History of Ericsson's AXE 10 at REDT

Javier Barahona Bueno

1. The AXE-10 system, description and general characteristics

The AXE-10 digital switching system is an inseparable part of Telefónica's trajectory in providing its customers with state-of-the-art communication services. Before detailing the applications, milestones and impact that the AXE-10 had and has on Telefónica's network, it is interesting to make a brief description of the most relevant characteristics associated with its architecture.

1.1 Modularity

The basic principle behind AXE-10 is modularity, which can be defined as the "ability of a system to be scaled up or modified with minimal difficulty", which is the key to its continued development and a way to achieve an open system adaptable to the demands of the future. Modularity implies easy handling and adaptability to all the demands of the market and its evolution.

The modularity in AXE-10 is materialized at different levels to provide its basic quality

- **Multi-functionality**: Multi-functionality means that the same AXE-10 system can be used in all applications, from small local nodes to large international switching centers. Commercial communications services provided to customers of any of the networks (RTB, ISDN, multi-generation mobiles) are supported in rural, urban, suburban and metropolitan areas.

The different levels at which the modularity of AXE-10 materializes are:

- **Hardware Modularity**: refers to the AXE-10's assembly system, consisting of hardware, which is designed in modular units that offer a high degree of flexibility for installation and/or expansion, or reorganization.
- **Software modularity**: AXE-10 is built as a set of independent blocks (known as function blocks), each of which performs a specific function and communicates with each other using defined signals and interfaces. Function blocks can be added, deleted, or modified completely independently.
- **Functional modularity**: The various components are defined in terms of the functions they perform. This means that functions can be added, removed, or modified without altering other parts of the system.
- **Application modularity**: Modularity makes it easy to introduce different network service applications on the same node.

The levels of modularity described underpin the multifunctionality of AXE-10 by providing the necessary technological flexibility to offer new services, technologies and functionalities in accordance with the evolution of markets and user demands.

1.2 Compliance with network operator requirements

AXE-10 responds to the needs of network operators in a competitive environment by providing complete network solutions tailored to the profiles and conditions of the services that operators provide to their customers.

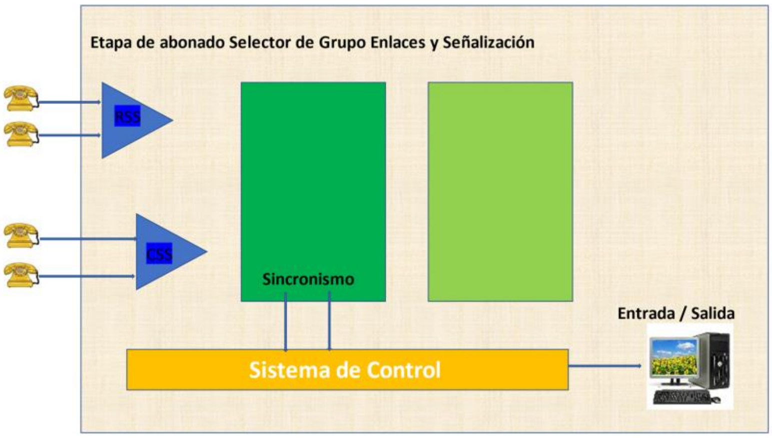
The main features of AXE-10 for network operators are:

- Network nodes that can be controlled locally or centrally via data communication links
- A set of features that provide an open interface for advanced network management systems completely tailored to the needs of network operators
- A network operator support structure built around a global response center (GRC) that provides expert support 24 hours a day globally
- Advanced hardware developments including reduced footprint required, lower power consumption, and increased electromagnetic compatibility (EMC) protection
- Performance at critical service levels, i.e., 99.999% availability

1.3 Architecture of the AXE-10 as a communications node

The AXE-10 architecture that implements a communications node, such as a local exchange (CL), consists of four main parts: (See figure below)

- Switching, which includes a line switching stage and a line group switching stage
- Linking and signalling stage
- Synchronization
- Control system (including an input/output or I/O system)



i. Commutation

Line Switching Stage

The line switching stage performs functions such as power supply to connected utility customer lines, analog-to-digital conversion (for Basic Telephone Network (RTB) customers), signal exchange (signaling), local line interconnection, and line concentration to the line group switching stage.

The line switching stage is constructed from a series of modular units, each of which provides a certain line connection capability. Subscriber lines terminate in RSS (unit located relatively far from the local exchange, remote unit) or CSS (unit located in the exchange itself) and both units concentrate the service towards the switching stage of line groups. Communication service concentration involves allocating a certain number of output circuits (towards the line group switching stage) to a larger number of incoming circuits (user lines of communication services). The dimensioning of the concentration stage of the communication service is based on traffic theory and ensures that the service is provided in accordance with the criteria of the network operator.

The switching is fully digital, incorporating digital input and output lines that employ pulse-coded modulation (MIC) or PCM.

Line Group Switching Stage

Establishes, monitors, and disconnects service connections between groups of lines that access different line-switching stages or other nodes in the network. The switching function involves the interconnection of incoming time slots (e.g., those channels on the MIC line from the line switching stage) with outgoing time slots (e.g., those channels on a MIC line connected to another node in the network) for the transfer of voice or data information.

The switching is again fully digital, but in contrast to the line switching stage, the line group switching stage does not perform any concentration and is configured in such a way that all line groups can be connected to each other simultaneously (non-blocking configuration). The line group switching stage has a fully modular design with a wide variety of configurations to meet different sizing requirements according to the service provision criteria of network operators.

ii. Links & Signage

Links are the lines of communication that interconnect the AXE-10 node with other nodes in the network to provide the various communication services between distant users. The control of the establishment, supervision and disconnection of the different services on these lines involves the exchange of information between the different components of the network.

The linking and signaling stage interconnects the AXE-10 node with other nodes in the network for the exchange of signaling messages and the exchange of voice or data information

MIC lines coming from other nodes in the network directly access the line group switching stage. Depending on their behavior on each established connection, the corresponding channels of the MIC line can be considered as outbound or inbound to or from the distant network node to which the MIC line is physically connected.

iii. Synchronization

Both MIC lines and all digital switches require synchronization for proper operation. It follows that the entire network of communication nodes needs to be synchronized in its entirety. Precise clock pulses define at every moment when a certain channel begins in an MIC sequence and when a certain stored voice information should be read and written. These pulses are provided on the AXE-10 by three high-precision clock modules that allow them to be synchronized from external sources in accordance with the operators' network synchronization strategy.

iv. Control System

Control of the AXE-10 system is provided by a powerful distributed processing structure. This structure involves a central processor (CP) that performs complex decision-making tasks in real time, and a series of distributed processors that perform less complex, more repetitive tasks, but with real-time response.

The central processor is made up of two replicas configured in high redundancy that execute exactly the same sequence of instructions moment by moment. This configuration provides a scenario tolerant to failures of various kinds, both hardware and software, as well as enabling the extraction of information that can contribute to the identification of such failures.

Distributed processors are usually replicated themselves, but in a master/slave configuration that allows control in various failure situations. The criterion is again to sustain a fault-tolerant scenario while making it possible to extract information relevant to its identification.

The connection between the central and distributed processors is made by high-capacity buses.

v. Input/Output (I/O) System

The I/O system is part of the control system and provides support for human-machine communications at the AXE-10 node. The I/O system provides connections for digital terminals (such as personal computers) and for archival devices (such as hard drives).

It acts as an interface to:

- Operation and maintenance personnel involved in connecting users, locating faults, recording traffic statistics and managing the network.
- External systems, including billing centers and operation and maintenance centers (O&M's)

2. What did the AXE-10 system mean for Telefónica's Telecommunications? 80's. The Beginning of Digitalization

2.1 AXE-10 Enters the Scene, First Installation

The development of the AXE-10 comes from an earlier decade, the 1970s, from a joint effort carried out by Ericsson and Televerket, the Swedish state operator, through a joint venture called Ellemtel. The end of 1976 was set as the target date for the development of a pilot team, which was carried out in the Swedish town of Södertälje, located 30 kilometres south of the capital Stockholm, although it still had some analogue modules. The first commercial AXE-10 plant was opened in Turku, Finland in 1978

In January 1978 a mixed team of engineers from Telefónica and Intelsa was formed to carry out the necessary software developments in the AXE-10 to implement the various signalling existing at that time in the Telefónica network in Spanish, such as the rotary systems, the Spanish Multifrequency and other special services of the 0XY type.

This made it possible for the AXE-10 system to interconnect with the various types of nodes in the network. These software developments were carried out at Ericsson's headquarters in Stockholm throughout 1978. Subsequently, in Madrid, the integration and homologation of the System continued in models and the first installation in Atocha

Therefore, the arrival of the AXE-10 in Spain did not take place until 1980 when the Madrid-Atocha power station was installed, with 10,000 lines. That same year, orders were received for another 50,000 urban lines and 8,000 transit equivalents.

But it would not be until 1982 when the new system had the opportunity to demonstrate its capacity, performance and versatility, to become a very relevant player in the digitalization process of Telefónica's network.

> *"At 3:30 a.m. on Sunday, April 18, 1982, a piece of news shook all of Spain. The terrorist organization ETA, in a carefully planned action, had blown up part of the CTNE communications center located on Madrid's Calle de Ríos Rosas.*
>
> *Telefónica estimated the damage caused by the explosion of six plastic charge bombs at one billion pesetas, with a total of close to 170 kilograms of Goma 2, The importance of the exchange and the enormous destructive power of the explosions meant that services were affected at a national level, since the building brought together telephone exchanges for national and international traffic".*

After carefully assessing the damage, considering and reconsidering the real possibilities, Intelsa (a company created in 1970 and owned by Telefónica and Ericsson) in order to solve the problem quickly and efficiently, presented a proposal two days after the attack that guaranteed that a central of its AXE-10 system would be operational in the facilities that the CTNE owned in the Madrid neighborhood of Atocha within a month. This exchange would be able to take over the telephone traffic that had been impeded after the attack.

Within the promised timeframe, the exchange was functioning perfectly, resolving the serious anomalies of telephone traffic on an interprovincial scale. The new power plant, belonging to the AXE 10 system, was entirely electronic and could be considered one of the largest operating plants in the Spanish interurban network. With 5,776 links and a capacity of up to 60,000 calls/hour.

This sad chapter in the history of our country led to the consolidation of the AXE-10 switching system in Spain, becoming a key pillar of the digitalisation of the Spanish Telephone Network.

2.2 Reduction of the waiting list and universalization of the service

In 1986, the delivery of the first RSS remote selector, dependent on the AXE exchange of Zaragoza-Santa Isabel and installed in Montañana, with capacity for 2,048 subscribers, was the first step in the Spanish rural communications plan. With this delivery, the telephone switched network began its expansion in homogeneity and capacity to provide advanced services nationwide.

As described in the architecture section, AXE-10 incorporates the remote subscriber stage that allows for a significant reduction in the length of the subscriber loop (copper pair), while allowing for the design of a more efficient access network by sharing switching functions, at the level of line groups, signalling and links. central processor, synchronism, and input/output organs. With the addition of RSS, the switching functionality is distributed from the local exchange to the remote node. The RSS feed is connected to the local exchange via 2,048 Mbps links. Although physically separated from the local exchange, the RSS is under the total control of the latter, being an integral part of it, bringing all the functions and services of the AXE-10 local exchange closer to the remote user. It is important to note that connections between two users connected to the same RSS feed are made within the RSS, not requiring connection resources to the local node.

The reduction of the length of the subscriber loop will have a great relevance in the coming years in the deployment of both the Digital Integrated Service Network (ISDN) and xDSL technologies, where the length of the loop is a key factor to be able to provide services with a quality adapted to the criteria of network operators.

2.3 First international AXE power plant

The reliability, robustness and flexibility that the AXE-10 system demonstrated on a daily basis helped Intelsa to be awarded the international digital exchange in Madrid-Alcobendas, which would be delivered in 1988 with a capacity of 40,000 links.

For the first time in Spain, this plant incorporated a common channel signalling system. More specifically, the PUT application (User Part for Telephony Services).

Until the arrival of the Madrid-Alcobendas power plant, all the existing signalling at the switching nodes was by associated channel and required the incorporation of analogue components for the transmission of control signals through the voice channel (in-band signalling). Information between exchanges and users, and between the exchanges themselves, was carried out through the exchange of decadic pulses (the original dial discs) or as a combination of tones of different frequencies (DTMF).

Common channel signalling systems were designed for both analogue and digital networks. In 1980, the CCITT specified a common channel signalling system called No.7 (SS No.7), which was deployed at the Alcobendas plant.

In signalling system No.7, information between exchanges in the network is transferred as data packets. The data packets are composed of general information, such as flags and checksums, and of the information of interest, signaling in this case, it is sent in 10 to 15 octets that make up the so-called signal information field (SIF) in the so-called signal message units (MSUs).

2.4 New Supplementary Services Offering

The digitalization of the Basic Telephone Network (RTB) also brought with it a wide range of services to stimulate the use of the network and increase the revenues of its operators.

AXE-10 provides a full range of services, including core services and call management services. The basic RTB services incorporate the basic telephony service for voice and data transmission and include some complementary services such as abbreviated dialing or calls to fixed destinations.

RTB call management services offer the end user greater control and convenience in using their phone. Services include:

- Remote control of ancillary services, which allows end users to control a service even when they are away from their home or office.
- Distinctive Alerts service, which allows you to assign multiple directory numbers, each with its own distinctive signal, to a single line.
- Keyword switching, which allows end users to choose and change keywords if they have chosen to use one to control RTB add-on services.
- Call restriction services, which allow end users to control what types of outbound calls can be made.
- Call forwarding services, which allow end users to route incoming calls to another location.
- Three-party service, which allows an end user to invite a third party to participate in an ongoing call without having to make multiple separate calls.

3. What did the AXE system mean in Telecommunications at Telefónica? 90's. The Decade of Services

The end of the 1980s saw a great deal of activity throughout the country, especially in the field of telecommunications. In preparation for the major events of 1992, the telephone network was considerably improved, eliminating obsolete stretches and waiting lists. The Seville Expo, the Barcelona Olympic Games and Madrid's cultural capital demanded the delivery of telephone lines and exchanges for the fixed network, with multiple new services.

3.1 ISDN

In 1992, coinciding with the Universal Exhibition in Seville and the Olympic Games in Barcelona, Telefónica commercially launched the Digital Integrated Services Network (ISDN).

Ericsson contributed to Telefonica's ISDN offering with its AXE-10 switching system. The previous versions deployed in the nodes of the network during the 1980s were incorporated with the new functionalities offered by the new set of services and facilities provided by ISDN in accordance with the service criteria that Telefónica had offered commercially to its customers.

i. Built-in functionality with ISDN (Integrated Services Digital Network)

ISDN introduced two main functionalities:

The digital subscriber signalling system known as DSS1 (based on the first three layers of the Open Systems Interconnection Reference Model, OSI) in its two implementations:

- Basic Access, also referred to as 2B+D, is the interface defined for residential or small business customers. The physical connection is made using twisted-pair copper cables to connect and transmit data to the network. The entire operation operates in full-duplex mode, providing simultaneous data transmission in both directions. It consists of two carrier channels (B) at 64 kbit/s and an additional channel (D, delta channel) at 16 kbit/s. The B channels are used for voice and user data and the D channel combines connection and service management and low-speed data packets.
- Primary Access, also called 30B+D, is the interface defined for business clients or the connection of digital switchboards. The physical connection is made by pairs of cables, or by means of coaxial cable. Digital transmission is carried out using MIC technology. It consists of thirty B channels and one D channel. It makes it possible to establish thirty simultaneous digital communications through B channels. The bit rate of channels B and D is 64 Kbit/

And a new implementation of the Common Channel Signalling System No. 7 that incorporated capabilities to support the services offered by ISDN.

- **PUSI** (User Party for Integrated Services), a signalling protocol between exchanges, necessary to ensure the end-to-end operation of ISDN applications, subsequently also used in the deployment of mobile networks.

ii. Built-in functionality with ISDN (Integrated Services Digital Network)

ISDN with the digitization of the access interface provides:

- Simultaneous connection. Two or more simultaneous connections on the same line are allowed.
- Shorter connection establishment times than systems based on analogue technologies.
- More reliable connection and higher and more symmetrical data transmission speed.
- Noise, echoes, crosstalk, and other types of distortion that plagued analog transmission are eliminated.
- Users can use multiple devices such as computers, phones, faxes, and so on the same line
- Multiple digital services. It allows multiple services to be transported over the same copper pair, such as data files, voice, fax, Internet web pages.

iii. Carrier Services

- Telephony at 7 kHz
- Facsimile groups 2 and 3 facsimile group 4
- Teletext, videotext, videotelephony

iv. Supplementary Services

- Closed group of users.
- Identification of the calling user.
- Restriction of the identification of the calling user.
- Logged-in user ID.
- Restriction of logged-in user identification.
- Call waiting ID.
- Direct dialing of extensions.
- Multiple subscriber numbers.
- Abbreviated dialing.
- Three-way conference.
- Call forwarding.
- Call transfer within the passive bus.

- Pricing information.

3.2 GSM mobile telephony

Although Intelsa introduced the NMT-450 (Nordic Mobile Telephony) system in Spain in 1982, it would not be until the following decade with the arrival of GSM when the explosion of Mobile Telephony would take place, as previously it was only envisioned for a minority use of customers.

> *"In July 1995, Telefónica Móviles began marketing the GSM service, with the license that the Government had assigned it months before. This goes from an analogue technology (TMA) to a digital one, with a large number of novelties and which was called 2nd Generation (2G)".*

The GSM system was born from the consensus of a working group, called Groupe Special Mobile (GSM) created by the European Postal and Telecommunications Conference (CEPT).

The work to define this standard culminated in 1991, with a memorandum of understanding signed by the telecommunications operators of 13 countries in Copenhagen, including Spain and Telefónica, with the purpose of being implemented in the signatory countries.

Over time, this system became a global standard that, while retaining the acronym GSM, was renamed the Global System for Mobile communications.

AXE-10 played an important role in the deployment of Telefónica's GSM network.

i. Components of Mobile Networks

The main components of a cellular mobile network are:

Base Station **(BE),** which is where the mobile device connects using radio technologies to communicate with the cellular network of mobile services. The EB manages a certain geographical area called a cell.

Mobile Service Switching Center **(MSC),** which is the control component of the cellular network. The MSC's functions include switching, signalling, billing and interworking with other networks. The MSC also provides the interface to databases that store information about users, their devices, and their services.

Databases, **(DB).** They store information such as the current location of a mobile device, its services, etc. The databases are continuously updated as the mobile device moves through the network with worldwide coverage. Mobile cellular network databases are embodied in Base Location Records **(HLRs).**

Operation and Maintenance Center **(OMC),** which allows the network operator to monitor and control the network from a central location.

ii. Mobile phone basics include

Roaming, which is the movement of a mobile device that is not being used when moving from one cell to another.

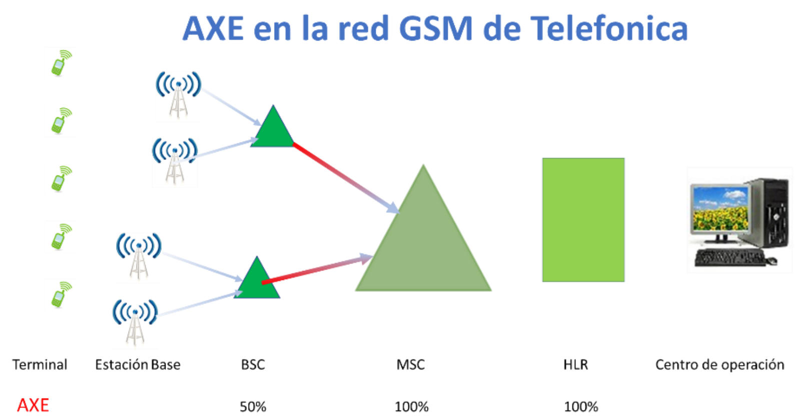
Handover, which is the change of a connection to a new radio channel on another base station, as the device moves between cells while a connection is in progress.

Location logging, which is the process by which a mobile device transmits its current location to network databases. A mobile device sends a location update message to databases every time it changes cells on the mobile service network.

Paging, which is the process by which the mobile service network informs a device of an incoming connection request. The MSC instructs all base stations within the last known location to transmit a search message to the mobile device.

iii. AXE-10 on Telefonica's GSM network

The reference implementation of the GSM architecture incorporates a new network element, the Base Station Controller (BSC). The figure below shows the proportion of AXE technology in Telefónica's network.



3.3 Smart Grid Services

A smart grid is "a communications network controlled by a software services layer that allows new services to be developed without the need to modify the network's switching nodes." In the smart network environment, voice calls arriving at a public network switching node are suspended while the switching node requests instructions from an associated computer system on what to do with the call.

A smart grid enables the rapid creation and delivery of advanced ancillary services for customers over fixed and mobile networks.

The AXE-10 also played an important role in the deployment of new services, either due to the demand of the business itself, or due to new regulatory requirements such as the entry into force of the new 9-digit numbering plan, or number portability.

i. New 9-digit numbering plan

The new numbering plan came into force in Spain on 4 April 1998. It refers exclusively to phone numbers and is defined as a closed 9-digit plan. This plan complies with the requirements described in Recommendation E.164 of the International Telecommunication Union (ITU).

The international format of telephone numbers, in the case of Spain, includes the national destination code (NDC) inserted in the subscriber number (SN). ITU awarded Spain country code 34.

ii. Smart Grid Numbering

Smart grid numbering, unlike geographic numbering, is not tied to a specific location. With smart grid numbering, a national prefix is used, since the company can be located in any city in Spain. This type of numbering is usually used in companies of different kinds, whether for customer service, telesales or other services.

Types of Smart Numbering:

- 900 – Automatic charge: the cost of the call is paid by the user who receives it, and it is free of charge for the user who makes it.
- 901 – Shared payment: With this type of numbering, the cost is shared between the caller and the person receiving the call.
- 902 – Payment by the caller: The cost of the call is paid by the user making the call, with the user receiving the call being paid in most cases.

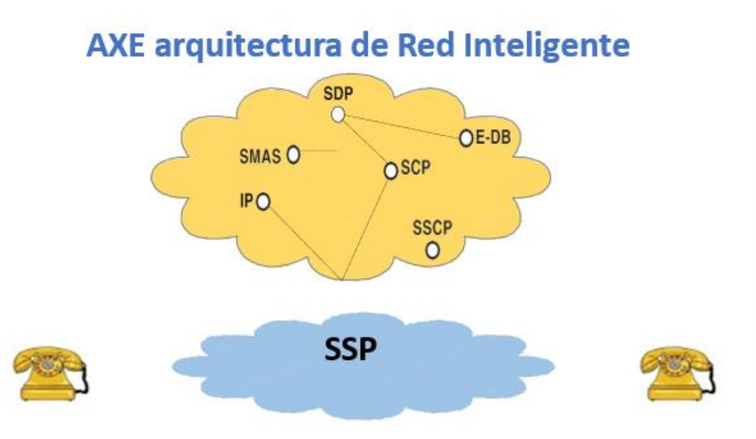
iii. Number portability service

Number portability, telephone portability or mobile portability is a right that all customers of fixed or mobile telecommunications services have, to change from one telephone company to another, keeping the same telephone number.

With the entry into force of number portability, it usually takes a maximum of 24 hours from the date of submission of the application.

iv. Ericsson Smart Grid Architecture

The figure below shows Ericsson's implementation in the AXE-10 for Smart Grid services.



3.4 What did the AXE system mean in Telecommunications at Telefónica? First decade of the 21st century. The decade of consolidation.

The first decade of the 21st century could be called the decade of consolidation for AXE-10 technology.

i. National Supervision and Operation Center (CNSO)

The installation and commissioning of the CNSO in 2002 marked a major milestone both in the change in Telefónica's Operation and Maintenance (O+M) management model, and in the change of orientation of its organization towards the global vision of Services and Customers. The CNSO was developed adapted to the TMN (Telecommunication Management Network) model

The Centre has Communications Systems based on specific management networks that allow all the information from the Digital Switching Centres, Transport Networks, IP and ATM Networks, Power and Air Conditioning Plant, Submarine and Satellite Communication Plant and TV Services to be transported to the centre where it will be processed.

The AXE-10, as explained in the introductory chapter, has an input/output system, known in this decade as IOG 20, which allowed the integration of all the AXE-10 nodes installed in the Telefónica network, in its different variants, fixed, mobile, service nodes, etc., with the newly created CNSO

The IOG-20 performs data handling tasks such as printouts, commands, alarms, statistics, and data for loading and secure storage of information on magnetic media, which can be on hard disk, optical disk and floppy disk.

ii. Third generation of mobiles, 3G

The growth and exponential demand for mobile telephony led to a considerable increase in AXE-10 deployments due to its flexibility, configuration capabilities, adaptation to service requirements and quality of service, as well as due to the relevance that this technology had, and continues to have, within Telefónica's mobile network.

Additionally, the arrival of the third generation of cellular technologies (3G) meant a greater consolidation of this technology, because although it is true that the base station controller nodes (BSC) and the base stations themselves (BSS) incorporated new platforms, both the switching part of the service (MSC) and the databases and authentication registers, continued to be maintained entirely on the AXE-10 platforms.

iii. In real estate

In 2002, the company that Telefónica created in 1998 to manage its real estate assets, Inmobiliaria Telefónica, took over two ambitious plans for the operator: the sale of buildings and the management of the City of Communications, Telefónica's new headquarters on the outskirts of Madrid.

Ericsson, and more specifically the AXE-10, played an important role in the real estate efficiency project with a participation of around 40%, in the installation of new fixed network power plants, which using the new BYB 501 mechanics contributed significantly to reducing the need for space and energy consumption.

In mid-2004, Telefónica closed its plan to sell real estate assets launched in 2002. The company managed to divest more than 300 buildings from its real estate assets.

3.5 What did the AXE system mean in Telecommunications at Telefónica? First decade of the 21st century. The Decade of Consolidation

The second decade of the 21st century could be called the decade of the beginning of the substitution of traditional circuit-switching technology and therefore of the AXE-10

In 2015, Telefónica started the FARO project, whose main objective is to definitively shut down its copper network in the country by the year of its centenary in 2024, and replace all fixed broadband accesses with fibre. The plan is already well advanced and the number of plants that have been shut down since the beginning of the plan has risen to 2,200.

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