently. Better if you don't talk about them much, because that usually happens when they stop working. Thanks to the very good professionals who continue to make them grow, optimally, at the frenetic pace of traffic growth, and to those who supervise and maintain them, so that they continue to offer those five nines in quality.

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