Titulo:	The Strategies Associated with The Migration of Networks to 4G
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The networks need to provide higher speeds than those offered today. For it, considering that in the spectrum radio technologies is the scarcest resource in the development of these technologies and the new developments is essential to maximize the performance of bits per hertz transmitted. Long Term Evolution optimize spectral efficiency modulations with new air interface, and more advanced algorithms radius. These capabilities is the fact that LTE is an IP-based technology that enables end-to-end offer high transmission rates per user and very low latency, ie delay in the response times of the network around only 10 milliseconds, so you can offer any real-time application.

LTE is the latest standard in mobile network technology and 3GPP ensure competitiveness in the future, may be considered a technology bridge between 3G networks - current 3.5G and future 4G networks, which are expected to reach speeds of up to 1G .

LTE operators provide a simplified architecture but both robust, supporting services on IP technology. The objectives to be achieved through its implementation are ambitious, first users have a wide range of added services like capabilities that currently enjoys with residential broadband access at competitive prices, while the operator will have a network fully IP-based environment, reducing the complexity and cost of the same, which will give operators the opportunity to migrate to LTE directly.

A major advantage of LTE is its ability to fuse with existing networks, ensuring interconnection with the same, increasing his current coverage and allowing a data connection established by a user in the environment continue when fade the coverage LTE. Moreover, the operator has the advantage of deploying network gradually, starting initially at areas of high demand for broadband services and expand progressively in line with this.

Las redes necesitar proporcionar velocidades mayores a las ofertadas a día de hoy. Para ello, teniendo en cuenta que en tecnologías radio el espectro es el recurso más escaso, en la evolución de estas tecnologías y en los nuevos desarrollos es esencial maximizar el rendimiento de bits por hercio transmitido. Long Term Evolution optimiza la eficiencia espectral con nuevas modulaciones en la interfaz aire, así como los algoritmos radio más avanzado. A estas capacidades se suma el hecho de que LTE es una tecnología basada en IP de extremo a extremo que permite ofrecer altas velocidades de transmisión por usuario y latencias muy bajas, es decir, retardos en los tiempos de respuesta de la red en torno a sólo 10 milisegundos, por lo que permite ofrecer cualquier tipo de aplicación en tiempo real.

LTE es el último estándar en tecnología de redes móviles y asegurará la competitividad de 3GPP en el futuro, pudiendo ser considerada una tecnología puente entre las redes 3G – 3.5G actuales y las futuras redes 4G, de las que se esperan alcanzar velocidades de hasta 1G.

LTE proporcionará a las operadoras una arquitectura simplificada pero robusta a la vez, soportando servicios sobre tecnología IP. Los objetivos que se persiguen con su implantación son ambiciosos, por una parte los usuarios dispondrá de una amplia oferta de servicios añadido con capacidades similares a las que disfruta actualmente con accesos a banda ancha residencial y a precios competitivos, mientras que el operador dispondrá de una red basada en entorno totalmente IP, reduciendo la complejidad y el costo de la misma, lo que dará a las operadoras la oportunidad de migrar a LTE directamente.

Una gran ventaja de LTE es su capacidad para fusionarse con las redes existentes, asegurando la interconexión con las mismas, aumentando su actual cobertura y permitiendo que una conexión de datos establecida por un usuario en el entorno LTE continúe cuando la cobertura LTE se desvanezca. Por otra parte el operador tiene la ventaja de desplegar la red LTE de forma gradual, comenzando inicialmente por las áreas de gran demanda de servicios de banda ancha y ampliarla progresivamente en función de ésta.

INDEX

Glossary

- 3GPP: 3rd Generation Partnership Project
- 3GPP2: 3rd Generation Partnership Project 2
- ARIB: Association of Radio Industries and Businesses
- ATIS: Alliance for Telecommunication Industry Solutions
- CCSA: China Communications Standards Association
- CDMA: Code Division Multiple Access
- CDMA2000: Code Division Multiple Access 2000
- EDGE: Enhanced Data Rates for GSM Evolution
- E-UTRAN: evolved Universal Terrestrial Radio Access Network
- ETSI: European Telecommunications Standards Institute
- EV-DO: Evolved Data Optimized
- FDD: Frequency Division Duplex
- FRAMES: Future Radio Wideband Multiple Access System
- GPRS: General Packet Radio Services
- GSM: Global System for Mobile communication
- HARQ: Hybrid Automatic Repeat-reQuest
- HSPA: High Speed Packet Access
- HSDPA: High Speed Downlink Packet Access
- HSUPA: High Speed Uplink Packet Access
- HSS: Home Subscriber Server
- IEEE: Institute of Electrical and Electronics Engineers
- IPTV: Internet Protocol Television
- LTE: Long Term Evolution
- MBMS: Multimedia Broadcast Multicast Service
- MBSFN: Multicast-Broadcast Single-Frecuency Network
- MIMO: Multiple Input Multiple Output
- MME: Mobility Management Entity
- NGMN: Next Generation Mobile Networks
- OFDM: Orthogonal Frequency Division Multiplexing
- PAPR: Peak to Average Power Ratio

- PCI: Peripheral Component Interconnect
- PCRF: Policing and Charging Rules Function
- PDSN: Packet Data Serving Node
- PDC: Personal Digital Cellular
- PS: Packet Switched
- QoS: Quality of Service
- QAM: Quadrature Amplitude Modulation
- QPSK: Quadrature Phase-Shift Keying
- RAN: Radio Access Network
- RTT: RadioTransmission Technology
- SAE: System Architecture Evolution
- SC-FDMA: Single Carrier Frequency Division Multiple Access
- SGSN: Serving GPRS Support Node
- TDD: Time Division Duplex
- TDMA: Time Division Multiple Access
- TIA: Telecommunications Industry Association
- TTA: Telecommunications Technology Association
- TTC: Telecommunication Technology Committee
- TTI: Transmission Time Interval
- UMB: Ultra Mobile Broadband
- UMTS: Universal Mobile Telecommunications System
- UTRA: Universal Terrestrial Radio Access
- UTRAN: Universal Terrestrial Radio Access Network
- WCDMA: Wideband Code Division Multiple Access
- WLAN: Wireless Local Area Network

Summary

This thesis exposes the broad theoretical study of the new wireless technology called LTE. First of all, it should be mentioned that this third generation technology is being implemented gradually in our country, sodevelopment of this work is focused to show the most important featuresof this technology, considering its main advantages and disadvantages.

LTE is the latest standard in wireless networking technology and ensure competitiveness in the future 3GPP and may be considered a technology bridge between the existing 3G/3.5G networks and future 4G networks, which are expected to reach speeds of up to 1 Gbps. Will provide operators with a simplified but robust architecture at a time, supporting IP technology services, as this kind of applications are those that dominate the wireless telecommunications market.

Its main objective is to provide a mobile system able to achieve data transfer rate of 100 Mbps downlink and 50 Mbps uplink. LTE operates in frequencies with variable bandwidths to 20 MHz. Will also provide low latency in order to reduce access times to a service and network response to your request. In addition to these technical improvements, the economic aspect is also important in the development of LTE, including costs of deployment and commissioning as well as migration to LTE UMTS stations.

The coexistence and cooperation of technologies such as GSM / GPRS is also an important requirement. LTE implies not only the radio network if not also to the network core, for this the working group called SAE, try to find the optimal solution of network capable of supporting these changes. LTE uses new delivery methods and models that have been completely renovated to achieve an architecture less complex than existing UMTS.

Introduction

Telecommunication systems of second generation such as the Global System for Mobile Communication (GSM), allowed wireless voice traffic. Currently the number of mobile phones exceeds the number of fixed telephone and mobile phone penetration nears 100% in several markets. This explosive growth in the number of mobile phone users, joined the state of the art suggests a strong demand for mobile broadband applications, such as, the Internet navigation of high speed, sending and receiving e-mail, the mobile TV, fast downloading of multimedia content or interactive games. Satisfy that demand, getting the services attractive to the user while allow operators to reduce the operating expenses primarily requires continue progress in the development of today's mobile networks.

Is how has come to a constant evolution of mobile broadband, and the way it has been deployed technologies like GSM, GPRS, EDGE, WCDMA (UMTS), HSPA and LTE is currently waiting in with regard to 3GPP technologies. The long term evolution of UTRAN (Universal Terrestrial Radio Access Network - Network of Universal Terrestrial Radio Access) is a technology developed for packet radio access optimized high-speed data and low latency for also support voice services.

The aim this thesis is covering mainly the development of a theoretical study on the technical and commercial LTE, based in updated publications. Analyzing the structure necessary for the deployment of LTE networks which is based on the System Architecture Evolution (SAE - System Architecture Evolution), which allows evolution to All-IP network and supports the continuity of service and mobility between networks heterogeneous access. LTE is also assessed with other technologies to demonstrate the advantages to them and investigated medium access techniques and modulation, all in order to provide clear content, accurate and conceptually complete.

Objectives

GENERAL OBJECTIVES

- Develop a theoretical investigation of the characteristics of the new wireless technology for wireless broadband called LTE (Long Term Evolution).
- To study the feasibility of implementing this wireless technology in the field of telecommunications and wireless service.

SPECIFIC OBJECTIVES

- Analysing the structure necessary for the deployment of LTE wireless networks.
- Investigate modulation techniques present in this technology.
- Assess LTE compared with other similar technologies, analyzing in most technical and general aspects.
- Analyze the potential technical and economic implications, in conjunction with the development, which could happen by the implementation of this technology within the domestic market.
- Identify the advantages and disadvantages considering the features developed.

Chapter 1

3G Evolution

In this first chapter presents a review of the evolution of cellular networks delving on concepts related to the Third Generation Mobile Telecommunications (3G) and migratory routes towards the same. In order to achieve a prior knowledge to the study being conducted in the following chapters.

1.1 Background.

Since the first experimental activities with the radio communication in 1890, the paththat has advanced mobile radio communication has been quite extensive. To understand the complexities that have the 3G mobile communication systems today, it'simportant to know as they appeared, as well as evaluating the evolution of cellular systems, from an expensive technology to a few individuals, a communication systemphone used by almost half the world's population.

The development of mobile technologies has also changed, from a national or regional interest, to become a global task undertaken by standards developing organizationssuch as the Third Generation Partnership Project (3GPP).

Cellular technologies specified by the 3GPP are more developed in world, with a number of users exceeds 2 billion in 2006. The latest study developed in 3GPP, is an evolution of 3G radio access referred to the long-term evolution (LTE) and the evolution of packet core network access (SAE).

1.1.1 Before 3G.

It all started decades ago with the deployment of analog cellular services. In the U.S. Federal Communications Commission (FCC) approved the first commercial telephone self-service office in 1946, operated by AT & T. In 1947 AT & T also introduced a concept of frequency reuse cellular radio, which became fundamental to all mobile communication systems[22].

The first steps on the way communications were dominated by telephone monopoly, which developed because of the high absorption of subscribers, which resulted in the use of mobile communications to become an international concern, inviting industry to participate in the process.

The first international mobile communication system is the analogue NMT system (Nordic Mobile Telephony) which was introduced in the Nordic countries in 1981 while in North America was introduced analog AMPS (Advanced Mobile PhoneSystem). Other analog cellular technologies were deployed around the world, such as TACS (Total Access Communication System) and J-TACS (Japanese Total Access Communication System).All of them had an equipment of similar characteristics, with a quality of deficient sound, existing the Crosstalk between the users, which was a common problem, including in addition that it was of great size and very little aesthetic. With an international system, as NMT arrived the concept from roaming or itinerancia, also giving services for users who travel outside the local area of their operator. This originated a ampler market for the telephony, thus catching to more companies in the area of the movable communications.

The analogical cellular systems leaned in the “Traditional Telephone Service or Basic telephony”, being this one of great importance in relation to some additional services that were demanded. With the arrival of the digital communication during the decade of the 80, it appeared the opportunity to develop to the systems and

norms of one second generation of movable communications.
In Europe, the administration of telecommunications CEPT1, initiated the GSM (Global System for Mobile communications) and thus to develop a project for all the European continent based on the mobile phone system. GSM continued with their activities in 1989 in just created ETSI (European Telecommunications Standards Institute). After evaluating the proposals given in the middle of the decade of the 80, which were TDMA, CDMA and FDMA, last standard GSM is based on TDMA.

The development of a digital cellular standard was performed simultaneously by TIA (Telecommunications Industry Association) in the U.S., resulting in TDMA based IS-54 standard, which is referred to below as US-TDMA. A little later the development of a standard called CDMA IS-95 was completed by the TIA in 1993. In Japan, the second generation TDMA standard was also developed, which generally refers to PDC.

All these standards were of narrow band, oriented towards a bandwidth reduced for the services of voice. With the second generation the opportunity arrived to offer services on data in movable communications networks. The main services of data introduced in 2G are: the text message (SMS) and the circuit of commutation of packages of data, that allows to the service of the electronic mail and other applications. The speed peak of the data transmission in 2G initially was of 9.6 Kbps. The high speeds of data transmission later introduced in the evolved systems 2G, by means of the allocation of Time manifolds slots to a user and by the modified systems of codification.

Data packets via the cellular systems became a reality during the second half of 1990, with the GPRS (General Packet Radio Services) introduced in the GSM and data packets are also included to other cellular technologies As the Japanese standard PDC (Personal Digital Cellular). These technologies are often called 2.5G. The success of the iMode service in Japan on wireless data gave a clear indication of the potential applications of packet data in mobile systems, despite the slow speed of data transmission supported at this time.

With the advent of 3G and higher bandwidth of the UTRA radio interface was possible a wide range of new services that were mentioned only in 2G and 2.5G. The development of 3G is now handled by the 3GPP, however, initial steps were carried out 3G in early 1990, well before the formation of the 3GPP. The internationalization of the norms and standards was an important factor in determining the basis for 3G. GSM began as a pan-European project, but soon attracted interest from around the world where GSM is deployed in a number of countries outside Europe. GSM is currently deployed in over 160 countries worldwide.

1.1.2 UMTS

UMTS delivery images, graphics, video communication and another type of broadband information, as well as voice and data simultaneously. The main long-term goal of the third generation is to integrate all kinds of services offered by the different technologies and current networks : GSM, EDGE, DECT (Digital Enhanced Cordless Telephone), ISDN, Internet, etc.

The advantages of UMTS with respect to the existing cellular networks can be summarized as follows:

- Increase the capacity and quality of the voice.
- Multimedia applications with higher data rates.
- Highest peaks in the data rates for the transmission of information.

To achieve all this, the new technology will be based on a technique completely different to the well-known in GSM/EDGE, called WCDMA (Wideband Code Division Multiple Access) . Due to the large bandwidth required for the new signs, it has been necessary to allocation of new frequency bands. Part of the spectrum has been allocated for UMTS, also in every European country and some Asians, this spectrum is has split auctioned or led to competition between the operators concerned to a very high cost.

1.1.2.1 Services offered by UMTS.

The new system, UMTS, will offer new and better services, such as multimedia services and high-speed services that are easy to use, and that will address all the needs and individual preferences of users.

The market for UMTS comprises a wide range of applications, which can be classified into six main types of services:

1. Voice (S - speech). The voice service is a symmetrical service with the same amount of information in the link of rise (UL) than in the fall (DL). Corresponds with voice services point-to-point and many points (teleconference). It also includes voice mailbox.This is a basic service of voice between 8 and 16 kbitls.

2. Simple Messaging (SM - Simple Messaging). It is a asymmetric service which is considered as the evolution of the SMS service (Short Message Service) of GSM.This is type services e-mail and messaging between 9.6 and 16 kbitls. It also includes services in e-commerce simple as orders and payments.

3. Circuit-switched data (SD - Switched Data). This symmetrical service provides access to low-speed LAN of marking, access to the Internet and intranet and fax to a data rate of 14 kbith.

4. Multirnedia Average (MMM - Medium Multimedia). This service is assumed as asymmetric and will work in bursts. Includes the services of predominant a single direction: access to LAN networks, intranet and the internet; applications to work in collaboration; interactive games; services of lottery and betting; messaging services and electronic commerce more sophisticated as multipoint and public information.

5. High multimedia (HMM - Alto Multimedia). It is a asymmetric service, such as the previous one, which requires higher bit-rates and sizes of files. Applications include: high-speed LANS, access to the intranet and the Internet; audio and video clips on demand; and purchase online.

6. High interactive multimedia (HMM). Symmetric service that requires a data rate reasonably continuous and high-speed with a minimal delay. It is primarily for services of video telephony, video conferencing , collaborative work and telepresence.

The first three classes of services are seen as logical extensions of the mobile market 2º generation and the last three are entirely to the new market of mobile multimedia. Table 3-1 shows a summary of the main characteristics of the different services.

Service	Kind of Service	Rate of bits (Kbps)	Asymmetric Factor	Transmission Mode
HIMM	High Interactive Multimedia	128	1	Circuit
HMM	High Multimedia	2000	0,005/1	Package
MMM	Medium Multimedia	384	0,026/1	Package
SD	Switched Data	14	1	Circuit
SM	Simple Messaging	14	1	Package
S	Speech	12	1	Circuit

Table-1 Classes and characteristics of UMTS services

1.1.2.2 Modulation Technique (CDMA)

UMTS combines W-CDMA and TD-CDMA (Time Division - Code Division Multiple Access). CDMA is a technique of multiple access spread-spectrum (SSMA - Spread Spectrum Multiple Access Technique). SSMA uses signals with a transmission bandwidth that is several orders of magnitude larger than the RF bandwidth required minimum. SSMA has many properties that make it particularly suitable for use in the environment of mobile communications in radio. This technique converts a signal of narrowband in a signal of broadband by multiplying the original signal by a sequence of pseudo-noise (PN). SSMA is not very efficient in bandwidth when used for only a few users, but if it is in a scenario of a large number of users, since many users can share the same anchojde band widened. Another fundamental reason why we are considered systems SSMA for communications without cable is by resistance to the spread multipath with fade.

In CDMA sequence PN used to multiply the signal of narrow-band called spreading code. All users of a CDMA system use the same carrier frequency and can be transmitted simultaneously without which there is no interference between them, because each user has its own data code word pseudo-random that is approximately orthogonal to any other word of code used by another user. For the detection of the original signal, the receiver needs to know the word of code used for the transmitter. Each mobile station operates independently without any kind of knowledge about the rest of the users.

It is important to indicate that in UMTS used two types of different codes: codes "scrambling" and codes of channel. Both codes have a different nature and also have a different role in the link of rise and linkage of depression:

- The code "scrambling" does not affect the bandwidth of the signal, applies once the signal has been widened. It belongs to the family of codes type Gold and are not in any type of orthogonality between them, if they do not apply the code "scrambling" right to the received signal the result is a signal similar to white noise Gaussian. Its function is to split the signal from different sectors and cells in the link of the descent. While the link of rise, each terminal shall be identified by a code "scrambling".

- The code of channel is responsible for widening the signal from the data rate original until the rate of chip. It belongs to the family of codes type OVSF and are orthogonal to each other, to apply the code correThe function of this code is to separate the connections for each user within the cell in the link of the descent. The function of this code is to separate the connections for each user within the cell in the link of the descent. In regard to the link of rise, the code of channel distinguishes between the data channel and the control channel signalling or transmitted from the same terminal.

1.1.2.3 Problem "near-far"

It is caused by the fact that the sequences of widened from different users are not exactly orthogonal to each other, so after the correlation appear certain contributions other than zero, which added to the original signal, cause noise, this noise level is called ground noise after decorrelation.
To combat this problem in UMTS is essential an effective control of power. This ensures that each mobile located inside the coverage area of a base station be delivered the same signal level to the receiver of the base station. Power control is implemented in the base station and operates through a fast display levels indicators of the power of the radio signal (RSSI - Radio Signal Strength Indicator) of each mobile and later change command level of power in the link of the descent. The frequency of the power control in UMTS is 1500Hz, faster than that used in GSM, where this problem is not so critical.

The main features of CDMA could be summarized as follows:

- The same frequency spectrum can be shared by many users of a CDMA system. And both TDD and FDD can be used.

- CDMA does not have a limited number of users, since the system gradually degrades overall performance due to an increase of the soil of noise in a linear fashion , according to the number of users is increased. In turn, the performance improves when the number of users is decreasing, because that decreases the ground noise.

- The undesirable effect of spread with multipath fading is substantially reduced. This type of systems are not only resistant to these disturbances of the channel but are also capable of taking advantage of the different echoes from the multipath effect to improve the performance of the system. This process is carried out by a type of receptor called receiver Rake, which combines the information obtained from the reception of various versions delayed the original signal.

Is affected by the problem near-far, which can be resolved by a proper control of power.

1.1.2.4 RF Spectrum

The use of the spectrum is different depending on the specific situation of each region or country. The European organization ERC (Europeo de Radiocomunicaciones Commitee) has awarded 155 MHz of spectrum as a band for the 3º generation terrestrial, figure 3-3. The government approves that every part of the spectrum is offered to 3G operators, except a small amount to private applications of high speed broadband .

The radio interface can operate in two modes: mode Frequency Division Duplex (FDD) or the mode Time Division Duplex (TDD). The possibility of operating in both FDD and TDD allows effective use of available spectrum in accordance with the frequency given in the different regions. In FDD transmissions of links of rising and falling used two different frequencies , therefore are allocated to the system a couple of frequency bands with a determined separation. On the other hand, TDD is another duplex method based on the transmission of the link of rising and falling at the same frequency by means of the synchronization of time intervals.

1.1.2.5 Radio Interface

Unlike GSM, where the coverage and capacity of the cells are concepts that can be studied separately, in UMTS, on the other hand, both are correlated and should be considered simultaneously in the study of dimensioning.

1.1.2.6 Basic Parameters

The basic parameters in UMTS for the radio interface on WCDMA are proposed by ETSI. Due to the current process of standardization, some of these parameters can be modified. The main parameters are summarized in table-2.

Multiple Access Technique	DS- WCDMA
Duplex Scheme	FDD
Chip Rate	3.84 Mcps
Carrier	5 Mhz spacing between operators
Frame length	10 ms

Technical or multiple variable rate	Variable spreading factor & multicode
Usar date rate	8kbps; 12.2kbps; 32kbps; 64kbps; 128kbps; 256kbps; 384 kbps; 2Mbps
Transmitted peak power in the mobile terminal	2ldBm terminals with voice service only or 24dBm for data terminals
Peak power transmitted to the base station	43dBm or 46dBm depending on traffic conditions in the area.

Table-2 Basic parameters of the WCDMA radio interface

The technique used is based on the multiple-access techniques by spread spectrum . UMTS uses a particular type called multiple access broadband by direct sequence, DS-CDMA, which converts a signal of narrowband in a signal of broadband with aspect of noise before transmission.

1.1.2.7 New Concepts

UMTS, is based on a technology totally different to TDMA in GSM, therefore appear new concepts with which it is necessary to become familiar in order to study and understand the behavior of these new cells. Among them, the Node B indicated the base station in UMTS. These new concepts are:

1 . Load in the cell or increase of the noise.
2. Soft Handoff or change in gradual cell.

1.1.3 3G Research.

In parallel with the large deployment and evolution of 2G mobile communication systems in 1990 were put great efforts in research activities on the 3G.

In Europe, the Commission of the European Union (the EU) finances the program mainly call Investigation and Development in Technologies outposts of the Communications in Europe (RACE), carrying the first stage of the initial investigation where 3G was named like Universal System of Comunicaciones Móviles (UMTS).

In the second phase of RACE, project CODIT (Code Division Testbed) and project ATDMA (Advanced TDMA Mobile Access) were developed like concepts based on technologies Wideband CDMA (WCDMA) and Wideband TDMA.
The following phase in relation to the European investigation was the ACTS (Technology and Advanced services of Communication), that carried the project Future Radio Wideband Multiple Access System (FRAMES), that was the one in working with the terrestrial component of the interface UMTS radio .The definition of the scheme of original multipie access of FRAMES (FMA), satisfied the requirements that had to realise for the systems of terrestrial mobile radio of 3G. The FRAMES was completed in 1996, on the basis of decisions in different parts from the world, and in addition it combined broadband technology WCDMA and TDMA, with or without relaxation.

At the same time in Japan, the Association of Radio Industries and Businesses (ARIB) was in the process of defining a 3G wireless communication technology based on WCDMA. Korea also began work on WCDMA at the time, and the U.S. developed like a concept called WIMS (WWW Interactive Multipurpose Server).
The FRAMES project was presented to the 3G standardization activities in ETSI, when other multiple access proposals were also introduced by the industry. ETSI proposals joined in five groups, meaning also that the WCDMA proposals from both countries, U.S. and Japan did the same between them.

The standardization of WCDMA was developed in parallel in the ETSI and ARIB in the end of 1998. With it kept a parallel deployment of the specifications in various regions, leading to the current organization of the 3GPP partners are ARIB, CCSA, ETSI, ATIS, TTA and TTC.

1.2 Standardization

1.2.1 Standardization process.

To establish a standard for mobile communications is not a simple task, it must follow a continuous process.Standardization forums are constantly changing their standards, to try to meet new demands for services and functions. This process is different in different forums, but includes four phases which are illustrated in Figure 1.1:

1.Specification: where you decide what to get with the standard.
2.Architecture: which are determined the main building blocks and interfaces.
3.Detailed specifications: where each interface is specifically detailed.
4.Testing and Verification: where the interface specifications have shown the result of work in real life.

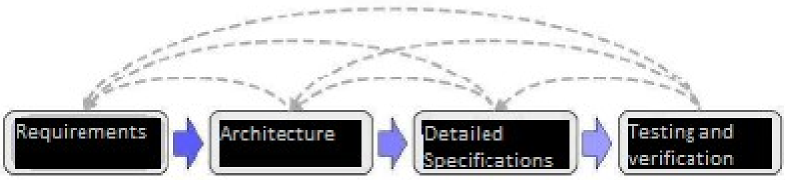


Figure 1.1 **Stages of standardization and the iterative process**

These phases can be iterar and in addition superpose themselves. For example, they can be incorporated, be modified or handicappeds during the last phases, if the technical solutions require it. In the same way, the technical solutions in the detailed specifications can change due to the problems found in the phase of test and verification.

Standardization begins with the requirements phase, where the standards body decides what should be done with the standard.This phase is usually relatively short. In the architecture phase, the standards are decided on the architecture initially must meet with the requirements, also include decisions on benchmarks and standardization of the interface to use. This phase is usually quite long and can change the requirements. This phase is usually quite long and can change the requirements. Then we have the detailed specification phase where interfaces are identified. During this process, the standards body may find that you must change the aspects that were taken by the decisions in the architecture, or even in the requirements phase.

Finally, we continue with the testing and verification phase that is generally not a real part of the standardization, but is carried in parallel through testing by suppliers and interoperability testing between suppliers.This phase is the ultimate test of the standard. During this stage can be found in the standard errors and can also change the decisions of the other phases.To verify the quality of standard are needed the products therefore the application of these starts after or during the detailed specification.

The test and verification phase ends when the tests are stable can be used to verify that the equipment is meeting with the rule or standard. Usually, the period is one to two years from the time the standard is completed in its entirety until commercial products are on the market. However, if the standard starting from zero, it may take more time because there is not set of components where to begin.

1.2.2 3GPP

El 3GPP es el organismo que desarrolla los estándares que especifican el 3G de UTRA y los sistemas GSM. 3GPP se inició en el año 1998 y es una asociación de proyectos de tercera generación formada por los siguientes organismos de estandarización que son:

ETSI: European Institute of Standards and Telecommunications	Europe
ARIB: Association of Radio Industries and Businesses	Japon
TTA: Telecommunications and Technology Association	Korea
CCSA: Standards Association and Communications of China	China
ATIS: Alliance for Telecommunications Industry Solutions	North-America
TTC: Committee on Technology and Telecommunications	North-America

The technical part of 3GPP is composed of four groups of technical specification or TSG (Technical Specification Groups), see Figure 1.2, each is composed of different working groups, these are:

The TSG RAN (Radio Access Network), this group works on the specification of HSPA / LTE, is responsible for the functions, interfaces, and protocol of the access network. It consists of the following groups:

- **RAN 1**, is responsible for the physical definition (Layer 1) of the Access Network UTRAN. This includes specification of modulation, channel coding, physical layer measurements, etc.

- **RAN 2**, Works with the interface protocols radio used in the top of the physical layer. This includes layer protocols 2 for the transmission of data.

- **RAN 3**, is responsible for the overall architecture of UTRAN. This includes the definition of the interface between access network entities and the specification of the transport network.

- **RAN 4**, it is responsible for the radio frequency (RF) and the management of the radio resource requirements of the operation.

- **RAN 5**, produces evidence of specification based on the documents of the RAN 4.

The TSG SA (Services and System Aspects), is responsible for the architecture and service definition and consists of the following groups:

- **SA 1**, is responsible for the high level of service characteristics and requirements. It also produces documents in the system and service capabilities, used like a reference for other groups.

- **SA 2**, defines the network architecture and its features to be supported by network entities based on the documents of the SA 1. It also produces specifications that are used as reference by the group in charge of detailed interface specifications.

- **SA 3**, establishes safety requirements for the system and produce security specifications for the algorithms to be applied in the network.

- **SA 4**, works in the specification language, audio, video and multimedia codecs applied to circuits and packages.

- **SA 5**, specifies the architecture, the procedures for the related with the management of the network interface, including the configuration and performance management.

The TSG CT (Network Core and Terminals), is responsible for the network core and specifies the protocols of the network access. It consists of the following groups:

- **CT 1**, especifica los protocolos de la capa 3 que se utilizan entre el núcleo de red, y los terminales para establecer sesiones de comunicación de circuitos.

- **CT 3**, is responsible for the interconnection of networks, networks between 3GPP and networks of circuits or external packages. This includes signalling or protocol of interconnection.

- **CT 4**, is responsible for the definitions of complementary services such as call transfer or SMS.

- **CT 5**, works with UMTS OSA (Open Service Access or Service of Open Access) and produces Applications Programming Interfaces to facilitate UMTS services.

- **CT 6**, is responsible for the format of the Subscriber Identity Module (SIM), specifying the data of the content of the SIM card and your organization.

Radio Access Network), is responsible for the evolution of GSM/EDGE based on Radio Access Network. As UMTS comes from the GSM technology, it is very significant for a network core and for services of great expectation.This is the reason why this technical group begins initially of the ETSI, and finally moved to the organization 3GPP at the end of 2000. It consists of the following groups:

- **GERAN 1**, is the equivalent of RAN 1 and defines the physical interface of network access GSM/EDGE.

- **GERAN 2**, is the equivalent of RAN 2 and works in the definition of radio protocols.

- **GERAN 3** is the responsibility of the adoption of specification testing of network access.

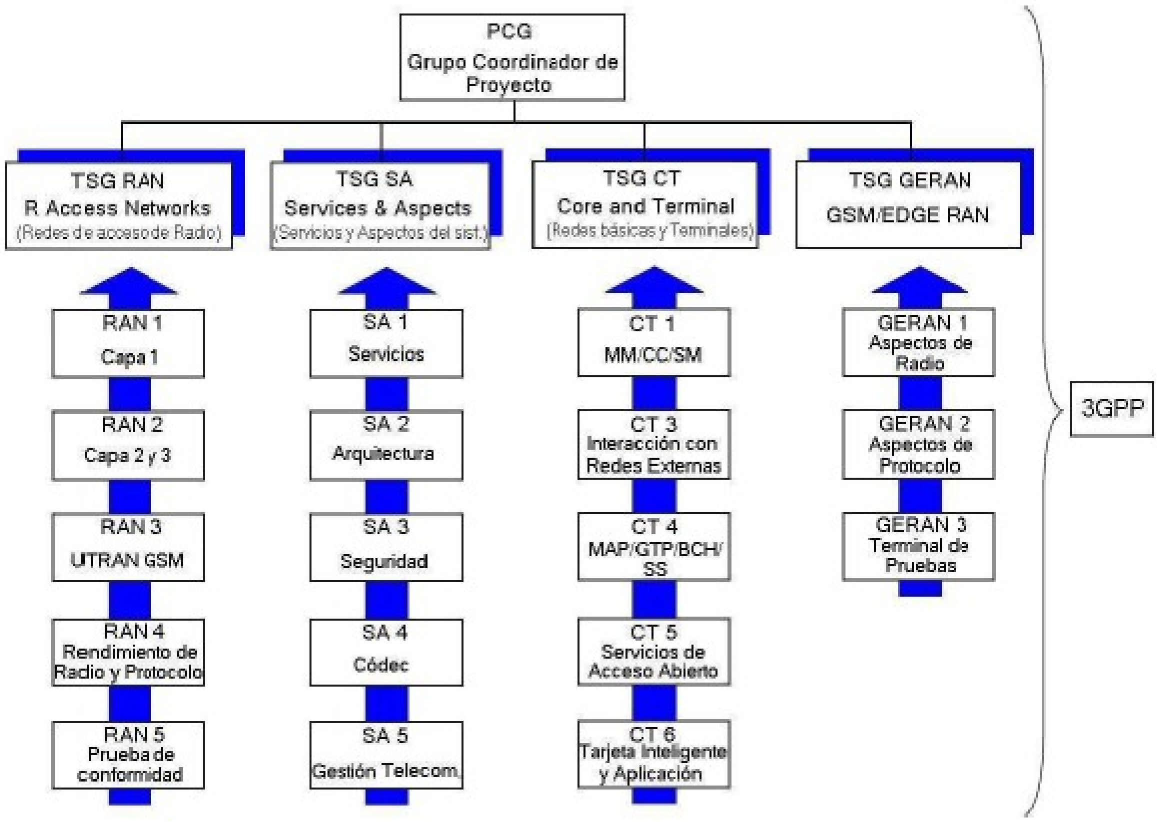


Figure 1.2 3GPP Structure

In the field of application of UMTS evolved, the structure of the 3GPP will not change. All of the TSG and most of its working groups will be expanded its scope in order to cover all the requirements and specifications of the evolution of UMTS.

There is also a parallel project called 3GPP2 which was formed in the year 1999 and the responsibility to develop the specifications for 3G, but for CDMA2000, which is the 3G technology of the CDMA 2G, based on the standard ES-95. This global project also has the organization's participation of partners such as ARIB, CCSA, TIA, TTA and TTC.

The scope of 3GPP in the beginning was the world's production of specifications for a mobile system 3G based on the network core of GSM evolved,including WCDMA and TD-CDMA. The task of maintaining and developing GSM/EDGE has been added at a later stage in the 3GPP.

The work in the 3GPP is carried in ITU into account of the recommendations and the results obtained, in addition, the partners are obliged to identify regional needs that may give rise to different alternatives of the standard. Examples of this are the frequency bands regional and special requirements of local protection of a region.

The specifications are updated after each series of meetings of the TSG, which are made 4 times a year. These specifications are called emissions or versions that are more known by its English name of Releases.The documents of the 3GPP is divided within the Releases (see Figure 1.3), when each of these has a set of added features in comparison with the previous version. These characteristics are defined and agreed upon by the Elements of work and carried by the TSG. The following is a brief description of the versions of the 3GPP.

Release 99 (Rel-99): this is the first version of specifications 3G, which contains all the features necessary to comply with the requirements of IMT-2000 for access radio of WCDMA. It is also established the basis for the future traffic of high-speed transfer , as well as the circuit-switched in packet switching.

Release 4 (Rel-4): contains the changes in the domain of the network core and create new communications interfaces. For the transport you can use ATM or IP in the domain of voice. They are also introduced other features, such as:

· Multimedia in domain circuit-switched (CS-Circuit Switched).

· Handover in real time in the domain of packet switching (PS-Packet Switched).

· Support IPv6 as optional and MMS.

Release 5 (Rel-5): describes the best speed of the data channel for the downlink (HSDPA-High-speed downlink Packet Access), which allows speeds of up to 14.4 Mbps and presents the structure of the network to be fully IP instead of ATM. It also introduces:

· a Quality of Service (QoS) in the domain name PS for the whole journey (fin a final).

· IMS (IP Multimedia Subsystem): IPv6 support and use of SIP to establish session.

Release 6 (Rel-6): improves the speed of the uplink (using HSUPA) of up to 5.76 Mbps, introduces MBMS, and interoperability between UMTS and WLAN. The main improvements are:

· Handover between 3G and WLAN.

· MBMS (Multimedia Broadcast Multicast Service): service for text, video, audio, etc.

· IMS phase 2: QoS for voice and multimedia.

Release 7 (Rel-7): published in March of the year 2007, improves the speeds of the uplink and downlink (HSPA+). It uses MIMO which is the use of multiple antennas in the receptors, it is defined LTE. Among the major improvements is:

· The use of 64QAM modulation for modulation.

· CPC: The connection of packages continues to data users.

· Introduction of LTE/E-UTRAN.

· Melting NodoB and RNC (Radio Network Controller) in the access network radio.

· VoIP for mobile phones.

Release 8 (Rel-8): used like a technique of access, and a variable bandwidth from 1.25 MHz to 20 MHz. Among the improvements are:

· Introduction of SAE/EPS in the network architecture.

. Support for access not WCDMA.

· BY as air interface.

· MIMO: settings of 4x4.

· Beamforming or configuration of the beam: smart antennas.

· IMS common to FMC.

· Priority of multimedia service.

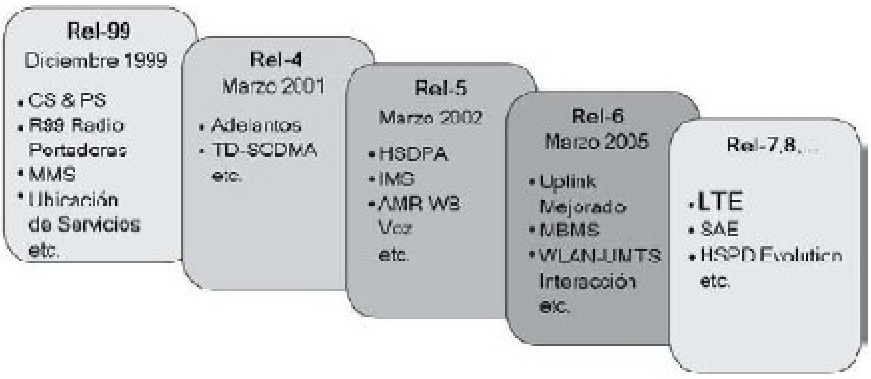


Figure 1.3 Releases del 3GPP

1.2.3 ITU activities with respect to IMT-2000

ITU is the United Nations agency which is responsible for regulating telecommunications in the world, between the different operators and managers.
The areas of activity of the ITU IMT-2000 are:

· Development of Telecommunications (ITU-D), which performed studies and activities of cooperation, aimed at the establishment of IMT-2000 in developing countries.

· ITU Radiocommunication Sector (ITU-R), which is responsible for studies and drawing of recommendations on aspects of radio of IMT-2000 and systems of the future.

· Standardization Sector (ITU-N), which deals of studies relating with the network aspects and applications of IMT-2000 are; convergence of services fixed-mobile, mobility management, multimedia functions mobile, interworking of service, interoperability of equipment and mobile Internet.

For the rules of the Radio Regulations, the works has developed by the Commission Study Group 8 of Mobile Services of the ITU-R, within it establishes the special Task Group 8 (Task Group) dedicated to IMT-2000, which works supported both of the ITU-R and standardization sector ITU-T.

IMT-2000 can be specified with a set of interdependent recommendations of the ITU, providing the framework for a wireless access global linking various networking systems terrestrial and satellite.The number of the Recommendations of IMT-2000 defines a frame of reference for the development of 3G systems, it also sets a series of objectives, description of services, general characteristics of the radio interfaces, spectrum requirements, movement of terminals, and electromagnetic compatibility requirements .

The specifications of the radio interfaces have been developed in various recommendations of the ITU-R. The recommendation ITU-R M-1455 defines the fundamental characteristics of the radio interfaces of IMT-2000. The M-1455 contains basic features proposals, it gives a list of the recommended values in different magnitudes.This recommendation expresses that the radio interface of IMT-2000 would be a single standard, with various modes of operation, which could be classified in CDMA, TDMA or a combination of both. The group includes CDMA systems inexpensive DS-CDMA with FDD, TDD and FDD systems multi-carrier.

The main recommendation is the Recommendation ITU-R M. 1457, which identifies the detailed specifications of the radio interface of IMT-2000. The recommendation includes a family or set of five interfaces terrestrial radio which are shown in Figure 1.4 , as well as the organizations that develop the specifications.

IMT-2000 Interfaces Radio Terrenales (Recomendación UIT-R M.1457)		
Complete name	Common name	Organization
Direct spread of CDMA from IMT-2000	ULTRA FDD	3GPP
Multi-carrier CDMA from IMT-2000	CDMA 2000	3GPP2
IMT-2000 CDMA TDD	ULTRA TDD	3GPP
Single Carrier TDMA IMT-2000	UWC 136	ATIS/TIA
FDMA/TDMA in IMT-2000	DECT	ETSI

Figure 1.4 ***Interfaces Radio Terrestrial IMT-2000***

In each radio interface has been developed the assessment process, convergence and the achievement of quality objectives for different environments radio operational, while ensuring global compatibility and international roaming.

With the continued development of the radio interfaces IMT-2000, including the evolution of UTRA to E-UTRA (UTRA evolved), ITU recommendations should also be updated . The Working Group 8F, continuously revised Recommendation M. 1457.In the year 1999 was adopted the five interfaces for IMT-2000 on Figure 1.4 and in the year 2007 was added Mobile WiMAX as the sixth interface called "IMT-2000 BY TDD WMAN". In addition to the maintenance of the specifications of the IMT-2000, the main activity of the ITU-R Working Party 8F, is the development on the subsequent systems to IMT- 2000, appointed currently as IMT-advanced.In this development include studies of services and technologies, market forecasts, principles of standardization, the estimation of the needs of the spectrum and the identification of frequency bands candidates for IMT-advanced. The spectral work also involves exchange of studies between IMT- advanced and other wireless technologies.

1.3 3G Spectrum

The work in the development of the spectrum of 3G mobile systems, began when the World Radio Conference (WRC) of ITU in the year 1992, identified the frequencies that were available for use in future IMT-2000, around 2 GHz. Goal 3 G original is a unique and comprehensive air interface of IMT-2000. In practice, the 3G systems are closer to this goal than when they were 2G, since WCDMA has proved to be the more dominant of the standard IMT-2000 within the commercial deployment.

Most of the developments in WCDMA have been specified in the spectrum for 3G, which identifies the frequency bands 1885-2025 MHz and 2110-2200 MHz (see Figure 1.5), as intended to be used by national administrations that wish to implement IMT-2000.

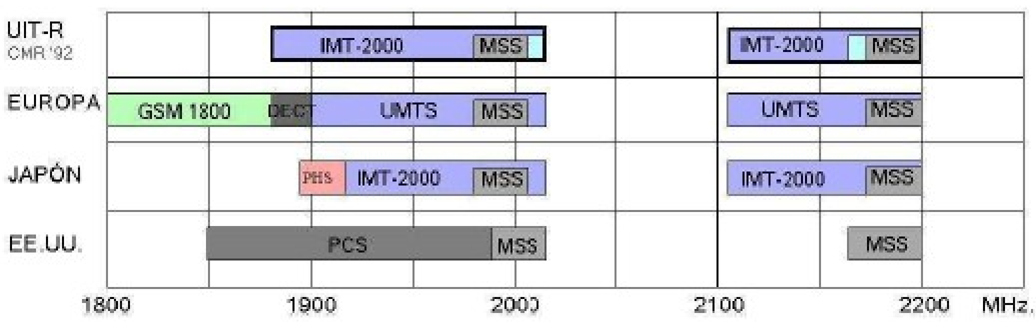


Figure 1.5 Spectrum of frequencies

The resolution, something dissenting between the regions of the frequency bands allocated for 3G, it means that there is no single band that can be used for 3G roaming throughout the world. Great efforts, however, have been in the definition of a small set of bands, which can be used to facilitate roaming and as well the devices multi-band can provide greater efficiency in this type of world service.

An additional spectrum for IMT-2000 was identified at the World Radio Conference 2000 (WRC-2000), where it was considered the need to add 160 MHz of spectrum, this was foreseen by the ITU-R. Furthermore, it was established that WCDMA would be deployed in 17 existing bands of frequency 2G identified by IMT-2000 and that are currently used by GSM. This approach is known as reorganization, which helped in part by the deployment of WCDMA in the U.S. , in the cellular bands in 850 MHz and the PCS band in the 1900 MHz, since there were no new frequencies available for this deployment. Also this reorganization WCDMA in GSM bands has begun in Europe and in Asia.

The agreements of frequency in all world described in recommendation ITU-R M. 1036, it can identify which parts of the frequency spectrum bands are paired (paired bands) and which are unpaired (unpaired bands). For the spectrum of bands paired, the frequency bands of uplink and downlink, are identified by the management of Frequency Division Duplex (FDD). The unpaired, for example, can use Time Division Duplex (TDD). There is to know that the band with greater global deployment 3G continues to be the 2 GHz.

The 3GPP defined for the first time the 2 GHz band in the UTRA Rel-99, with the frequency bands for UTRA FDD and UTRA TDD (see Figure 1.6).

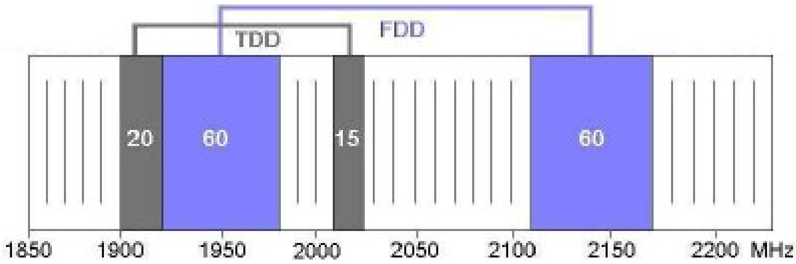


Figure 1.6 Band known as WCDMA FDD and TDD andTD-CDMA

FDD is used in the paired components of the band IMT-2000, of which, the bands 1920-1980 MHz represent the uplink and 2110-2170 MHz the descendant. TDD is used in the components not paired occupying the frequencies of 2010 MHz to 2025 MHz and 1900 MHz to 1920 MHz. This gives an availability of 60+60 MHz for FDD with 12 carriers and 15+20 MHz for TDD with 7 carriers.

The new band IMT-2000 (see Figure 1.7) is approximately 2.6 GHz with a total of 190 MHz of spectrum, which are available for the deployment of IMT-2000 and other mobile systems. In Europe, the spectrum includes 2+70 MHz for the FDD systems and 50 MHz of empty space in the middle that can be used, for example, to TDD The same range of 2.6 GHz is also available for the use of mobile phones, including IMT-2000 in the USA.

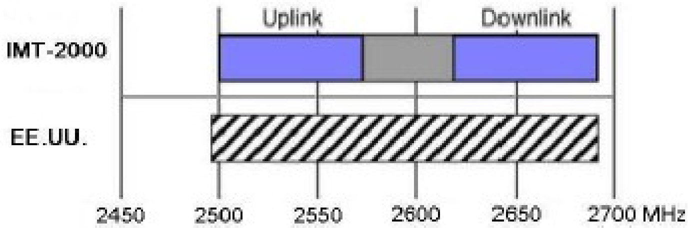


Figure 1.7 Frequencies about 2.6 Ghz

1.4 Evolution of the system

GSM and WCDMA together represent 85% of subscriptions global mobile, and their participation continues to grow. WCDMA is designed to coexist with GSM, including an uninterrupted handover and terminals of dual mode. Most of the WCDMA networks are deployed in the current GSM network EDGE and EDGE Evolution can be developed in an efficient manner along with WCDMA and its evolution. In the same way, LTE is designed to coexist with GSM and WCDMA.

The CDMA 2000 (world-wide in terms of subscribers to mobile services), has decreased since the year 2004 and currently has a slight increase of 10 %. A series of major CDMA operators have been converted to GSM/WCDMA talking about evolution of voice, having access to the benefits of extensive ecosystem GSM/WCDMA, the economy of scale, and the low cost of mobile devices. The solution of CDMA, EV-DO, is now developed commercially. To promote the evolution, a number of CDMA operators are focused on the technologies, HSPA, WiMAX and/or 3GPP LTE. The high level of an evolving system is illustrated in Figure 1.8.

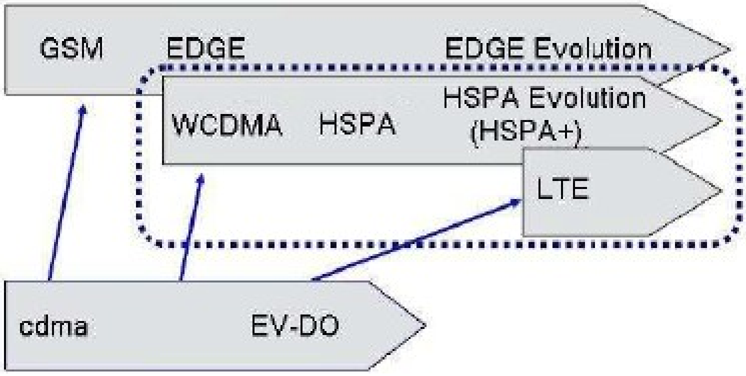


Figure 1.8 Evolution system

Looking back at history GSM, several countries have reached more than 80% of cellular penetration, and the global account of GSM subscribers exceeded 2 billion in 2006, fifteen years after the opening of the first network. The early experiences of GSM, showed that the growth rates are very high when it has terminals attractive, small size and in addition to possessing a low energy consumption. It took about seven years for GSM reached 100 million subscribers and WCDMA only six years. Currently, there are more than 150 commercial networks WCDMA with more than 130 million subscribers.

1.5 Architecture of the system evolved

Approximately at the same time of the evolution of HSPA and the start of LTE, the 3GPP decided to make sure that an operator can coexist easily between HSPA and LTE through a network core. This work was done by the Working Group SA carrying out the study of the System Architecture Evolution (SAE).

The study of the architecture of the system evolved, it focused on how the network core 3GPP will evolve in the next network core of the coming decades. The current network core was designed in the 1980s for GSM, expanded during the 1990s, for GPRS and WCDMA.

The operation of a network at a general level is quite simple. Base stations are equipped with creating a large mesh in the shape of cell or cell, connecting using radio waves two terminals with the drivers of these base stations (see Figure 1.9).This form of diaper is not accidental but that responds to a scheme which allows the reuse of a certain set of frequencies allocated in different cells, provided that these are not adjacent, increasing network performance on the one hand (the number of frequencies available is limited) and saved on the other.

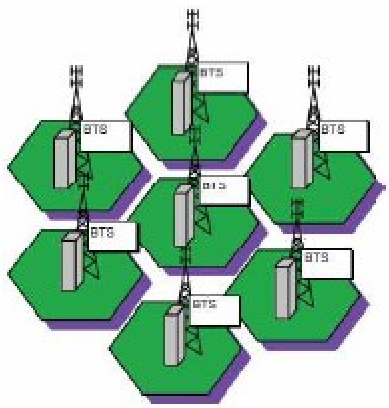


Figure 1.9 Position Cells

A network is basically around two types of elements and a proper combination of these, enabling communication both between mobile phones, such as between a mobile phone and a telephone. These elements are:

· base station: what they are responsible for transmitting and receiving the signal.

· Pbxs: allow the connection between two specific terminals.

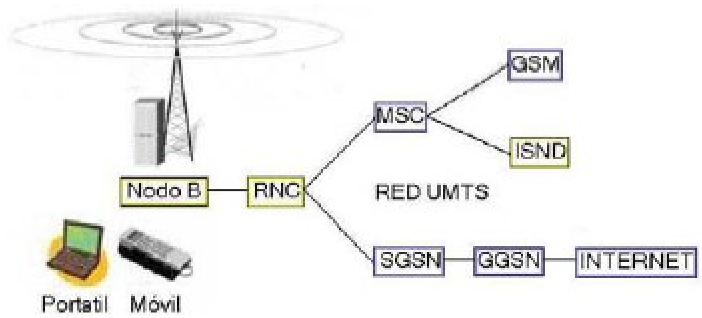


Figure 1.10 Arquitecture 3G

In Figure 1.10 shows the architecture 3G, where the data arrives at the node B (base station) which is responsible for collecting the signals sent by the terminals, passing these to the RNC or driver of the Radio Network to be processed. The set of nodes and the RNC constitute a structure called Radio Access Network (RAN), which connects the terminals with the network core or Core Network, from which is distributed by the various systems through a series of commutations. According to their destination, shall pass through the MSC (Mobile Services Switching Center) or by the SGSN (Serving GPRS Support node) and GGSN (Gateway GPRS Support Node).

The philosophy SAE is focused on the domain of packet switching and migrate outside of the domain of circuit switching. This is done through the next "Release 3GPP", so as to reach the evolution of the network core packages, Evolved Packet Core which will support both HSPA Evolution and LTE, ensuring that LTE may be deployed in smaller islands, only where necessary. A deployment with a gradual approach can be seen in Figure 1.11.

Figure 1.11 Deployment strategy HSPA and LTE

In the first place, the operator can update your network HSPA to a network with a capacity HSPA Evolution and then add the cells LTE where lacks the capacity or where the operator wants to test the new services that cannot be supplied by HSPA Evolution. This approach reduces costs since the deployment of LTE, since it is not necessary to build more, because it has national coverage from the beginning.

Chapter 2

TECHNIQUES FOR ACCESS TO THE MEDIUM

This chapter describes the techniques that you use LTE for the medium access control , explaining primarily as works the uplink and downlink according to the types of air interface that occupies LTE. In addition, it continues with a technical insight of the various systems with which obtains better yields in the transmission of data.

2.1 Transmission Systems

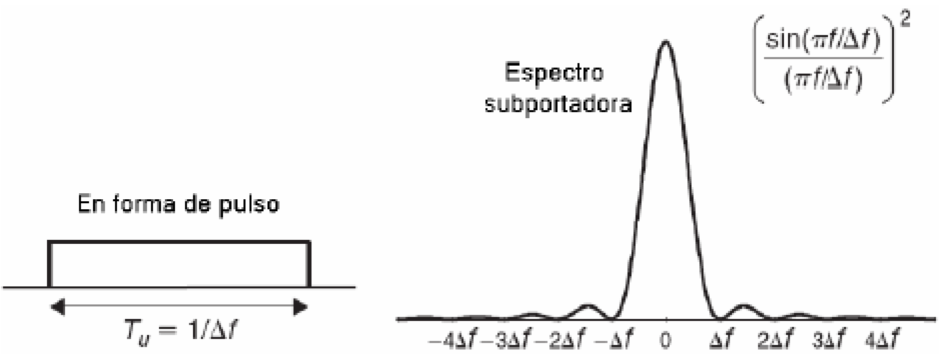
2.1.1 OFDM

OFDM (orthogonal frequency division multiplexing) has been adopted as the system of downlink transmission of 3GPP LTE and is also used for other technologies such as WiMAX and DVB broadcast. The transmission by means of OFDM can be appreciated as a kind of transmission multi-carrier. The basic characteristics of the transmission of OFDM are:

· The use of a relatively large number of subcarriers narrow-band, a simple multi-carrier will consist of few subcarriers, each with a relative bandwidth. For example, a multi-carrier WCDMA with 20 MHz of bandwidth , could consist in four subcarriers, each with a bandwidth on the order of 5 Mhz. In comparison with the other systems, the OFDM transmission may involve several hundreds of subcarriers is transmitted on the same radio link to the same receiver.

. It has a simple rectangular pulse in the time domain configured as shown in Figure 2.1a. This corresponds to a form of sync function frequency-domain , as illustrated in Figure 2.1b.

. The compact frequency domain subcarriers with a deviation n f = 1/Tu, where Tu is the time of the modulation of the symbol by subcarrier frequencies (see Figure 2.2).



Time domain(a) **Frecuency domain(b)**

Figure 2.1 Basic spectrum OFDM in time domain and frecuency domain

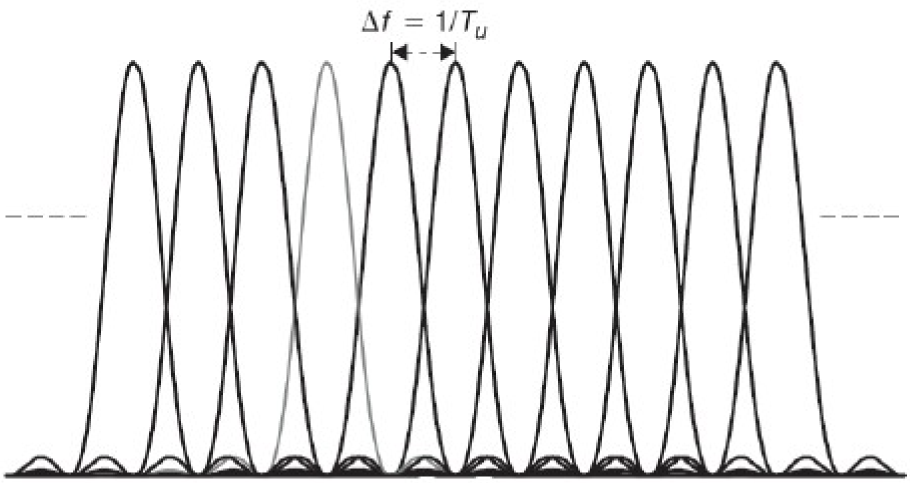


Figure 2.2 Carrier deviation of OFDM

The number of OFDM subcarriers can vary from less than one hundred to several thousand, with a deviation from subcarriers ranging from hundreds of KHz a few KHz. The deviation of subcarrier frequencies to use depends on the types of environments in which it is to operate the system, including such aspects as the maximum expected selectivity of frequency of the radio channel (maximum expected time of dispersion) and the maximum transmission speed of variation channel (maximum expected Doppler spread).

As an example, for LTE basic deviation is equal to 15 KHz. On the other hand, the number of subcarriers depends on the transmission bandwidth, in the order of 600 subcarriers in case of operation on a spectrum allocated 10 MHz, and less or more subcarrier in the case of small or large bandwidths of transmission respectively.

An illustrative description of an OFDM modulator core is presented in Figure 2.3 . This consists of a bank of modulators Nc complex, where each modulator corresponds to a subcarrier OFDM. Transmission is based on blocks, implying that during each interval of OFDM symbol, the modulation of the symbols Cn is transmitted in parallel. The modulation of symbols can be QPSK, 16QAM or 64QAM.

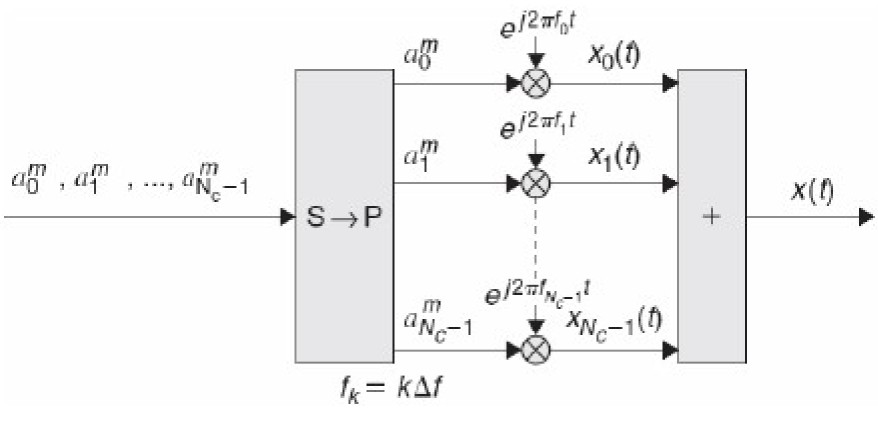


Figure 2.3 OFDM Modulation

The "physical resource" in the case of the OFDM transmission, it is often illustrated as a grid of time-frequency according to Figure 2.4 , where each column corresponds to a symbol OFDM and each row corresponds to a subcarrier OFDM. Figure 2.4.

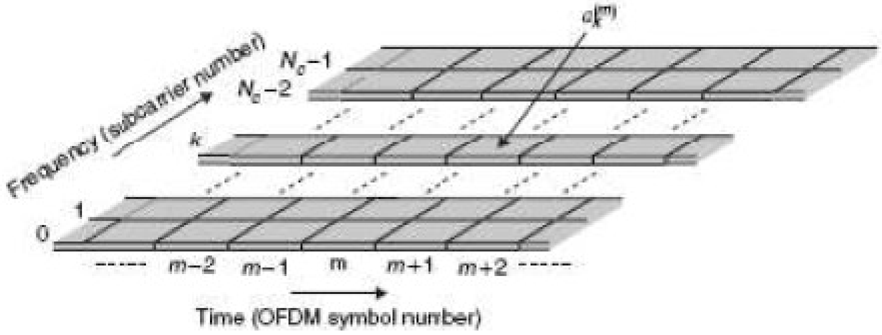


Figure 2.4 Grid OFDM time-frequency

The basic principles for the demodulation OFDM are shown in Figure 2.5 , consist of a bank of optical correlators, one for each subcarrier. Taking into account the orthogonality between subcarriers, in the ideal case, two subcarriers OFDM not cause interference between if after the demodulation, taking into account that in the spectrum the neighboring subcarriers clearly overlap, as can be seen in Figure 2.2.

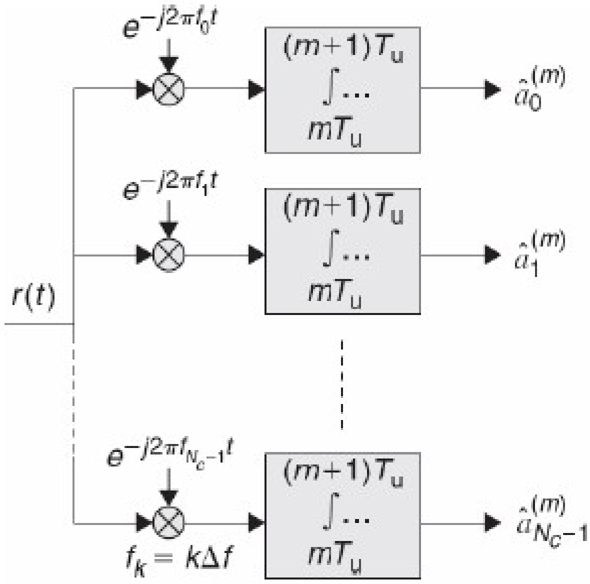


Figure 2.5 Basic Demodulation OFDM

The absence of interference between subcarriers is not due to a separation of the spectrum of a subcarrier, on the contrary, the orthogonality is due to the structure of frequency domain each subcarrier in combination with the specific choice of "f", however, with the type of transmission multi-carrier, corruption of the frequency domain, as for example, due to a frequency selective of the radio channel, you can lead to a loss of orthogonality intersubportadora and so a interference intersimbolo (ISI). To handle this and make a solid signal, is used the insertion of the cyclic prefix (interval foster care) , as shown in Figure 2.6 , by adding the prefix cyclical NPC < N samples to the output signal of the OFDM modulator, obtains a signal of length Ns=N+NPC, so that the duration of the symbol increases, but in such a way that you will not lose orthogonality between carriers already that is copied to the start part of signal carriers orthogonal between them.

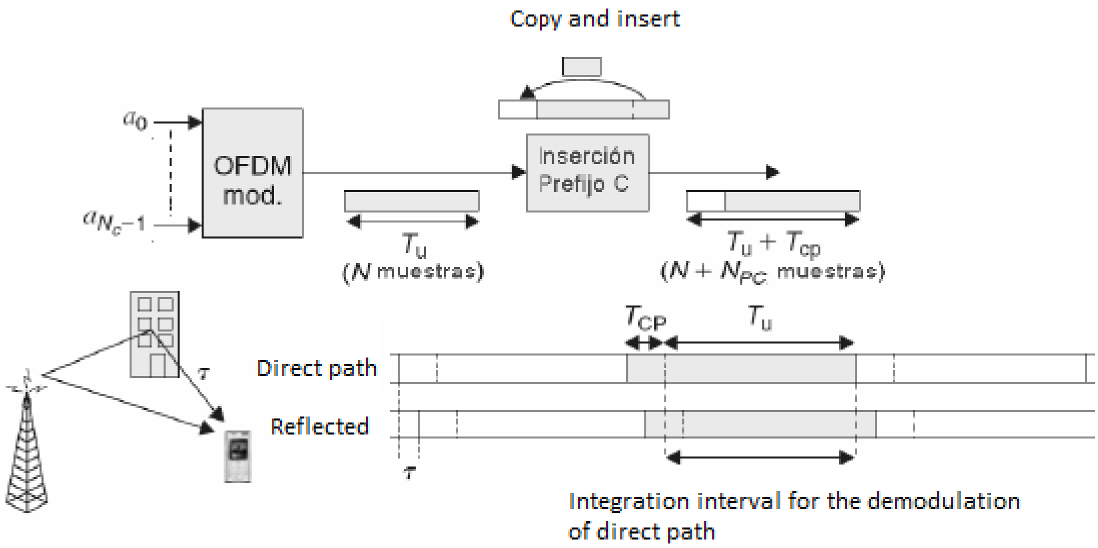


Figure 2.6 Cyclic prefix insertion

Then, this transmission system in the downlink, is attractive for several reasons. Due to the corresponding long-time symbol of the OFDM in combination with a prefix cyclical, OFDM provides a high degree of robustness in front of the selective channel frequency. Although there is corruption of the signal, this can be handled in a principle by medium of the equalization on the receiver side, the complexity of this becomes something unpleasant for deployment on a mobile terminal a bandwidth above 5MHz. In addition OFDM is optimal for downlink, especially when combined with spatial multiplexing.

The additional benefits of OFDM are:

. OFDM provides access frequency domain, thus allowing an additional degree of freedom to the channel dependent compared with HSPA.

· Flexible allocations of bandwidth are easily supported by OFDM, at least from the perspective of base band by the variation in numbers of subcarriers that OFDM uses for its transmission.

· Transmission broadcast/multicast, where the same information is transmitted by multiple base stations, which is simple with OFDM.

2.1.2 SC-FDMA

For the uplink of LTE, has selected a type of transmission with single carrier based on DFT-spread OFDM (DFTS-OFDM), due to the combination of the properties such as:

· Small variations in the instantaneous power of a transmitted signal.

· Possibility of low complexity for a high quality of equalization frequency-domain.

· Possibility of FDMA with flexible allocation of bandwidth.

The basic principle of the transmission of DFT-OFDM is illustrated in Figure 2.7 . It is similar to the OFDM modulation, and is based on a block adapted to the generation of the signal.

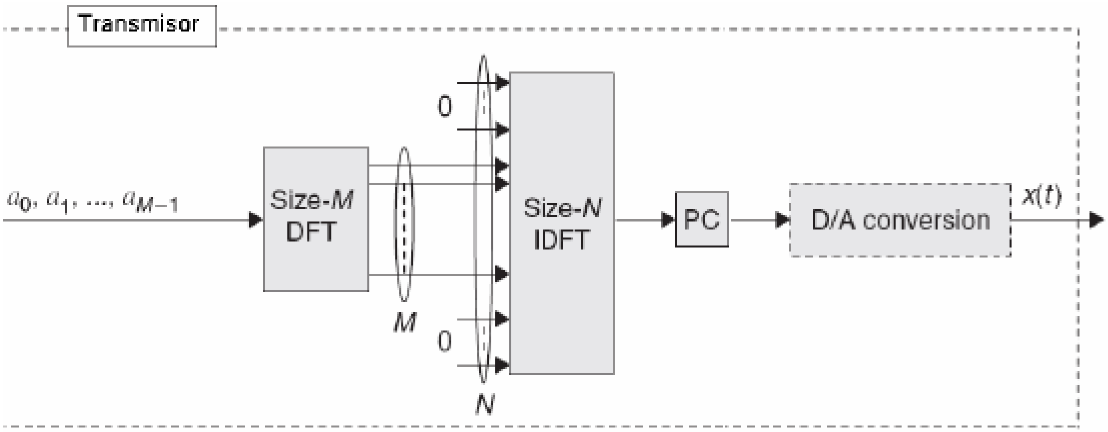


Figure 2.7 Signal generation DFTS – OFDM

Also, like in OFDM, it is preferable to insert a cyclical prefix for each block in the transmission. The presence of a cyclic prefix allows a minor complexity of equality of the frequency domain in the receiver side. The main benefit of DFT-OFDM, compared with a transmission multi-carrier OFDM, is that it reduces variations in the power of instant transmission, which leads to the possibility of increasing the efficiency of the power amplifier.

The basic principle of the demodulation DFTS-OFDM is illustrated in Figure 2.8, and the operations are basically reverse the generation of the signal shown above in Figure 2.7.

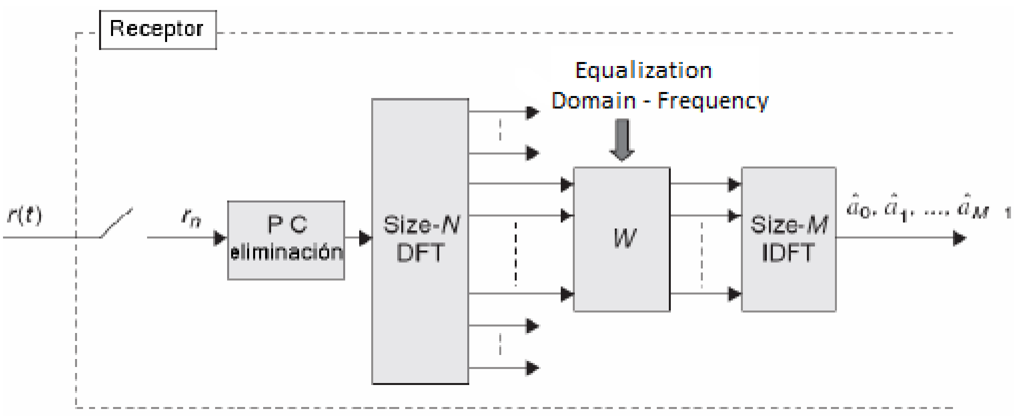


Figure 2.8 Signal demodulation DFTS – OFDM

The use of a modulation with a single carrier in the uplink, is caused by a lower value in the relationship peak average of a transmitted signal in comparison with the transmission multi-carrier. The relationship peak average of a transmitted signal and the average of the transmitted power, it may be for a given power amplifier. The transmission of single carrier, therefore allows the more efficient use of the power of the amplifier, which translates an increase in coverage that is very important for the limited power of the terminal. On the other hand, the equalisation to handle the corruption of the signal single carrier , because of the withering away of frequency selective, that is a minor issue in the uplink by the few restrictions on the processing resources of signal in the base station in comparison with the mobile terminal.

In contrast to the uplinks not orthogonal WCDMA/HSPA, which also operate by medium of transmission of single carrier, the uplink in LTE is based on the separation of orthogonal users in time and frequency, in principle, the separation of the orthogonal user can be achieved in the domain of the time only by the allocation of the total bandwidth in the transmission of the uplink to a user at a time. The orthogonal separation is beneficial, because it prevents the intercell interference (ICI). However, the allocation of a great resource instantaneous bandwidth to a single user, it is not a sufficient strategy in situations in which the speed of data transmission is limited, Mainly by the transmission of power more than bandwidth. In such situations, a terminal is designated to transmit only in a part of the total of the bandwidth, and other terminals can be transmitted in parallel with the rest of the spectrum. Therefore, as the uplink of LTE contains a component of frequency domain multi-access, the transmission system of this link is also called as a Single Carrier - Frequency Division Multiple Access (SC-FDMA).

The key to these transmissions is normally the speed and the significant variations in conditions snapshots of the channel. These variations are due to; fainting by shadow, loss of path dependent in the distance that significantly affect the average received signal and finally, interference in the receiver due to the transmission of other cells and other terminals that also impact the level of interference. All of these variations must be taken into account for a better quality of the link.

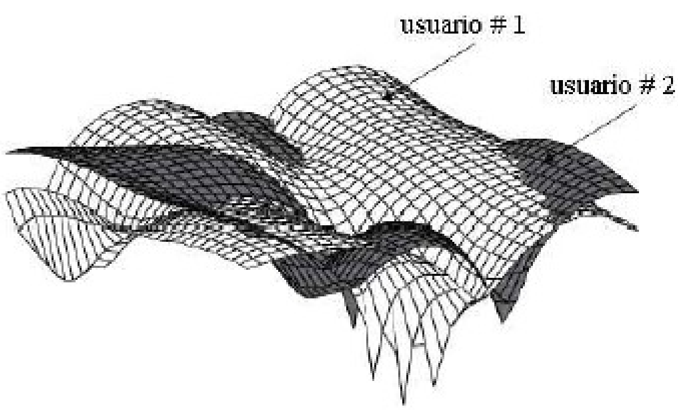
2.2 Channel programming and adaptation of date rate.

The heart of the transmission system of LTE, is the use of transmission channels shared, it is well adapted to the different resource requirements posed by data packages and it also makes several other key technologies used by LTE.

The controls programming, in each moment of time, should be allocated for those users that share resources. This also determines the speed of transmission of data to be used for each link, transmission speed adapted that can be viewed as a part of the programming. Programming is a key element and to a large extent determines the overall performance of the downlink, especially in a network very charged. Both transmissions of uplink and downlink are subject to a tight schedule. In relation to HSPA, programming downlink transmits a user when the conditions of the channel have the advantage of using the maximum speed of data transmission, and the Enhanced Uplink (uplink improved), however, as LTE has time domain and also access to the frequency domain, due to the use of OFDM and SC-FDMA on their respective links.

The scheduler to each regional frequencies can select the channel of user with the best conditions. In other words, the configuration of the channel of user in LTE may take into account changes not only in the time domain, such as HSPA, but also in the frequency domain, this is illustrated in Figure 2.9 .

The channel programming is based on variations in the quality of the channel between users to obtein a gain in the capacity of the system. For sensitive services to this delay (delay), a programming with domain only in time can be performed for a particular user, despite the fact that the quality of the channel is not in all its boom. In situations like this , the exploitation of the variations in the quality of the channel also frequency-domain will help to improve the overall performance of the system. In LTE, programming decisions can be taken as often as once every 1 ms, and granularity in the frequency domain is 180 Khz.



(a)

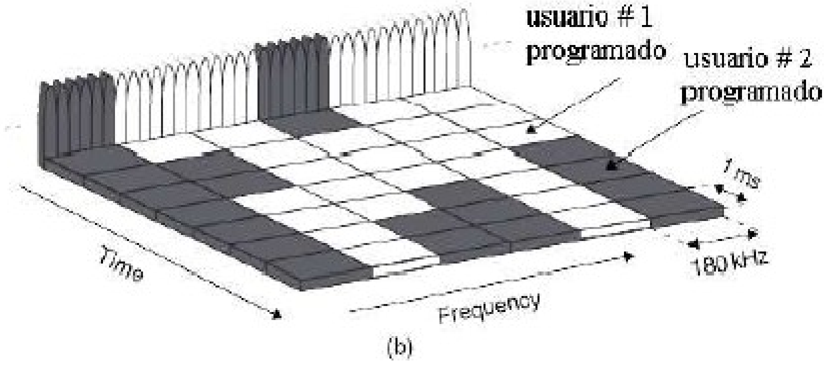


Figure 2.9 Downlink channel scheduling dependent on time and frequency domain

2.2.1 Downlink scheduling.

Initially assumes a downlink based on TDM with a single user programmed in a moment. In this case, the use of radio resources is maximized if in each moment of time, all resources are allocated to the user with the best condition snapshot of the canal:

. In the case of the adaptation of the link based on the power control, implies that the lower power possible transmitted may be used for a particular data rate and it also minimizes the jamming of the broadcasts in other cells in a specific link (see Figure 2.10 (a).

. In the case of the adaptation of the link based on the speed control, it implies that the highest values of data transmission speed are achieved for a particular transmitted power or for a particular interference in other cells (see Figure 2.10 (b).

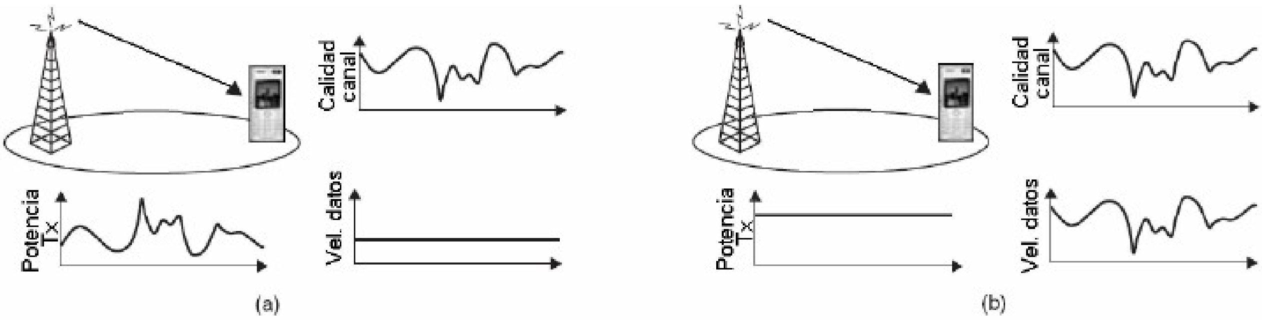


Figure 2.10 **(a) Power control** **(b) Velocity control**

However, if it is applied to the downlink, the control of the transmitted power in combination with the programming TDM, implies that the total available from the cells that transmit power, was not used in its entirety. Thus, the speed control of data is generally preferred[1].

The above is an example of channel programming dependent, where the programmer takes into account the conditions snapshots of the link radio. The programming of the user with the best conditions of the link radio, it is often referred to as programming max-C/I (or maximum percentage). Given the conditions for the different links radio, almost at any time there is a channel of user whose quality is close to its maximum point (see Figure 2.11). As well, finally the channel used for the transmission tends to have a high quality, and a high transmission speed to be used, by generating a high-capacity system. The gain obtained by the transmission to the users in favorable conditions is commonly known as diversity multi-user, appearing greater profits , large variations of the canal and a large number of users in a cell.

In the downlink, each report of the terminal is an estimate of the quality snapshot of the canal to the base station. These estimates are obtained by the measurement of a reference signal, transmitted by the base station and is also used for the purposes of demodulation. Based on this estimate, the developer of the downlink can allocate resources to users, taking into account the qualities of the channel. In the beginning, the terminal scheduled can assign a combination of 180 KHz bandwidth blocks of resources in each schedule interval of 1 ms.

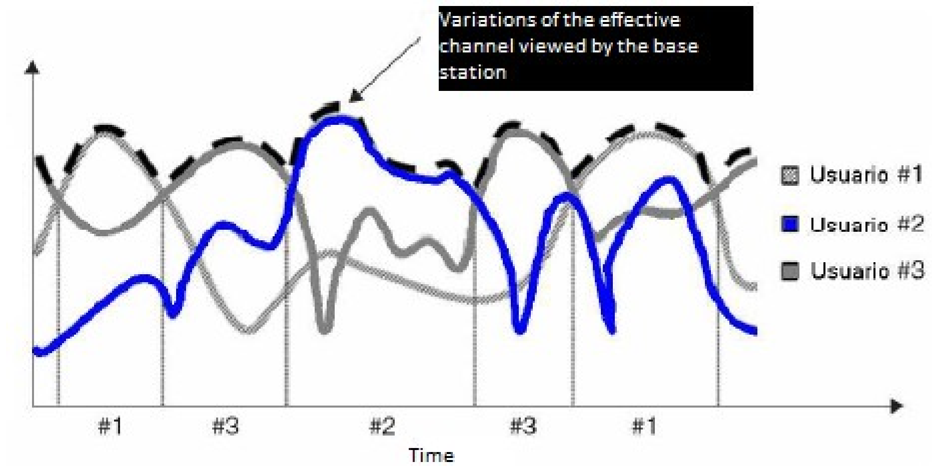


Figure 2.11 Dependent channel programming

2.2.2 Uplink scheduling.

Mainly the power resources of the uplink is distributed to users , while in the downlink resources are centralised in the base station. In addition, the maximum transmission power of uplink of a single terminal, it is often typically lower than the output power of a base station, which generates a significant impact on the programming strategy. In contrast to the downlink, where you can often use TDMA, normally the programming uplink is shared between the frequency and /or domain by adding code to the domain of the time as a single terminal does not have the sufficient power to use efficiently link capacity.

The uplink of LTE is based on the separation of orthogonal users, and this is the work of the programmer of the uplink to allocate resources in both domains, time and frequency (TDMA/FDMA combined) for different users. The configuration decisions are very important, the study by medium of 1 ms, the control of mobile terminals that are authorized to broadcast within a cell during a certain time interval , you must also take into account that frequency transmission takes place, and what type of uplink data format (transport) will be used. There is to know that only one region of adjacent frequencies may be assigned to the terminals on the uplink as a result of the use of a simple carrier in the transmission of the uplink of LTE.

The channel conditions can be taken into account also in the process of programming of uplink, similar to the programming of the downlink.However , as will be discussed later, obtaining information about the channel conditions of uplink is a task not trivial, therefore, different means to obtain diversity in a uplink are important as a complement to the cases where the channel programming is subject to the uplink is not used.

2.2.3 Inter-Cell interference.

LTE offers orthogonality between users within a cell in both links, ascending and descending. Thus, the performance of LTE in terms of efficiency of the spectrum and the available data transmission speeds, is more limited by the interference of other cells in comparison with WCDMA/HSPA. The mediums to reduce or control the interference between cells can potentially provide important benefits to the performance of LTE, especially in terms of service, such as data speeds, that can be offered to users in the edge of the cell.

Interference coordination inter-cell is a configuration strategy where the data transmission speeds on the edge of the cell are increased through the adoption considered interference between cells. Basically, the interference coordination involves certain restrictions in the frequency domain for the settings of both links in a cell and for the control of interference between cells. Transmission of power is restricted in parts of the spectrum in a cell, the interference in the nearby cells in this part of the spectrum is reduced[29]. This part of the spectrum can be used to provide higher data transmission speeds for users of the cell nearest or neighbor. In essence, the factor of frequency reuse is different in different parts of the cell (see Figure 2.12).

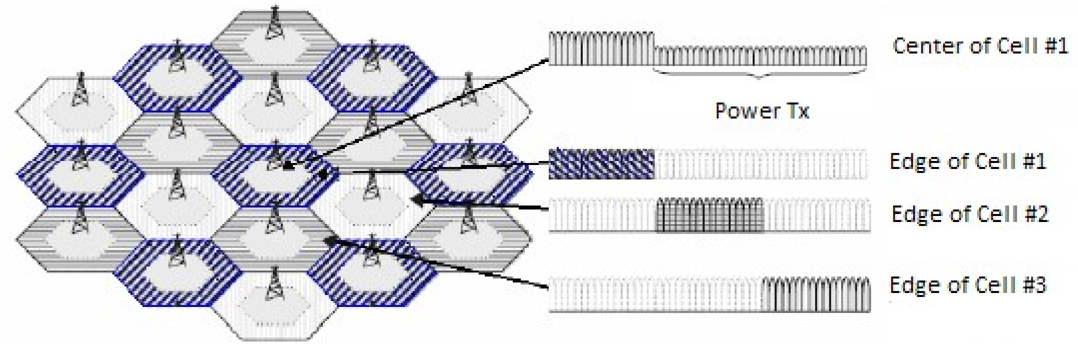


Figure 2.12 Coordination of interference between cells, where parts of spectrum is restricted in terms of power transmission

We need to know that the co-ordination of interference between the cells is mainly a configuration strategy, for the situation of the cells close together. This means that it is interference coordination is largely a matter of implementation and hardly visible in the specifications. This also implies that such coordination can be applied only to a selected set of cells, depending on the requirements set up by a particular deployment.

2.3 Selective retransmission support.

The schema type to retransmissions selective called Hybrid ARQ (HARQ) with fast combination, is used in LTE. The HARQ is the combination of codes of error correction (FEC) with an approach to handle the errors of relay called ARQ (Automatic Repeat request), used in virtually all modern systems of communication. In a schema ARQ, the receiver uses a failure detection code, usually a cyclic redundancy check (CRC), to detect if the package is received in error or not. The HARQ uses the error correction code to correct a subset of all those errors and is based on the detection of errors to detect errors incorrigible. The packets received erroneously are discarded and the receiver requests the retransmission of packets damaged. However, despite the fact that the package has not been possible decoding, the signal received still contains information, which is lost by the elimination of the packets received erroneously. This deficiency is handled by the system HARQ with rapid combination. In the HARQ, received packets with error are stored in a memory, and they are later combined with the relay for a single combination of packages that is more reliable than their elementary.

The relay on any system HARQ, by definition, must represent the same set of bits of information as the original transmission. However, the collection of bits is encrypted transmitted in each relay can be selected in a different way. The HARQ with fast combination is therefore classified inside a method of combination of packages and incremental redundancy, depending on whether the bits broadcast must be identical to those of the original transmission or not.

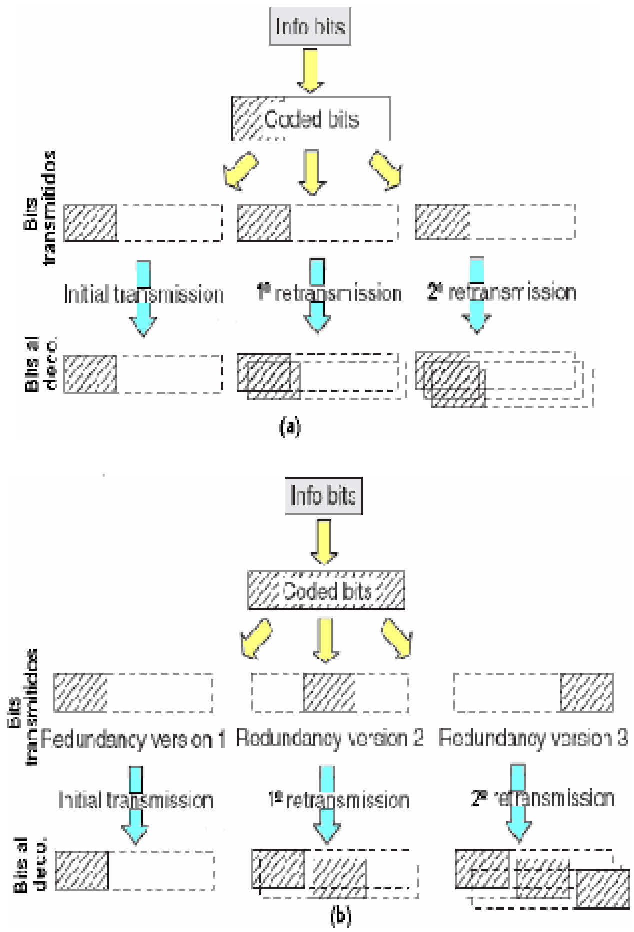


Figure 2.13 (a) Chase combining , (b) Incremental Redundancy

For many similar reasons that in HSPA, LTE uses this system to allow the terminal a rapid application of broadcasts, the wrong reception of the transport and by providing a tool for the adaptation of the speed of transmission including. The retransmissions are requested rapidly after each packet transmission , which minimizes the impact on the performance of the user from the erroneous reception packages. The increase in redundancy is used in the fast combination and buffers receivers with soft bits to be able to make a soft combination between attempts to transmission.

In the soft combination, radio signals received from different locations are combined coherently before decoding. In this way you will get much better benefits, not only does it gets a diversity gain, but also a power gain of the order of 2-3 dB. However, this strategy requires more memory in the terminals to store the soft bits in each radio link and that the transmissions between cells are synchronized in a certain range[21].

2.4 Multiple Antennas

LTE has the characteristic of being compatible with the support of multiple antennas at both the base station and in the terminal as an integral part of the specifications. The use of multiple antennas is the key technology to reach the objectives more competitive in the performance of LTE and are used in different ways (see Fig. 2.14):

. Multiple receiving antennas can be used in a different way. For the transmissions of the uplink, it has been used in many cellular systems for several years. However, as the reception with double antenna is the reference line for all the terminals LTE, the performance of the downlink is also best taken advantage. The easiest way to use this system is the diverse reception classic to suppress the fading, but the additional benefits can be achieved in scenarios of interference limited if the antennas are also used to not only provide the diversity against this, but also to remove the interference.

. The transmission of multiple antennas to the base station, can be used to transmit various and different types of beamforming. The main objective of the beamforming is to improve the reception SNR, and possibly to improve the capacity of the system and coverage.

. The multiplexing space, referring to the MIMO system, using multiple antennas at both the transmitter and the receiver, is the support for LTE that gives rise to a higher speed of data transmission, allowing the channel conditions, with scenes of limited bandwidth for the creation of several parallel channels.

As an alternative or supplement to the reception with multiple antennas, the diversity and "beamforming" can also be achieved through the implementation of multiple antennas at the receiver side . The use of these antennas to transmit is important primarily for the downlink , i.e. in the base station. In this case, the use of multiple antennas to transmit provides an opportunity without the need to add receiving antennas and a corresponding reception in a chain to the mobile terminal. On the other hand, due to reasons of complexity of the use of multiple antennas to transmit on the uplink, i.e. in the mobile terminal is less attractive. In this case, it is usually preferable to apply additional antennas for reception and corresponding reactions in the receipt of the base station.

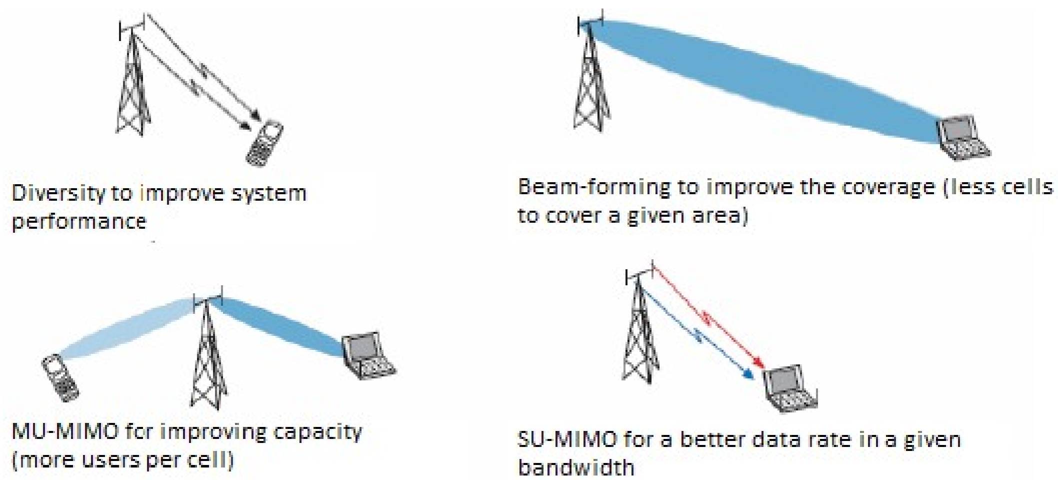


Figure 2.14 Multiple antenna techniques in LTE

In general, the different techniques of multiple antennas are beneficials in different situations . For example, in the low ratio of SNR and SIR (signal to interference), MIMO provides benefits relatively limited. On the other hand, in these scenarios of multiple antennas in the hand transmitter must be used to increase the relationship SNR/SIR by means of the beamforming. On the other hand, in situations where the relationship of SNR and SIR is high, for example, in small cells , increasing the quality of the signal that provides, in addition profits relatively minor as feasible speed of data transmission, are mainly limited to the bandwidth instead of SNR/SIR. In these situations, the spacial multiplexed should be used instead to take full advantage of good conditions in the channel. The system of multiple antennas used is under the control of the base station , so you can select an appropriate plan for each transmission.

2.5 Multicast and Broadcast support

The diffusion or broadcast of multiple cells, involves the transmission of the same information from multiple cells. Through the exploitation of this in the terminal by the effective use of signal strength from multiple sectors can be achieved a substantial improvement in coverage (or a great dissemination of speed of data transmission). This is already developed in WCDMA, where in the case of broadcast/multicast of multiple cells, a mobile terminal can receive signals from multiple cells (see Figure 2.15) and be activated by a combination of soft these within the receiver.

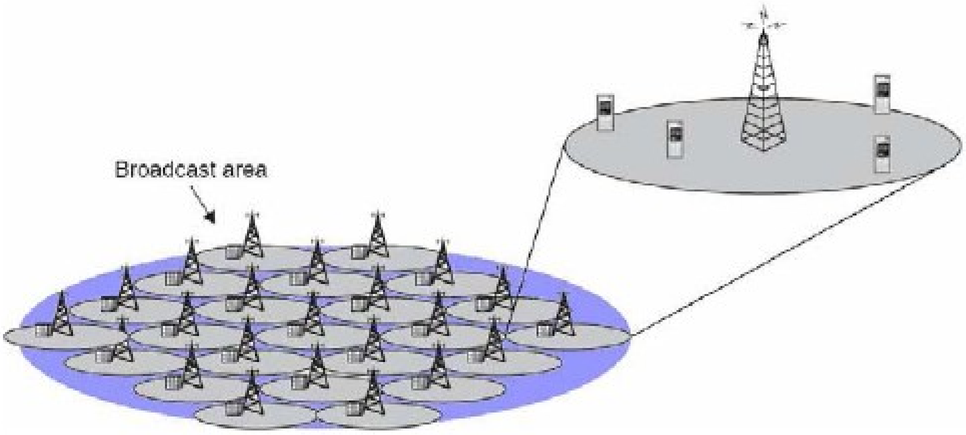


Figure 2.15 Broadcast scenario

This has to LTE a step beyond to provide greater efficiency of dissemination multicelda. Through the transmission of identical signals from multiple sectors of cell (with identical coding and modulation), but also synchronizing the time of transmission between cells, the signal to the mobile terminal shall be published exactly as a transmission signal from a single sector of the cell and subject to the spread multi-path. Due to the stability of the technical OFDM, the spread multi-route is also referred to as the multicast transmission-Broadcast Single-frequency Network (MBSFN), not only serve to improve the received signal, but also to eliminate the interference between the cells. As well, with OFDM, the performance broadcast/multicast multiple cells eventually may be limited only by noise and can then, in the case of small cells reach extremely high values.

2.6 Spectrum flexibility

A high degree of flexibility of the spectrum is one of the main features of the access radio of LTE. The aim of flexibility is to enable the deployment in different spectra , with different characteristics, including different arrangements or duplex systems, different frequency bands of operation and the different sizes of available spectrum.

2.6.1 Flexibility in the duplex systems

An important part of the requirements of LTE in terms of flexibility of spectrum, is the possibility of deploying access radio based on LTE in both spectra, matched and unmatched , these must support LTE in both the frequency division and the division in time based on the duplex systems. Frequency Division Duplex (FDD), as illustrated in Figure 3.16a, implies that the transmission of uplink and downlink occur in different frequency bands when they are sufficiently separated. Time Division Duplex (TDD), as illustrated in Figure 2.16b, implies that the transmission of uplink and downlink occur at different time intervals do not overlap. Therefore, TDD can operate on the spectrum non-paired while FDD requires the spectrum couplet.

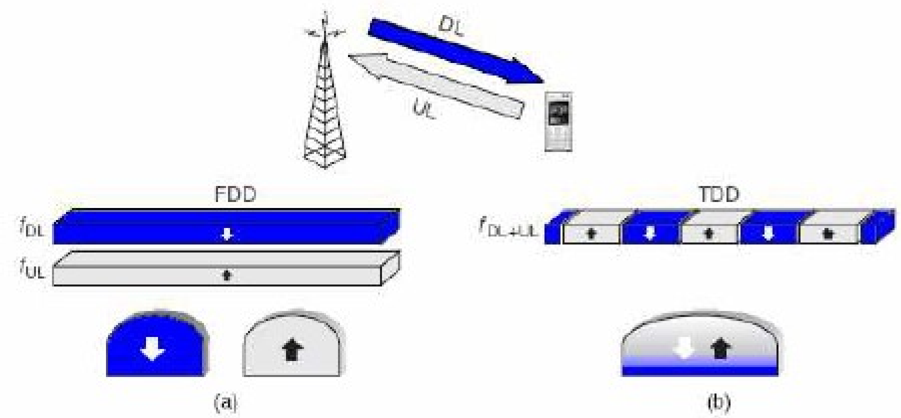


Figure 2.16 (a) FDD **(b) TDD**

Support for both spectrums, is part of the beginning of the specifications Release 99 through the use of FDD based on access radio of WCDMA/HSPA in the allocations and paired TDD access-based radio of TD-CDMA/TD-SCDMA, in allocations not paired. However, this is by medium of relationship of different access technologies radio and, consequently, the terminals of qualified operations FDD and TDD are relatively rare , in contrast, LTE supports both operations within a single access technology radio, highlighting a minimum deviation between FDD and TDD for the basis of the access radio. The difference between the two operations lies mainly in the structure of the frame) illustrated in Figure 2.17.

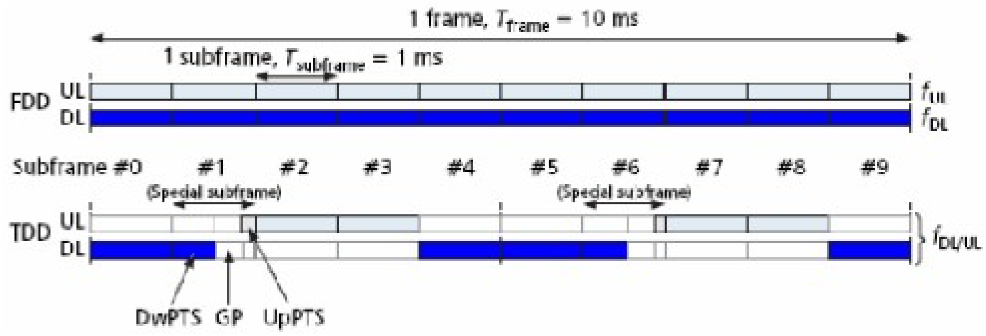


Figure 2.17 Frame structure

In the case of operation FDD (upper part of Figure 2.17), there are two carrier frequencies , one for the transmission of uplink (fUL) and one for the downlink transmission (fDL). Thus, during each frame, there are ten sub-frames of uplink and ten sub-frames of the descending, and the transmission of both can occur simultaneously in a cell. Accordingly there is a relationship one-on-one between the sub-frames of uplink and downlink , which are exploited in the design of signalling connection control.

In the case of operation TDD (bottom of Figure 2.17), there was only one carrier frequency , and the broadcasts of uplink and downlink always are separated in time, this also is carried out within the cell. As the number of subplots of uplink and downlink can be different, there is no correspondence one-to-one among the subplots, giving rise to some minor differences in the signalling connection control design between the FDD and TDD.

2.6.2 Flexibility in frecuency band of operation

LTE is predicted to development on the basis of the need to know when and where the spectrum may be available, either for the allocation of a new spectrum for mobile communication , such as the band of 2.6

GHz (see Figure 2.18), or by the migration to LTE of spectrum currently used for other technologies, such as the second generation of GSM systems, or even the radio technologies non-mobile such as the current spectrum of broadcast. As a result, it requires that the access LTE radio must be able to operate in a wide range of frequency bands, from 450 MHz to 2.6 Ghz.

FDD			
Banda	"Identificador"	Nombre banda	Frecuencias (MHz) UL/DL
1	IMT Core Band	2.1 GHz	1920-1980/2110-2170
2	PCS 1900	1900 MHz	1850-1910/1930-1990
3	GSM 1800	1800 MHz	1710-1785/1805-1880
4	AWS (US & other)	1.7/2.1 GHz	1710-1755/2110-2155
5	850	850 MHz	824-849/869-894
6	850 (Japan)	800 MHz	830-840/875-885
7	IMT Extension	2.6 GHz	2500-2570/2620-2690
8	GSM 900	900 MHz	880-915/925-960
9	1700 (Japan)	1700 MHz	1750-1785/1845-1880
10	3G Americas	Ext 1.7/2.1 GHz	1710-1770/2110-2170
11	UMTS1500	1500MHz	1428-1453/1476-1501
12	US 700	Baja 700 MHz	698-716/728-746
13		Alta 700 MHz	776-788/746-758
14			788-798/758-768
17			704-716/734-746

TDD		
Banda	"Identificador"	Frecuencias (MHz)
33,34	TDD 2000	1900-1920 2010-2025
35,36	TDD 1900	1850-1910 1930-1990
37	PCS Center Gap	(1915) 1910-1930
38	IMT Extension Center Gap	2570-2620
39	China TDD	1880-1920
40	2.3 TDD	2300-2400

Adicional (FDD&TDD)		
	3.5 GHz	3400-3600
	3.7 GHz	3600-3800

Figure 2.18 Currents Bands 3GPP, in red main LTE

The possibility of operating a technology access radio in different frequency bands is nothing new. For example, the triple band GSM terminals are common, capable of operating in the bands of 900, 1800 and 1900 MHz. From the point of view of access to the functionality of radio, this does not have a limited impact on the specifications of the physical layer of LTE, which does not assume any specific band[15]. What can be differentiated in terms of conditions between the different frequency bands that are mainly the RF requirements more specific such as; allow maximum transmission power, requirements and limits on out-of-band-emission (emissions outside of the bandwidth), etc. One of the reasons for this, is that the external constraints imposed by regulators, can vary between the different frequency bands.

2.6.3 The bandwidth flexibility.

Related to the possibility of developing the access radio of LTE in different frequency bands , is the opportunity for LTE to enable it to operate with different bandwidths of transmission in the uplink and downlink. The main reason for this is that the amount of spectrum available for LTE may vary considerably between different frequency bands and also as a function of the exact situation of the operator. In addition, the possibility of operating in different spectrum allocations, it gives the possibility of gradual migration of the radio spectrum other access technologies to LTE.

LTE supports the operation in a large range of spectrum allocations, reached by a transmission bandwidth flexible that form part of the specifications 3GPP. Efficiently supports a very high speed data transmission when the spectrum is available and when the need for a wide transmission bandwidth, however, a large amount of spectrum are not always available, either due to the band of operation or a gradual migration from another access technology radio, in which case LTE can operate in a transmission bandwidth more narrow. Obviously, in such cases, the maximum achievable on the speed of data transmission will be reduced proportionately. More specifically, as illustrated in figure 2.19 , LTE allows you to register for a global system of bandwidth from small frequencies as 1.4 MHz up to 20 MHz, where the highest are required to provide increased speed of data.

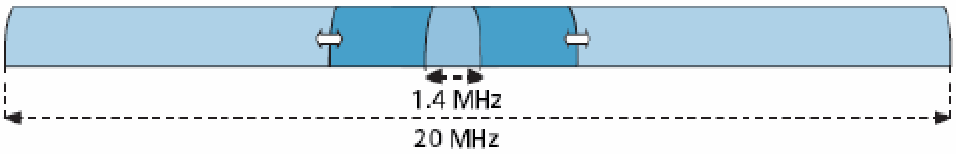


Figure 2.19 LTE Spectrum Flexibility

All terminals LTE support the greatest bandwidth. Unlike previous cellular systems, this offers the opportunity to operate for different bandwidths in uplink and downlink , allowing the use of asymmetric spectrum.

2.7 Modulation Schemes

A direct way to provide high data transmission speeds within a given bandwidth, is the use of modulation of a higher order, which implies that the alphabet modulation is extended to include more alternatives of signalling and for more bits of information are allowed to make communication by means of the modulation of symbols.

The modulation schemes available for user data in the uplink and downlink are QPSK, 16QAM and 64QAM. The first two are useful in all of the devices , while the support to the 64QAM on the uplink is the ability of the equipment user.

In the case of the QPSK modulation, the alphabet of the modulation consists of four different alternatives for signalling, which can be illustrated as four different points in a two-dimensional plane (see Figure 2.20a). With 4 different alternatives of signalling, QPSK allows up to 2 bits of information that are not communicated during each interval of modulation of symbol. Through the extension 16QAM (Figure 2.20b), 16 different alternatives for signalling are available allowing up to 4 bits of information. The extension to 64 QAM (Figure 2.19c), with 64 different alternatives for signalling, allows up to 6 bits of information that are reported by range of symbol. At the same time, the bandwidth of the signal that is transmitted in a principle is independent of the size of the alphabet of modulation and mainly depends on the modulation rate, i.e. the number of symbols of the modulation per second. The maximum bandwidth used is expressed by bit/s/Hz.

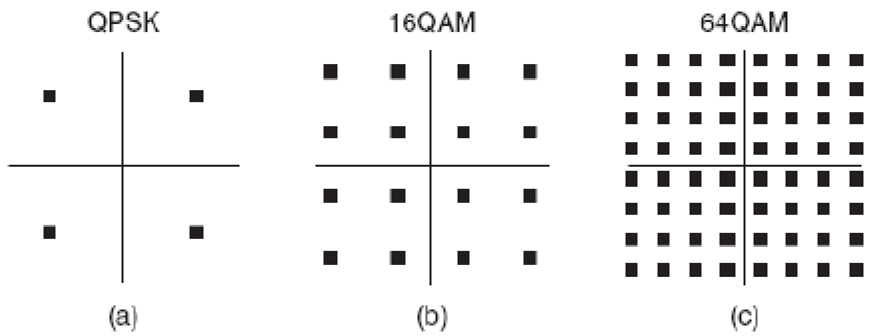


Figure 2.20 LTE Modulation constellations

The use of the modulation of a higher order provides a better use of bandwidth, making possible the transmission of data at high speeds, however, this increase goes hand in hand with a reduced immunity to noise and interference, why it is preferred 64QAM only when the channel conditions are favorable, as for example, when the terminal is static and close to the base station (see Figure 2.21). We can see in the figure, which to adverse conditions , when you are away from the base station and on movement, you must use modulation QPSK.

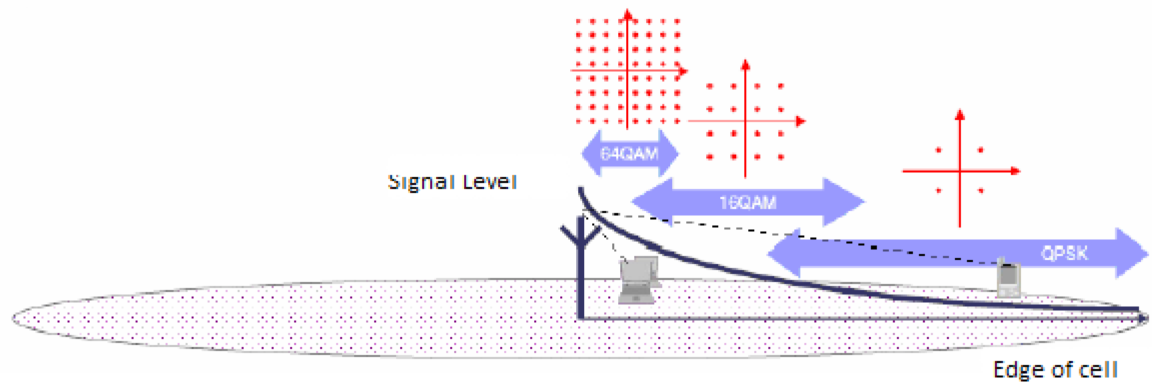


Figure 2.21 Adaptative modulation

The choice of the type of modulation and rate coding is done based on information from the channel that the terminal sends to the base station. The equipment user evaluates the conditions radio link and, according to this, it sends an indicator to the base station, called CQI (Channel Quality Indicator).

MANAGEMENT

2.8 THE OPERATIONAL CHALLENGE

New business opportunities in the face of decreasing revenue due to competition and business - disruptive technologies is a necessity for Telecom operators in today ' s world. Triple play is a tool to drive the business of broadband to mass market. Business growth will be achieved via a customer. The customer is no longer separate from the technical structure of the service(s). This implies an integrated approach regarding the service offer (fi xed/mobile/Internet) toward a world of full service convergence. Multiple play strategy may lead to the definition of new services or the enhancement of existing services. This will be built on the presence/availability of the voice line in the home toward comfort and high quality sound, e.g., high - definition (HD) voice and the mixing of voice and data. Users are not only looking at the level of functionality for a given price, they are also considering the level of trust they might have for a new service.
Another element to consider is the economic investment network operators will have to face in new broadband technologies which are fiber network infrastructure, built largely from scratch. Network operators need to find new sources of revenue able to provide reasonable return - on - investment (ROI).

Successful entry into the new business paradigm and creation of new sources of revenue are essential. Definition of a clear and fair regulatory framework is also necessary. In such an open communications world, protection of personal data (various identities like names and addresses, family or profession, location or history of purchases) is already an inescapable customer requirement.

2.8.1 Service Offer Requirements

There are many options that can be taken at the marketing and commercial levels. Triple play services characteristics, i.e., Internet access, throughput, TV broadcast, video and the potential penetration expected are essential features in the design of network and IT architecture and operation.

In order to properly design the network and IT infrastructures to support targeted triple play services, one must take into account factors like technical eligibility of customer line, deployment pace, encoding techniques, service nature, and QoS for the particular service access.

In a situation where most of the triple play offers are accessed today on copper, service eligibility (copper quality, line length, and copper cable diameter) of the access lines is mainly based on the technical capability of the line to carry the requested throughput. Encoding technique is also a parameter that could influence eligibility of the line to certain services.

It is important to know from the outset the true nature of the triple play services sold. For instance, when accessing TV service, it is crucial to know if the access is restricted to one program or if simultaneous access to several programs is part of the service. Additional parameters like peak bandwidth requested, service level agreement (SLA) and QoS level, mean time to recovery (MTTR) requirements, Nomadism envisaged or not, typical customer density average, customer distance and trends in bandwidth evolution. Several future milestones in service development or technology evolution need to be anticipated because they can have a strong impact on the chosen path of evolution. Examples are High - Speed Downlink Packet Access (HSDPA) which will multiply 3G backhauling scalability needs by 5, 3G radio access network (RAN) traffic transported on Gigabit Ethernet IP (GE IP)...

2.8.2 The Technical Challenge

To implement triple play and quadruple play services, with different technical characteristics and requirements, in infrastructures which have been built a long time ago to deal initially with a single service, is an interesting challenge. It is well known that analog circuit connection access to the PSTN has supported voice and data (fax, Minitel, tele - aplicaciones de detección, y así sucesivamente). One can also point out that ISDN is a tremendous standardization and implementation effort that benefited from digitalization of information supporting both circuit and data connections over unique copper access.
Broadband fixed and mobile technologies are today providing exceptional opportunities for Telecom operators to transform their business and their infrastructures. These services require closer network and IT, bringing together fixed and mobile infrastructures. The target is new innovative services and cost savings through common service enablers.

2.8.3 The Technical Tool Box

2.8.3.1 Customer Equipment

Contributes substantially to enrichment of service offers like voice (fixed and mobile), WebTV, broadcast TV, VoD, digital content, tele - actions, interactive video services, and so on. It applies to fixed and mobile handsets, PCs, TV sets, STBs, PLT (power line transmission) equipment, modems, residential gateways, wired, and wireless LANs.

2.8.3.2 Access Line and Aggregation/Backhaul Networks

When copper lines do not have the right characteristics to carry the requested bandwidth, satellite access can also be used to extend the number of customers eligible for broadband. But the main issue, essential for broadband service evolution, is the access network architecture. This includes the transformation of digital subscriber line access multiplexer (DSLAM) in multi - service access nodes (MSANs), the move towards an access using a non - specialized virtual circuit (VC), the move from ATM techniques towards Gigabit Ethernet techniques in aggregation and the reallocation of broadband remote access server (BRAS) functions to the MSAN.

2.8.3.3 Backbone Networks

This covers transmission equipment, IP routers, internetworking gateways, etc. The inherent characteristics of IP protocol and networks impose various implemention techniques, aiming to increase transport QoS such as multi - protocol label switching (MPLS), virtual private network (VPN), Diffserv, etc., in order to be able to carry the most demanding services like voice, real time video and TV. In the field of video content distribution different content distribution network (CDN) techniques and architectures have been developped for cost and QoS reasons.

2.8.3.4 Control Platform

One can notice that they are more and more based on the same computing technology and techniques than those used by Service Platforms. In the framework of IMS (IP Multimedia Subsystem), these control functions are more standardized than before, since a quite detailed functional architecture and a set of interfaces have been specified by 3GPP and TISPAN Standards Development Organizations (SDOs). IMS - controlled services give assurance to customers that the service offered remains fully controlled by operators.

2.8.3.5 Service Platform

They are the place where a number of innovative computing features are implemented, aiming at cost reduction, enhanced security, and better time - to - market (shared software between services, reusable developed software components, virtualization, etc.).

2.8.3.6 IS Equipment

The overall architecture of IS is a subject in itself and needs a deep transformation to serve triple play and quadruple play. All these elements need to be synchronized when working and reacting to each other in real time. All these elements need to be synchronized when working and reacting to each other in real time. This is the job of architects. When overall design and development of all pieces have been achieved, there is one last thing to do, that is to check that what has been conceived and developed is working together as planned.

2.8.4 The Global Vision

Today, with triple play there are new correlated actions to perform, i.e., service type requested analysis, mobility or nomadism and location update provision, appropriate required resources to set - up depending on the service request and the terminal used, security measures (IP open world), content provision (with partners), other services and content blending if required, usage monitoring, and so on.

Network operators have to elaborate global architectures combining agility and robustness. To do so and to take into account the world of complex interactions, an overall architecture is required. This will be the job of architects who have to think and act globally.

2.8.4.1 Vision for an Overall Architecture Supporting Triple and Quadruple Play

This vision is based on the following assumptions:

1. Devices / home network are an inherent part of the service infrastructure.
2. MSAN has become the unique access point (access technology agnostic).
3. A common control access technology takes care of the services and associated resources.
4. Open interfaces for customized services (APIs) are used by third - party developers.
5. Packet transport is based on IP enriched with MPLS and Diffserv. mechanisms.
6. A single layer for service platforms exists (access technology agnostic).
7. A single IS for all applications exists (access technology agnostic).

2.8.5 Key Issues to Consider When Designing Network and IS Infrastructures for Triple and Quadruple Play

There are a number of points that require particular attention when designing network and IS infrastructures for triple and quadruple play services. In the field of traffic, there is a necessity to design network architecture and network elements to take care of traffi c blocking points related to access to broadcast programs.

In the field of the required QoS for broadcast television, there are some peculiarities:

1. Permanence of service should be ensured during periods that are outside traditional working hours.

2. Image quality can be maintained without any pixelization thanks to technology like forward error correction (FEC) on the access line. A New fully IP based mechanisms are under development that will replace the ATM based VP.

3. When TV channel selection is done in the network, maintaining zapping time delay requires an Internet Group Management Protocol (IGMP) interaction between STB and DSLAM. The time delay of that interaction should remain small compared to synchronization time.

4. VoIP service quality is a critical issue, one solution could be to choose a dedicated virtual circuit (VC) for Voice, but the drawback is the access management and the ATM layer to implement and to manage.

2.8.5.1 Convergence and Mutualization

In an industry where fixed cost is important, there is a motivation to aggregate traffic, to group elements in order to decrease the average cost per unit. This logic, also found in IP networks where the granularity of the optical transmission links between IP routers is either 2.5 or 10 Gbit/s wavelength, has as a consequence, that any additional demand arriving at the IP backbone network is generally marginal in terms of cost per bit transported. Should be some assurance that forecasted demand will fill up the shared infrastructure, otherwise the cost of the new offer may increase dramatically. Another element to consider is the fact that mutualizing means concentrating different traffic demands on a limited number of equipments or systems. Failure of one of them may have an effect on several service offers. In such a condition, reliability of the network is a very first priority via redundancies to guarantee the required unavailability objectives. Load sharing or take over mechanisms need to be specified. The unavailability objectives should be explicitly specified at the very beginning of the service and network architecture design. Calculation of the projected unavailability should take care of equipment failures but also the unavailability resulting from software updates and reloading time delay. In the field of service and control platforms, the type of redundancy to adopt will depend on the type of service and data manipulated. Indeed, data required for service handling should be accessed by the backup platform.

2.8.5.2 Quality of Service (Q o S)

They are parameters linked to service continuity, session call set - up, and transport quality.
QoS Parameters are expressed via service unavailability objectives for one customer or a group of customers. The customer experience with telephony and broadcast TV is rather good today. However, broadband access via a number of services has, by construction, more complex architecture, more equipment, and a higher unavailability than telephony access or aerial TV. One particular point to look after is the unavailability of DSLAMs.

- QoS Session Call Set -up Quality Parameters: These parameters are only pertinent for services requiring session establishment.

- QoS Transport Quality Parameters: May depend on various factors like line attenuation linked to the length of the line, diaphonic disturbances, impulse noise, etc. These variations result in unacceptable pixelization in video signals. Possibilities exist to improve the situation by using redundancy of the video signal allowing FEC.

In IP networks, one important parameter is the packet loss rate. IP packet loss may result from temporary router overload or from failures of equipment that require a certain time for the network to reconfigure the routing tables. The impact of such packet loss is very much dependant on the type of service.

In the audio domain, voice quality of VoIP again becomes an important issue. Besides the IP transport mentioned above, the quality of speech coding is at stake. Packet encoding of voice signals introduces time delay and transcoding effects deepen the voice quality. Network operator architects should try, to the extent possible, to obviate network transcoding that is another drawback in traffic concentration on transcoding equipment.

2.8.6 Customer Premises Equipment (CPE) and Home Network

hese new capabilities of hand sets and home networks have resulted in a number of interactions with functions located in networks or IS. When dealing with various service types, this has introduced a lot of complexity in terms of customer usage. It is therefore a fi rst priority from an operator perspective to simplify the digital home experience through development of “ plug and play ” equipment.

2.8.6.1 The Home Network Complexity

From single play to multiplay, the number of connected devices is going to increase (set top box, connected TV, infrastructure devices such as PLC plugs and wifi extender, PC, laptop, UMA phones, SIP phones, game consoles, etc.). All these devices belong to the same home LAN whose complexity is likely to also increase. These devices get access to various classes - of - service, locally and remotely, like voice, video, TV, Internet, tele - detection applications, and so on. Inside cabling is also a diffi cult issue. Usually, traditional telephony cabling existing in homes is not sufficient to transport high bit rate. Therefore operators may have to propose to their customers PLT (power line transmission) or wifi technologies in order for them to have TV sets or PCs located far from the STB location.

2.8.6.2 Distribution of Functions between Network and IS Platforms and Residential Gateways

In classical networks, customer equipment was limited to network termination and quite simple hand sets. In classic telephony, the end of numbering for the called number, belonging to an open numbering plan, was performed by the local switching center. The situation with VoIP, accessed through residential gateways (RGWs), can be notably different and performed by either the RGW (by time out, which is simpler but increases the post dialing delay, or by received digit number analysis, based on data sent by the network via a specific protocol) or the service platform. With the installation of RGWs, there are a number of decisions to be made that should balance the pros and cons of allocating the function to the RGW or the service platform.

One important point to keep in mind is the fact that millions of RGWs are disseminated and require remote reliable and fast software upgrade mechanisms. The experience shows that the greater the number of functions implemented in RGWs, the more the customer calls arrive to the after - sale service. This results in significantly higer OPEX costs. These facts will certainly determine the limit of functions and data installed in RGWs.

2.8.6.3 The Home Network Paradox

Operators need to consider the home network as the last meter/yard of their network. On the other hand, they cannot control it totally since, for instance, deployed wireless technologies within the customer environment, have no guarantee as far as bandwidth, delay, and characteristics are concerned. Therefore, the delicate question of the limits of responsibility is raised. In PSTN it was clear. But with multi - play, the question is, where is the internal ending interface? The first approach could be to include all the devices provided by the operator (RGW, STB, WIFI extender, PLT plugs, etc.). Then how far must the operator (alone or with partners) manage connected PCs, connected TVs, and so on?

2.8.6.4 The Home Device and Applications

Self - installation could be an operator ' s strategy but the end - user may need to help set up his/her home LAN and services and maintain the right QoS. Assistance may be given through telephone. On their side, operator technicians on the ground need tools for home network infrastructure installation and performance monitoring for PLC, wifi...Finally, operator hotlines will need diagnosis and monitoring tools to remotely manage the home network.

2.8.7 Access Lines

For copper lines, network operators have to decide which of the xDSL techniques to use (ADSL 2, reach ADSL, VDSL, etc.) in order to make the concerned copper lines eligible, following economic analysis, to the targeted services and coverage.

Copper lines, being sensitive to noise impairments, especially for high bit rates, the implementation of dynamic line management (DLM) on DSL lines is recognized to give better conditions to offer triple play.
For optical lines, choice of fiber depends significantly on the considered geographical areas in a region or country. Operators may have to consider not only investment in their own optical fiber network but also, use of possible wholesale offers and possible associations to share investment. Today, operators´s strategy is certainly pushing copper to its full potential and is leveraging satellite availability for TV broadcast. In the fi eld of optics, Network operators are choosing either FTTH (GPON - based or point - to - point) or mixed optics and VDSL on copper (FTTB, FTTC). But massive deployment is very much linked to the regulatory regime and on acceptable return on investment (ROI).

2.8.8 Access Networks, Aggregation, and Backhauling

Dramatic increase in traffic requires adoption of new technology that provides a breakthrough to manage traffic growth. For cost reasons, Ethernet technology is ramping up in aggregation networks (DSLAM with Gigabit Ethernet network interface). Concerning access line connecting nodes, DSLAM moves towards true multiservice access nodes (MSAN) with IP routing capabilities, supporting fiber and DSL, residential, business, wholesale, and mobile backhaul.

2.8.9 An Illustration of the Fixed Access Network Transformation from Internet Access Support to Triple Play Support

In order to protect the different flows, some operators have chosen separated access paths for the various services (e.g., one VC for Internet, one for voice, and one for TV). Aggregation technology has moved from ATM to Gigabit Ethernet technologies (mainly for economic reasons in front of the huge increase of audio visual traffic, etc.). DSLAM technology has also evolved toward full Gigabit Ethernet (GEth) technologies. New service and control platforms have been developed for voice, TV, and video.

New principles for multiservice target architecture currently under intensive thinking refer to “ full routed ” mode box using mono virtual circuit (VC), end - to - end QoS based on Recommendation IEEE 802.1P and on IP priority mechanisms, access sharing simplifi cation (i.e., mono VC and mono IPv4 or IPv6 @ddress, extension of IP to MSAN and use of DHCP for all services via a utualised DHCP Server).

2.8.10 Backbone Networks

What is at stake is the capability of IP networks to become the universal transport network. Key issues turn around the ability of IP transport network to be able not only to absorb the huge increase of traffic coming from Internet access, peer - to - peer, and other multi - play operations, but to satisfy the QoS requirements of voice, TV, and other real - time video in terms of packets lost and latency in normal and abnormal conditions.

2.8.10.1 Content Delivery

Different content delivery network (CDN) architectures can be implemented using unicast and multicast techniques.
In centralized architecture, all the servers are localized at the network termination (NT)/network head location. Transmission of content is performed via a unicast flow, per client, from the source point to the residential gateway.
Caching and CDN technology improve VoD (and Web TV distribution) in the core network by reducing the bandwidth consumption over the network. Reduced server load and reduced latency are also benefits to expect. Cache and CDN servers can be centralized for servers with low audience programs or they can be located at point - of - presence (POP) level for servers with the most popular programs. Unicast flow distributes contents from centralized or decentralized servers to the residential gateway.

2.8.11 Service and Resource Control

2.8.11.1 Core Control and Application Servers

Service and resource control based on IMS standards is a way for network operators to guaranty that QoS and security of services sold are well under their control. In the overall IMS architecture one can point out the importance of application servers (AS), among other important functions like home subscriber servers (HSS), where the service customer data are stored. These application servers contain the service logic.

2.8.11.2 Service Platforms

One can say that it is, in many ways, the fulfillment, in NGN, of the Intelligent Network ambition in the public switched telephone network (PSTN) and public land mobile network (PLMN). Service platforms are considered by operators as a key tool for providing quickly innovated services.

2.8.11.3 Information System

It is more than ever the case that quick introduction of new and innovative offers like bundles, multi - play, etc., provide a means to stay competitive and become a full convergence operator.
Concerning the second point, the imperative move toward new business models, replacing or completing the traditional ones, requires IS architecture to be agile, open, and secure. Optimizing their market presence through partnerships (Telco 2.0 model) leads to more and more interaction and interoperability with third parties (content suppliers, audience, partners, distributors, MVNOs, wholesale, etc.). Customer management, therefore, has to be extended to prospects as well as Internet users. New business models like audience, content, etc., drive revenue types far from Telco ' s traditional revenue streams. Last but not least, multiple external (including customers) accesses to IS will increase the requirement for security.

There are two additional recent and important aspects to take into account:

- First, an online - driven customer relationship is becoming key today, where customers/end - users can manage their own services (self - service). This is a way to reduce OPEX (automated customer processes, simplifi ed and consistent customer journey across all sale channels) and get higher quality, higher efficiency, and higher customer satisfaction via quick time to market. This will result in better customer loyalty, knowing that customer experience and customer satisfaction are the two success pillars to reduce churn. This new approach, increasing customer interactions, also provides useful additional customer knowledge to prepare new pertinent offers and to increase sales.

- Second, leveraging of this customer knowledge asset is an important potential advantage. Customers should be seen from different angles, such as contract holder, end - user, family, communities, etc. This will allow customer personalization (e.g., business intelligence to push offers adapted to customer needs and habits) and will give opportunity to monetize the audience. This might lead to enhanced customer knowledge, up - selling and cross - selling, and, finally, to making the most of all customer, prospect, and Internet user interactions.

2.8.11.4 The Customer Front - End

The customer front - end manages the user relationship through all channels and all the customer interactions like self - service as well as points - of - contact in direct and indirect distribution. Its scope covers the order capture process, including real - time platform responses to availability requests, the corresponding resource assignment done, the sale story board, and the intelligence of the interaction process. Front - end also covers order configuration and the offer catalogue.

One of the main challenges of customer front - end evolution is to enhance the quality of the user interface by providing a simple, intuitive customer journey, with dialogue tailored to the customer profi le and sales channel. Another challenge is to boost online operation with the aim of having the most requests processed in real - time.

The portal layer aims to perform single authentication and identity management. It plays the role of a single syndication platform to collect back - end data. The presentation layer function is to adapt presentation to a particular channel, a particular device, and a particular user. The business layer is the place where common business logic has to be defined for all channels in order to allow inter - channel activity. This business logic contains the business rules, the access right management, etc. The business layer is the point to invoke services to the back - end.
It should be noted that the front - end, which does not store persistent data, accesses the customer platform or the service platform for service requests and/or repository requests. Tools required for troubleshooting, for advanced test and diagnosis, and for advanced sales are also part of the front - end.

2.9 THE OPERATIONAL CHALLENGE

An operating model is defined as the management scheme of Network, service platform, and IS infrastructure during the run phase in the service life cycle (three phases can be identified: think, build, and run). The run phase covers provisioning, delivery, monitoring, maintenance, performance analysis, billing, and management.

Multiple - play service characteristics imply more precision in the operation. Indeed, if the functional behavior of a set of interconnected equipment may be acceptable for one type of service, it might not necessarily be the case for another, even if requested by the same access. This is the reason why, besides traditional monitoring of interconnected pieces of equipment and functions, there is a need to look to individual services from an end - to - end perspective.

Therefore, in the context of a triple play service, it is required to support an end - to - end service customer view. This implies enhancement of the functional operating mode. This leads to introduction of a service management center function (SMC) for all technologies used by the services. This new function encompasses Network, IS, and service platforms from an end - to - end perspective, taking care of end - to - end QoS perceived by customers. Because the technical architectures supporting triple/quadruple play services are becoming more and more complex, the SMC is where end - to - end vision of the technical chains used by these services should be maintained. This is the right control tower to pilot service quality.

This is the case for the technical management center function (TMC) , which is responsible for technical management of the operational Network, service platform, and IS infrastructures for a given “ technology ” (one TMC per “ technology, ” i.e., transmission, IP routers, mobile radio access, fixed ADSL access, TDM –

based switches, etc.). TMCs should have full knowledge and control of the technologies used in a given infrastructure. They perform a number of important actions such as resource control and problem resolution, corrective and preventive maintenance quality analysis, crisis management, technology integration management, and planned work coordination. TMCs have to perform operations in conformance with industry standards and security requirements.

This is also the case for skill centers, which are responsible for the technical expertise related to a given technology. They are in charge of preparing, validating, and accepting the different equipment releases to be implemented and operating such equipment. The provisioning function is a traditional operation function responsible for the customer implementation using the installed resources (“ technical management of customers ”). It is usually located at the interface between sales and fi eld intervention and can be supported by the field intervention function if needed. The field operation function, also a traditional operation function, is responsible for the on - site interventions related to maintenance or provisioning and for customer interventions. The TMC remotely manages Network field operations actions, while the CCC manages customers field operation actions. The intervention dispatching function is part of the field operation scope. The last traditional operation function is the customer care center function (CCC) , responsible for the customer relationship and the after - sales service. It is the single point of contact for customers for all matters dealing with services provided by the operator. The CCC performs actions such as customer call handling (hotline) and ticket management. For non - complex problems, in particular, when they concern provisioning issues, CCC handles trouble tracking and trouble shooting. For complex issues, CCC may escalate, when required, to SMC, TMC or, if relevant, to field operations. Communication to the customers on the basis of the information received from operational and technical functions is also its responsibility. Figure 2 - 12 illustrates the central role of the SMC between CCCs and TMCs.

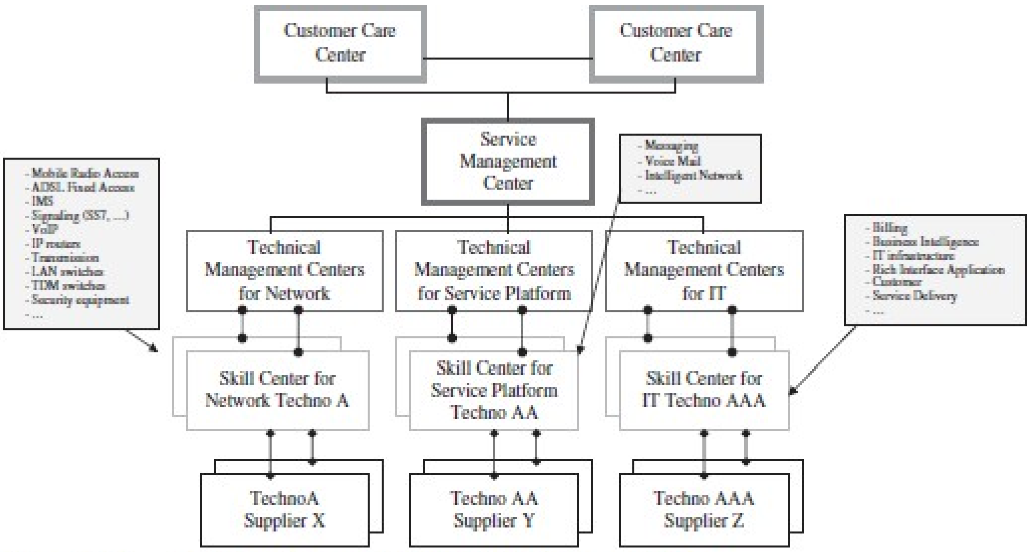


Figure 2-12. Relations between CCC, SMC, TMC, and SkCs

2.9.1 Focus on the Service Management Center Function (SMC)

The SMC ’ s responsibility is to control end - to - end QoS. SMC acts as an orientation and control tower able to translate, in technical terms for TMCs, a problem affecting customers. This end - to - end responsibility requires implementation of real - time service monitoring and perceived service quality analysis, service maintenance, service management, and operation functions and holds an essential role in internal and external communication. The real - time service monitoring function includes proactive monitoring of the behavior of the different services in order to have an understanding of end - to - end customer perception. Supervising and managing the service level agreement (SLA), e.g., monitoring thresholds, alert triggering, etc., monitoring, managing and optimizing the monitoring system are also performed. Service monitoring engineering consists of implementing and controlling all the tests needed to follow - up the QoS and adapt the monitoring tests and views to the customer perception and service evolutions. This task is essential in triple play services as technology and perception can evolve quite rapidly. The SMC is responsible for the technical QoS delivered to customers according to SLAs with the business owners. The SMC function is the single point of contact that provides information about the crisis status to the management line and business units.

2.10 THE CUSTOMER EXPERIENCE IN BROADBAND TRIPLE

There are four main phases in the customer experience: the sale, the delivery, the run and the aftersale.
During the sale phase , it is necessary to assure that customers understand what was sold to them (broadband access including the eligibility problem for copper access, VoIP with or without number portability, TV and VoD) in order to reduce the percentage of non - profitable calls from clients to the after sale desk.
In the delivery phase , the main issue is to organize the delivery in line with what was said to the customer during the sale phase. This prevents an increase in calls to the after sale desk. The run phase is also critical since it operates in real time " always on " access. The IP network is very different from past experiences on access and data networks. The after sale phase deals with after sale processes, call center activities, field operation intervention, and SMC actions. Reducing repair time and preventing useless customer calls to call centers and the consequent useless interventions on the ground are key issues to be solved.

2.10.1 The Customer Journey

The customer journey, which can be analyzed along many lines (price, device, service, sale channels, customer contacts, etc.), can be divided into six stages (Fig. 2 - 18):

A. Be aware. This is the stage where clear information and understanding of services, conditions of delivery, usage and pricing are provided to the customer by the service provider.

B. Join. This is the stage where a simple and peaceful buying experience needs to take place.

C. Set - up and fi rst use. This is the stage where a simple set - up and enjoyable first usage should take place confi rming the previous buying.

D. Use and get help. This is the stage where products are used and where the customer ' s expectation is to get the agreed service performance and the understandable right invoice and to obtain a reliable support answering his/her requests.

E. Evolve and renew. This is the stage where customer ' s needs evolve and where his/her expectation is to be informed of the operator ' s propositions (proactively or not).

F. Terminate. This is the stage where the customer is willing to terminate his/ her contract and needs to know how to proceed in a fair spirit.

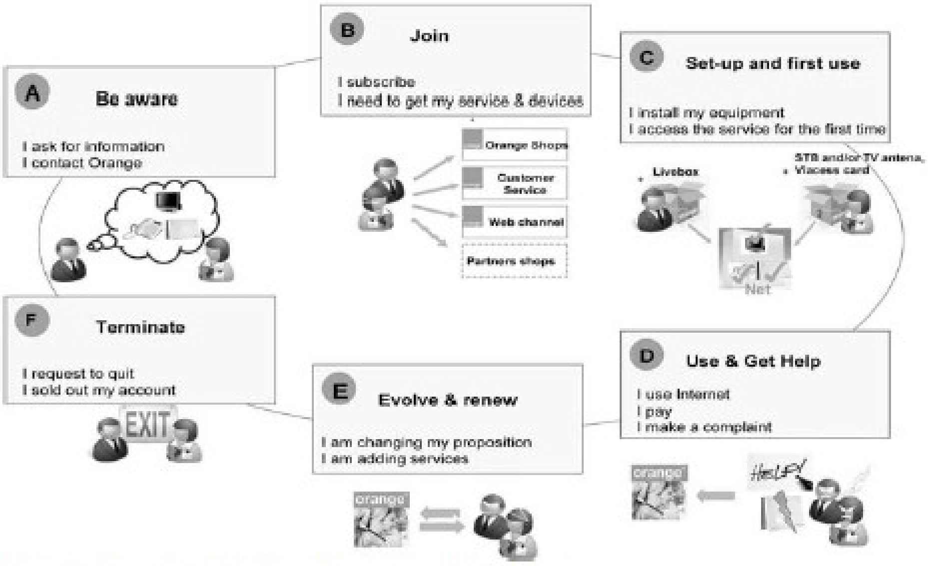


Figure 2-18. The six stages of the customer journey

2.11 NEXT GENERATION NETWORKS (NGNs)

2.11.1 Management

Management functions include the network and service management functions, management information base (MIB) and interfaces within the network. The objective is to guarantee expected level of security, reliability, availability, and QoS for the billable NGN services. This provides the following services across the network:

2.11.1.1 Fault Management

Fault management refers to the management of services and sessions at the agreed - upon levels even when there are faults, including overloads and disasters, in the service, application, and transport strata. Functions may include monitoring and control of utilization of resources during setup, maintenance, and release of sessions for NGN services. Since NGN supports a multitude of services, it is recommended that appropriate fi ltering and correlation be used to manage service - specific faults. When services span multiple technology and administrative domains, as would be the case for networks and services interoperability, one or more fault management mechanisms are required per bilateral agreement. This will help maintain service transparency across the NNI.

2.11.1.2 Configuration Management

This refers to developing, monitoring, and managing hardware and software confi gurations of devices, elements, and systems with an objective to maintain network operations without negatively affect ing services and revenues. For example, it is often desired to store the tested and approved configurations of the end - user terminals in a networked server so users can download them as they sign in for new features and services. Although this practice is very common in the cellular phone industry, Internet and IP - based television (IPTV) service providers are also finding it increasing useful. Similarly, for network elements ' confi guration management, specialized on - line and off – line servers are commonly utilized.

2.11.1.3 Accounting Management

Accounting management in the context of NGN commonly refers to recording the utilization of services and network resources with an objective to create a billing record. The recording can be done in various formats including the raw comma - separated - values that can be fed to format data in other acceptable standard formats in order to create customer readable bills. Measurement of the use of services and resources can be done in multiple ways. For example, per - service per - user paradigm is routinely utilized for cell phone users for voice data/text - messaging, video download, gaming, etc, unless fl at - rate billing is assumed. For enterprise customers, recording of network and service utilization and events like service outage and repair time for managing the service level agreement (SLA) are more important than documenting the service usage.

2.11.1.4 Performance Management

Performance management is concerned with monitoring the performance of networks elements, both transmission links and nodal devices, with an objective to maintain the desired level of service quality or SLA. Both active and passive monitoring devices and techniques are commonly used in NGNs. The challenge, however, is to locate and harden performance monitoring and management systems uniformly in the network without overburdening service creation, management, and delivery modules. Passive monitoring requires the use of splitters in the transmission links, and special - purpose hardware for off - line fi ltering/storing/analyzing the captured data. Active measurements can be conducted without signifi cant overhead, at any desired time, and for any desired time period. For transmission links, the parameters of interest are throughput and utilization, uptime and downtime, time to recover gracefully from overloads and disasters, etc.
For nodal device like switches and routers, parameters like delay, response time, local or remote switchover times for service quality maintenance during failures and overload, are of paramount importance.

2.11.1.5 Security Management

NGN security management includes managing the user ’ s identifi cation, authentication, authorization, certifi cate, etc. in an access - neutral fashion. Otherwise, it will be very difficult to maintain service continuity when the user (or session) moves from one access network to another or roams from one service provider to the other. Since NGN uses IP - based transport, additional mechanisms are required to protect both service and network from worms, viruses, intrusion, denial of service, etc. Simple monitoring - based mechanisms may not be sufficient. Proactive measures must be invoked. ITU - T Study Groups 13 and 17 addresses these issues. Once again, when services span multiple technology and administrative domains, as would be the case for networks and services (interoperability, one or more security management mechanisms are required per bilateral agreement. This will help maintain service transparency securely. In terms of the Telecommunications Management Network (TMN) functions, this encompasses both the Element and Network Management layers.

2.12 MANAGEMENT OF NG SERVICES

As discussed before, development and deployment of Next Generation services, in a cost - effective manner, is becoming increasingly complex. This is because users are demanding a multitude of services over various traditional (wireless and wireline) access and device Interfaces irrespective of the capability or domain of the service providers. NG service providers are expected to deliver voice and video calls over regular TV screens in addition to continuing these services seamlessly to screen - based POTS phone and hand - held devices (PDA, cell phones, etc.) per user ’ s convenience. The task of managing security, quality - and - continuity - of – service, mobility, and billing therefore become enormously convoluted.

2.12.1 Security Management of NG Services

Managing security in emerging NG networks is a very complex task. This is due to the drive to support IP - based convergence in both networks and services areas at the same time that hackers are becoming increasingly smart due to openness and ubiquity of the Internet.
Information security solutions must address user, end - point, service, and administration level security without compromising the flexibility and simplicity of use of the network and service. Certain popular

networking and service developments or offerings, e.g., peer - to - peer services over Internet, create more vulnerability in networks. Legislative measure alone cannot protect consumers, networks, and services because attacks on networks and services are often triggered by personal frustration and other factors. The challenge is how to operate the networks and services efficiently and cost - effectively without compromising privacy, security, and vulnerability of the services.
What is required here is an open and flexible framework to defi ne service - specific network security requirements, incorporate these requirements into network nodes ' and transmission links ' design and performance specifications, and test and certify the network and nodal security solutions before deploying these in an operational network. Then continuously upgrade the deployed protective mechanisms to outsmart the hackers and network attackers as the technologies evolve.

2.12.2 Device Configuration and Management of NG Services

Managing capability and confi guration of customer premises NG devices remotely, including those in enterprise, is an overwhelming task. The situation is more manageable in medium and large enterprises because of an existing process that is routinely followed for upgrading and adding new devices to the system or network. However, in small business and residential locations, the users add/move/modify devices sometime knowingly and on other occasions download plug - ins for the target services even without any direct knowledge of those plug - ins. The latter situation often causes malfunction and system - level crashing of the devices. To overcome these problems, various standards organizations are creating forums and focus groups, and a few of these are described below. ATIS recently established the Home Networking or HNet Forum (www.atis.org/HNET). The objective is to develop specifi cations and guidelines for interconnecting IP – based NG home appliances/devices/system by using the emerging technologies so that the services can be delivered seamlessly.

2.12.3 Billing, Charging, and Settlement of NG Services

Various paradigms of billing and charging are being discussed in Standards organizations, i.e., online (real - time) and offl ine (batch processing) methods of charging are the most common and useful ones. In this era of globalization, no service provider is an island, and hence it is highly desirable that one unified settlement scheme be used among service providers to support seamless mobility and consistency of services. Both policy - based service management and service - type based policy can be used to openly settle payment among the service providers. However, utmost caution must be exercised to avoid any sort of service degradation due to irregularity of settlement mechanisms.

2.13 NETWORK AND SERVICEMANAGEMENT FOR NGN

2.13.1 Introduction

Considering the diversity of services provided in NGN, demands for high quality, evolution of network technologies, and diversity of providers conducting businesses on the NGN environment, the NGN management functions must meet not only the requirements for traditional existing networks but also those from multifaceted aspects.

This chapter describes the requirements of NGN management by classifying them into the following categories:

- Network management operation requirements.
- Service management operation requirements.
- Service enhancement requirements.
- B2B realization requirements.

• Compliance with legal regulations requirements.

In each category, the requirements for FCAPS are listed and described in Table 2.13.1 . FCAPS refers to the Fault management, Confi guration management, Accounting management, Performance management, and Security management. They are represented as the general management functionalities in the ITU - T Recommendation M3400.

No.	Function	Description
1	Fault management	The fault management allows detecting a fault event in the network, identifying the cause of fault, locating and minimizing the impacts of the fault on services, arranging operations (issuing a trouble ticket), analyzing faults, and providing fault recovery. The fault management supports the following features: • Fault monitoring • Fault isolation and identification of the major causes • Fault diagnosis • Fault recovery • Trouble management
2	Configuration management	The configuration management provides NE (Network Element)/Path Route configuration management, NE parameter management, synchronization and modification management of configuration information with current network, status data collection, configuration information setting to NE, and NE control. The configuration management supports the following features: • Network planning and designing • Network construction • Service planning • Service provisioning • Status management and control
3	Accounting management	The accounting management allows measuring the network services usage amount per user, and notifying the amount to the service provider (service department). The account management also allows sending notifications to the users about their network services usage fees. The performance management supports the following features: • Measurement of the services used amount • Usage fee management • Billing, payment, and credit management • Settlement among service providers

Table 2.13.1

2.13.2 Network Management Operation Requirements

From the viewpoint of network operation management, reduction of network operating cost must be compatible with high - quality network maintenance. The major requirements include efficiency in providing network resources satisfying the demands, assurance for service provisioning quality, prompt and immediate interventions during failures, proactive handling against failure warnings, and real – time accounting. These requirements are described below:

1) Configuration Management:

• Providing the ability to manage NGN system resources, both physical and logical (including resources in the core network, access networks, interconnect components, and customer networks and their terminals).

- Integrating an abstracted view on Resources, which is hiding complexity and multiplicity of technologies and domains in the resource layer.

- Efficient network expansion according to the network utilization status.

- Provision of efficient test tools during network expansion Fault Management, Performance.

2) Management, and Security Management:

- Provision of integrated monitoring.

- Monitoring of network service quality (QoS).

- Early detection of network failures and QoS deterioration and identification and isolation of failure causes at early point.

- Advance detection of failure indicators.

- The ability to have proactive trend monitoring.

3) Accounting Management:

- Collection and accounting (rating) of service usage information in real time.

- Supporting the availability of management services any place any time to any authorized organization or individual (e.g., access to billing records).

4)Common Functions:

- Automation and acceleration of end - to - end operation process.

2.13.3 Service Management Operation Requirements

From the viewpoint of service management operation, service provisioning quality maintenance must be compatible with operating cost reduction. Since the quality of services has a direct relation with customer satisfaction, addressing the requirements from customers is quite important. The requirements from the viewpoint of service management operation are as follows.

1) Configuration Management:

- Automation and acceleration of service provisioning.

- Automation of provisioning from service level to network level.

- Automatic testing linked with service orders.

- Customers ' self - service provisioning.

2) Fault Management, Performance Management, and Security Management:

- Monitoring at SLA provisioning level.

- Early detection of SLA violation and early identifi cation of failure causes.

- Analysis of affected range at failure occurrence or QoS deterioration, and early.
- Prompt notifi cation to customer at SLA violation.
- Service quality confi rmation test at customer inquiry, dispatch of maintenance operation, and operation progress status notification.

3) Accounting Management:

- SLA - based accounting adjustment.
- Service usage logs and provided quality tracing.
- Real time information on accounting and settlement status for users.

2.13.4 Service Enhancement Requirements

Increase in highly sophisticated services due to the high - functionality equipments and the advancement of video services increases the needs for device remote control, video quality of experience (QoE) measuring, and other customer support requirements. In addition, it is also required to cope with service personalization based on the user access method and context information (location and presence). Since the advancement of services involves in the reduction of services lifecycle, lifecycle management has become necessary as a service management platform.
Based on this background, the following requirements need to be considered:

1) Configuration Management:

- Remote settings for terminals (mobile terminals and CPE) and firmware update.
- Service provisioning function corresponding to service lifecycle reduction.

2) Fault Management, Performance Management, and Security Management:

- Collection of quality information from terminals (mobile terminals and CPE).
- Monitoring quality of experience (QoE).

3)Accounting Management:

- Accounting function corresponding to service lifecycle reduction.
- Accounting model corresponding to user segmentation and access method.

4) Common Functions:

- Collection of user context information (presence, location, preference, etc.) from terminals.
- Providing user context information to service functions.
- Protection of user context information.

Chapter 3

LTE AND WIRELESS TECHNOLOGY

In this chapter we will know the evolutions of the different from mobile technologies and comparison of technical and commercial aspects among the similar technologies. Focus primarily on the competence of LTE, as they are Mobile WiMAX and UMB.

3.1 Background

The IMT 2000 has a group of radio interface with the aim of evolution 3G, where it highlights TDMA, CDMA, OFDMA. Every one of these groups work with their own techniques to improve the previous service. All this is standardized by the specification 3GPP and 3GPP2. In addition the IEEE has also been seen in the mobile service, evolve its wireless networks across the committee IEEE 802. According to the different interfaces radio we can be grouped mobile technologies as seen in the table 3.1.

Radio Interface	Tecnologies	Comment
TDMA	GSM, GPRS, EDGE, TIA/EIA-136 TDMA	First digital cellular appearance. Great success in the GSM telephony. Further improvements to the design of GSM / EDGE.
CDMA	CDMA2000 1xRTT, CDMA2000 ED-VO, WCDMA, HSPA, HSPA+, IEEE802.11b	Foundation for nearly all new 3G networks.Mature,efficient, dominating a wide area wireless systems for the rest of this decade.
OFDM/OFDMA	IEEE802.16/WiMAX, 3GPP LTE, IEEE 802.11 a/g/n, 3GPP2 UMB	Efficiency for broadcast systems, high bandwidth and high speed data transmission. It also provides flexibility in the amount of spectrum used. Well suited for systems planned for the next decade.

Table 3.1 Different Aspects of Wireless

3.2 Wireless Technologies.

3.2.1 3GPP Technologies

With emphasis on the aspect wireless, 3GPP has evolved a plan to recognize the strengths and limitations of each technology in order to exploit the unique abilities. Everything starts with the broad development that gets globally GSM, which is a technology 2G-based TDMA, that is the main step towards the evolution of technologies 3G. Nowadays GSM is a very efficient, however, there are opportunities for optimizations and improvements to the system. The majority of GSM networks have been supported by EDGE (Enhacer velocidades de transmisión de datos con la tecnología GSM de evolución or data rate for improved the evolution of GSM) that it is an improved GPRS, which is the original service packet data for networks GSM. The companies of standardization has already been defined by “Evolved EDGE”, and this is being developed and with the aim of double performance of the current systems of EDGE. At the end of the 1990s, due to the massive dynamics of the market, the majority of users in the world will still be paid by using technologies GSM/EDGE.

CDMA was elected as the basis of the technology 3G, including WCDMA for FDD and TDD UMTS. The evolution of data systems for WCDMA, such as HSPA and HSPA+, give improvements and simplifications that help-based systems CDMA un match systems capabilities of competition, especially in the spectrum.

According to some of the benefits of the interface OFDM 3GPP has specified a Cooperativas OFDMA reconfigurables as a basis for technology LTE, because it takes the best radio techniques to achieve levels of performance beyond what happens to CDMA. However, in the same way that 3G coexists with the second generation of integrated systems of networks, systems LTE simulcast systems with 3G y 2G. Múltimode devices will work through LTE/ 3G or even through LTE/ 3G/ 2G, depending on the characteristics of the market. Beyond the technology of radio, the new network Evolved Packet Core (EPC) offers a new core that allows you at the same time to promote the architecture and the integration of LTE with the two networks GSM/WCDMA, as well as the other wireless technologies. In the table 3.2 below, fast summary of different technologies designed to provide a framework for analysis.

Tecnology	Kind	Characteristics	Downlink	Uplink
GSM	TDMA	Cell technology developed world. Provides voice and data services via GPRS / EDGE.		
EDGE	TDMA	Data service for GSM networks. Enhanced Data GSM through GPRS.	70 Kbps to 130 Kbps	70 Kbps to 130 Kbps
Enolved DGE	TDMA	An enhanced version of EDGE that eventually could double rates performance.	150 Kbps to 500 Kbps	100 Kbps to 500 Kbps
UMTS WCDMA	CDMA	3G technology that provides voice and data. His current HSPA deployment applied to the data service.	200 Kbps to 300 Kbps	200 to 300 Kbps
HSPA	CDMA	Data Services UMTS networks. Improved original UMTS services.	1 to 4 Mbps	500 Kbps to 2 Mbps
HSPA+	CDMA	HSPA Evolution. Increased performance and reducing latency.	>5 Mbps	>3 Mbps
LTE	OFDMA	New technology that can use radio channels and deliver at very high rates of return. All communications with IP domain.	>10 Mbps	>5 Mbps
LTE Advanced	OFDMA	LTE advanced version designed to meet requirements of IMTAdvanced.		

Table 3.2 Characteristics of 3GPP technologies.

Expectations along the time of networks EDGE/HSPA/LTE with regard to the available features and capabilities, below stating the initial year of the development:

2009:

- Networks and devices will be suitable for Release 7 HSPA+, including MIMO, fostering the speed of HSPA 28 Mbps.

- Will Improve-based services and IMS (IP Multimedia Subsystem), for example, vos integrated, multimedia, location and presence.

2010:

- The available capacity of technology Evolved EDGE, increase significantly the rate of return on EDGE.

- The speed of pico HSPA+ will still more, up to a peak of 42 Mbps. LTE introduce the new generation in performance and performance of the use of 2x2 MIMO.

- Advanced architectures will be available through EPC/SAE, primarily to LTE as well as HSPA+, to benefit such as the integration of multiple types and architecture of network for better performance of latency.

- The majority of the new domain services package implemented on HSPA+ and LTE.

2011:

- LTE will have improvements such as 4x2 MIMO y 4x4 MIMO specifications and will be completed by Avanzada LTE.

2012:

- Advanced LTE will be potentially deployed in the early stages.

With the time the elements of basic infrastructure shall be subject to the consolidation, therefore , the reduction of the total cost of the network and the improvement of the integrated operations of access networks . In the present, for users with multi-device mode, access networks to be largely transparent.

Figure 3.1 reports on progress in HSPA and LTE, drawn from the time, showing duplicative of performance approximated by year.

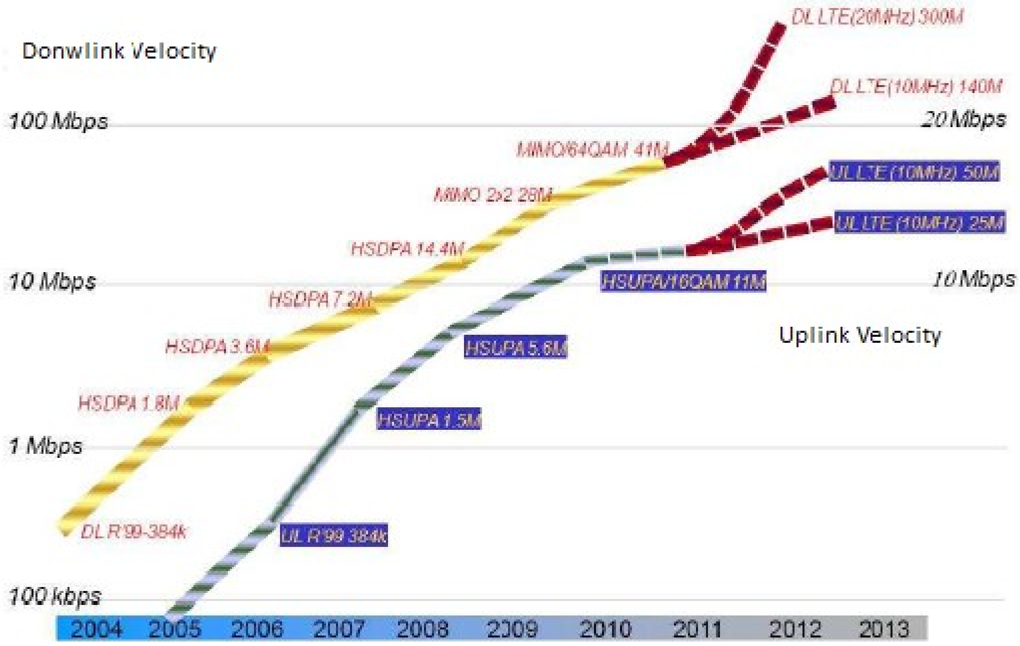


Figure 3.1 Peak Performances for the uplink and downlink.

In spite of the fast deployment of WCDMA UMTS, the majority of subscribers in the world will continue to use GSM at the end of the 1990s, then the majority of new users unpedagogic advantage of WCDMA. In the same way as it is reflected in the networks LTE since they are expected to the deployment is at the beginning of the next decade, as well in the middle of it, the percentage of paid to networks LTE it would be very considerable. In these years networks and devices will have the feature of tri-mode on GSM, WCDMA and LTE.

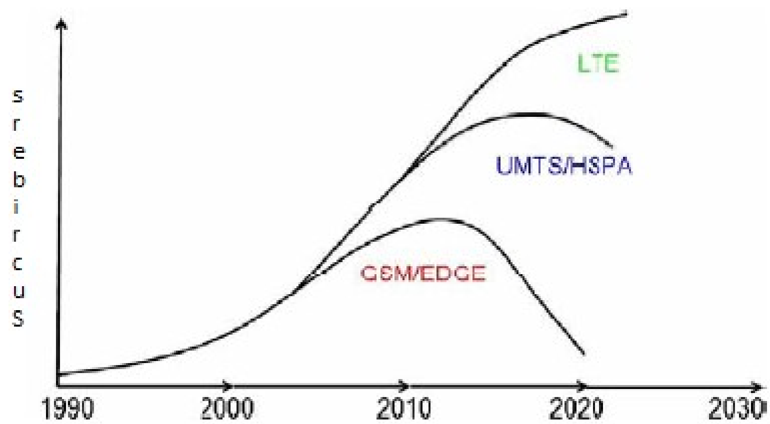


Figure 3.2 Technology adoption in decades.

Figure 3.2 shows the relationship of technologies for decades and the period of time it takes to any new technology to develop widely in the world. The building of data for technology can be seen in the table 3.3 which were presented in terms of interest rates of peak performance network and user concessional and typical.

	Network Peak	User Peak	Network Peak	User Peak
EDGE (type 2MS)	473,6 Kbps		473,6 Kbps	
EDGE (type 1MS)	236,8 Kbps	200 Kbps	236,8 Kbps	200 Kbps

Evolved EDGE (type 1MS)	1184 Kbps		473,6 Kbps	
Evolved EDGE (type 2MS)	1894,4 Kbps		947,2 Kbps	
UMTS wcdma Rel 99	2,048 Mbps		768 Kbps	
UMTS wcdma Rel 99 Practical Terminal	384 Kbps	350 Kbps peak	384 Kbps	350 Kbps peak
HSDPA (2006)	1,8 Mbps	> 1 Mbps peak	384 Kbps	350 Kbps
HSDPA	14,4 Mbps		384 Kbps	
HSPA first mplementation	7,2 Mbps	> 5 Mbps peak	2 Mbps	> 1,5 Mbps peak
HSPA	14,4 Mbps		5,76 Mbps	
HSPA+DL64QAM, UL 16 QAM	21,6 Mbps		11,5 Mbps	
HSPA+DL16QAM, UL16QAM,2x2MIMO	28 Mbps	> 5 Mbps	11,5 Mbps	> 3 Mbps
HSPA+DL64QAM, UL16QAM,2x2MIMO	42 Mbps		11,5 Mbps	
LTE (2x2 MIMO)	173 Mbps	>10Mbps	58 Mbps	> 5 Mbps
LTE (4x4 MIMO)	326 Mbps		86 Mbps	

Table 3.3 Performance of different technologies 3GPP blue is theoretical).

3.2.2 Competing Technologies.

Although technologies as GSM, GPRS, EDGE, UMTS dominate global networks developed in cellular technology, operators deploy other wireless technologies to serve in turn to a metropolitan area network as a local area network. This is the case of technologies CDMA2000 3GPP2 and WiMAX.

CDMA2000: is essentially based on one carrier, as 1xRTT (Radio Transmission Technology) and 1xEV-DO (Evolved Data Optimized). It is the other great cell technology unleashed in many parts of the world. 1XRTT version is currently the more widely implemented CDMA2000. A series of operators have implemented or are doing 1xEV-DO, where a radio carrier is dedicated to the high speed of functions of data. In July of the year 2008 there were 100 access networks EV-DO Release 0 and networks 42 EV-DO Rev ¡A deployed globally.

EV-DO uses many of the techniques used to optimize the HSPA spectral efficiency , including the modulation of higher-order of efficient scheduling and modulation and adaptive coding. For these reasons, it is only through the spectrum efficiency that is almost the same as the one that has HSPA. Technologies 1x operate in the frequency of 1.25 MHz, compared with the frequency of 5 MHz, which is used by WCDMA. Estos resultados dan a pico-theoretically by redeeming low, but the average processing for the high level of network payload, es similar. Under the conditions of half-load, due to the lower data rate achievable, EV-DO Rev A accomplishes a typical yield, slightly compared with HSPA. Operators have given to know the typical performance of the uplink for EV-DO Rev 0 from the 400 to 700 kbps and 600 Kbps a 1.4 Mbps for EV-DO Rev A.

Currently the networks deployed are based on any of the specification of the interface radio, Rev 0 or Rev A. In the year 2007 operators made in EV-DO Rev a technology available commercially.

One of the challenges of operators in EV-DO, is that cannot be assigned dynamically the whole of the spectrum resource between the functions of voice and high speed data . The channel of EV-DO not available for the circuit switched voice, and the supply of channels 1xRTT is only for data from medium speed. The use of data currently has expanded , which is not in the limitation optimization of resources of radio. Another limitation is using a separate channel for data services EV-DO, this is now prevented users to operate simultaneously to voice services and high-speed data, while it if possible with technology UMTS. Many users are taking a data connection tied to the portable computer, they use Bluetooth for example, and can start up and receive phone calls, while keeping its database.

EV-DO eventually offers a service voice using the protocols of VoIP through EV-DO Rev A, which includes greater speed of up and optimizing the mechanisms of Qos in the network and the protocols to reduce the head of the package, as well as to deal with problems such as the variation in the amount of latency between data packets received.

Beyond the EV-DO Rev. A, 3GPP2 has defined EV-DO Rev B that allows the combination of up to 15 or radio channels 1.25 MHz carrier at 20 MHz, reaching a rise of theoretical peak 73.5 Mbps.

After the EV-DO Rev B we find UMB (Ultra Mobile Broadband), which is based on Cooperativas OFDMA reconfigurables as LTE. UMB supports radio channels from 1,25 a 20 MHz. In one carrier of 20 MHz, with 4x4 MIMO, UMB offers a speed data peak 280 Mbps, see Table 3.4 . Service is not yet committed to UMB, since there are questions about the business case of operators CDMA2000, as has happened with the operator verizon you'VE selected to let as the technology of next election.

UMB and LTE it is running at the same time, they are more recent Technologies OFDMA like is the case of WiMAX.

	Downlink		Uplink	
	Network Peak	User Peak	Network Peak	User Peak
CDMA2000 1xRTT	153 Kbps	130 Kbps peak	153 Kbps	130 Kbps peak
CDMA2000 EV-DO Rev 0	2,4 Mbps	> 1 Mbps peak	153 Kbps	150 Kbps peak
CDMA2000 EV-DO Rev A	3,1 Mbps	> 1.5 Mbps peak	1,8 Mbps	> 1 Mbps peak
CDMA2000 EV-DO Rev B (3 carriers)	9,3 Mbps		5,4 Mbps	
CDMA2000 EV-DO Rev B (15 carriers)	73,5 Mbps		27 Mbps	
UMB (2x2 MIMO)	140 Mbps		34 Mbps	
UMB (4x4 MIMO)	280 Mbps		68 Mbps	

Table 3.4 Performance 3GPP2 technologies.

WiMAX, has become the potential alternatives in cellular technology for a wide area of wireless networks. It is based on Cooperativas OFDMA reconfigurables and newly accepted by ITU under the name of Cooperativas OFDMA reconfigurables TDD WMAN. Possesses a large trawls in the developed countries wishing to deploy networking using the alternative cable. The protocol characterizing the technology is the specification IEEE 802,16 , which was completed in the year 2001 and is principally to applications of telecommunications backhaul point-to-point and settings in line of sight using the spectrum of the 10 GHz.

The next big step in the evolution of IEEE 802,16 occurred in the year 2004, with the version of the standard IEEE 802,16 -2004. He said interfaces multi-radio, including OFDM-256 and Cooperativas OFDMA reconfigurables. Like the original version of the standard, the operation is fixed, i.e. subscriber stations is typically immobile. The potential applications include wireless services, Internet Service Provider (ISP), local telephony (as an alternative to cable modem, or DSL service) and backhaul celular for connections from the base station up to network infrastructure of the operator.

Suppliers are providing equipment certificates with the standard IEEE 802,16 -2004. The standard no compete directly with the cellular data and private networks Wi-Fi, so you can provide complementary services. In addition the access solutions, the host operator, private and municipal governments, universities and companies may use this version WIMAX in the bands no licensed to connectivity local.

The IEEE has also been a standard for mobile broadband called IEEE 802.16e-2005, adding capacity for mobility including the support as long as the operation is mobile , traspaso via base stations and through the players. A difference of the IEEE 802,16 -2004, operating in both licensed band, unlicensed the IEEE 802.16e-2005 (WiMAX Mobile) opera in the majority of licensed band. Networks of Mobile WiMAX are not compatible with the networks of the previous standard IEEE 802,16 -2004.

In the beginning Mobile WiMAX use 2x2 MIMO, TDD and radio channels 10 MHz a profile defined by WiMAX Forum known as WiMAX Wave 2. Beyond Wave 2, WiMAX providers define a new standard called wimax Liberación 1,5 , which includes several improvements for obtaining more efficiency and performance, and will be available at the same time that LTE. The later version, Mobile WiMAX 2,0 , this is designed to deal with the requirements of performance developed by the project of the IMTAdvanced. it'S called IEEE 802.16m, it works with the user on the move up to 120Km/h and will be available in the year 2011, data from it are not yet known.

	Downlink		**Uplink**	
	Network Peak	User Peak	Network Peak	User Peak
802.16e WiMAX Wave 1 (1x2 MIMO)	23 Mbps		4 Mbps	
802.16e WiMAX Wave 2 (2x2 MIMO)	46 Mbps		4 Mbps	
802.16m				

Table 3.5 WiMAX performance.

It must be understood that the IEEE 802.16e-2005 contains some aspects that can limit performance, especially in situations in which one sector contains a large number of mobile users. The performance of the MAC layer inefficient in front of the programming of the large number of users and , in some aspects, such as the control of the power of mobile station, messages are used signposting MAC more than the quick power control WCDMA used in and other technologies.

In relation to LTE, WiMAX has the following disadvantages; frame 5 ms instead of 1 ms, the combination of time to increase the redundancy, show imperfections of modulation and encoding on systems, and encoding possesses vertical in time for codification horizontal[10]. An account of the development are the requirements TDD networks in synchronization. This is not possible in a cell to transmit and an adjacent cell placed to receive at the same time. Operators in the same band must coordinate any of their networks or gangs of the guard, to make sure that not interfere with each other.

In reference to the economies of scale, the number of the subscribers GSM/WCDMA/HSPA approximates the billion, which in comparison with the number of subscribers of WiMAX is very high, since they or in the next five years could be number one.

From the point of view of technology, Mobile WiMAX role plays a little more trained today as compared with the versions HSPA. Mobile WiMAX in reality has to compete against HSPA development systems that offer similar capabilities to enhanced performance . With this, later, LTE will not far from develop.

3.3 Wireless Technologies Comparasion

Technologies are in a constant evolution, since the market where they are moving advanced at high speed. The high level of competence that will be generated, leading to the tendency of moving beyond the voice and provide personal access to telephony, Internet and multimedia services cost both in urban and suburban, and rural. The rise of these different wireless technologies can be seen in figure 3.3 , in conjunction with the maximum return of the building of each network.

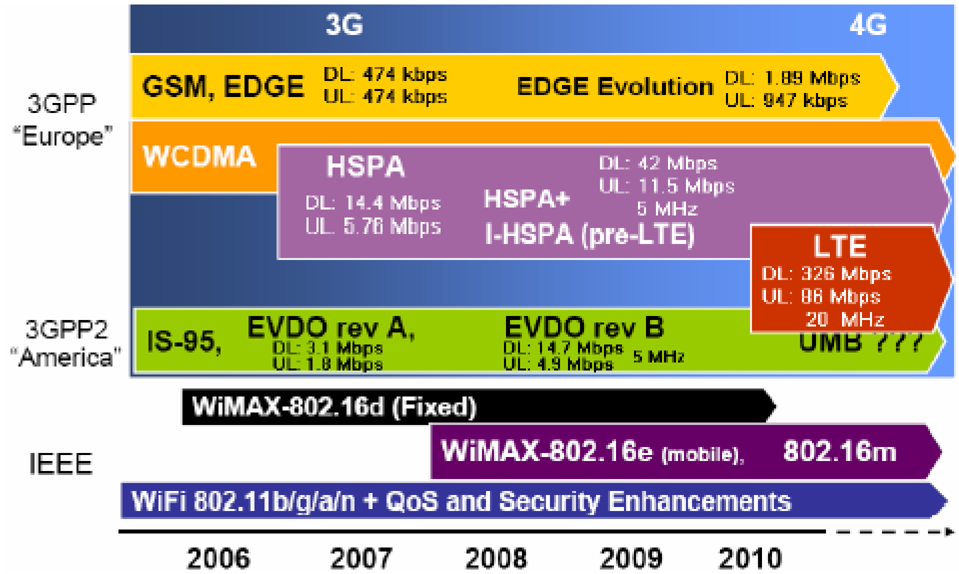


Figure 3.3 Evolution os Systems TDMA, CDMA and OFDMA.

The Peak value "throughput" is a very important indicator at the time of quantify the building of information that has each network. It is based on the value of higher level of available modulation and the lowest-coding (bug) over the network.

Other data indicators important to the evolution of mobile systems are: latency, spectral efficiency, quality of service, voice service and market position.

3.3.1 Latency

Defined like the round trip time to take the data in travel network . All information technology post-EDGE Rel'99 has lower latency, networking HSDPA, for example, latency is about 70 milisegundos (ms). HSPA is still more low latency, as well as in the case of LTE 3GPP. The values shown in the figure 3.4 reflect the measurement of commercial deployment of technologies.

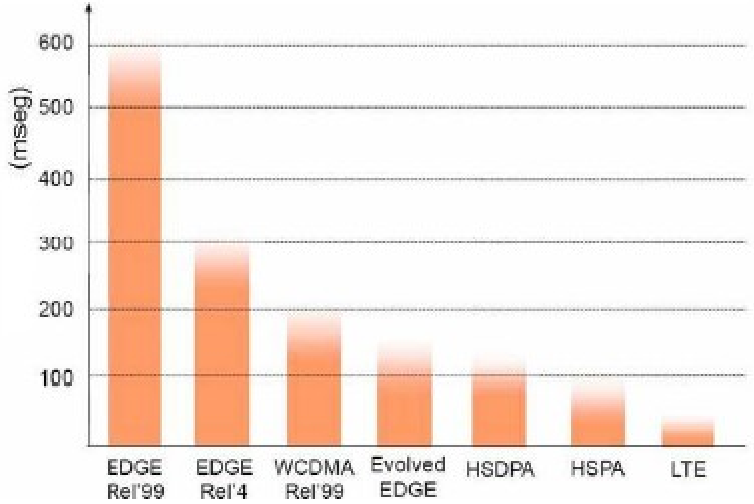


Figure 3.4 Latency of diffents 3GPP technologies.

3.3.2 Spectral Efficiency

The spectrum efficiency measures how well is used the spectrum of the wireless network, it is helpful to consider in order to improve the ability to increase the signal strength and reduce interference.

The evolution of data services are characterized by a growing number of users, that are increasingly greater demand for broadband. As the market grows, the deployment of wireless technologies with high spectral efficiency it is vital, by the thing to keep in mind; bands, amount of spectrum and the separation of the cell. An increase in the spectrum efficiency is reflected in an increase in the number of users or an increase in available capacity for each user. Also, this involves a price increases are generally greater complexity for users and equipment base stations.

The exact date for the deployment of greater spectral efficiency in the technology is difficult to predict, because very much depend on the growth of the market and of the types of applications to become more popular. There are technologies for example, to improve the system SRN minimizing interference that the hold antennas smart, or the interference of coordination and cells. In addition the techniques MIMO using Space Múltiplexación, have increased the rise of the rate of information transfer by a factor proportional to the number of transmission.

Figure 3.5 compares the spectral efficiency of the different wireless technologies based on an agreement of the 3G Americas, which shows the changing of the technological capabilities[34].

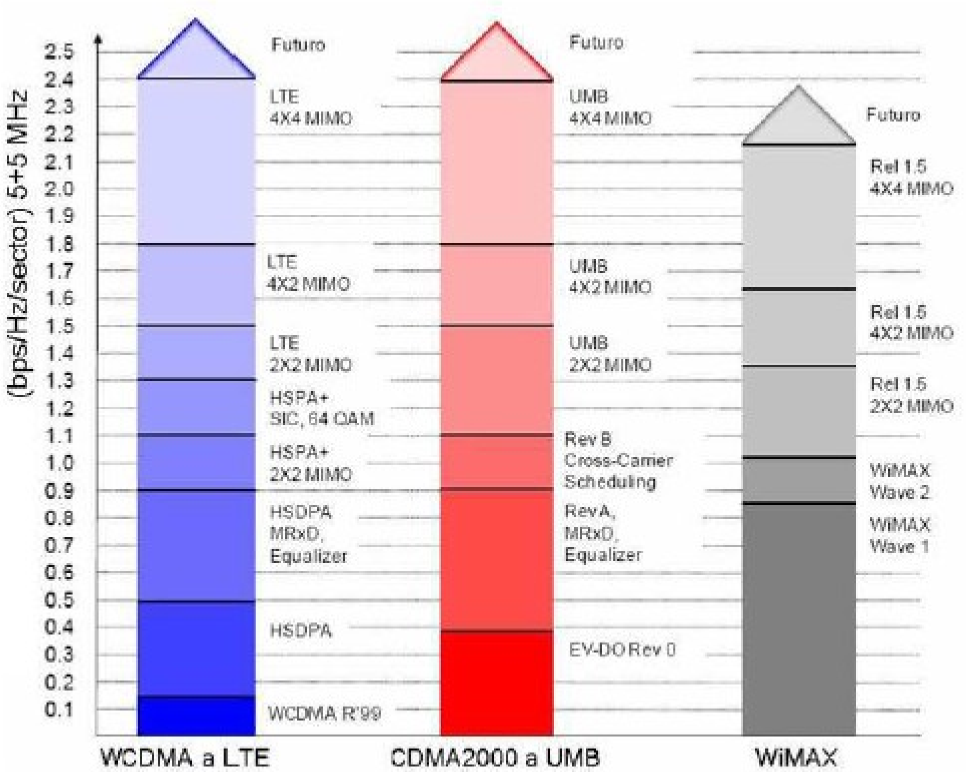


Figure 3.5 Spectral Efficiency Downlink.

The values shown are conservative, in the reasonable purpose for the conditions of the real world, in which are not all combinations of available features, however, are also representative data in continuous improvement of the spectrum efficiency.

With regard to the effective deployment, the enhancements such as 64QAM, are easier to develop for the players that other such as MIMO 2x2, as in the first can make a software update, while in the second is required for the implementation of hardware in the base station. As well, figure 3.5 does not necessarily show the current progress made by operators to increase the spectrum efficiency.

An important point to stress, is that is more efficiently LTE spectrally than other technologies, as WiMAX Wave 2. The cause of this would be a series of reason, for example , increase in redundancy in the bug fixes, modulation with fina granularity coding and systems, the efficiency of control of the canal, sueñan MIMO multiple (BMI) to allow the use of receivers based in the art of noise cancelling successive SIC (successive interference cancellation), and a lower indicator of quality of the canal delayed through the use of the frames.

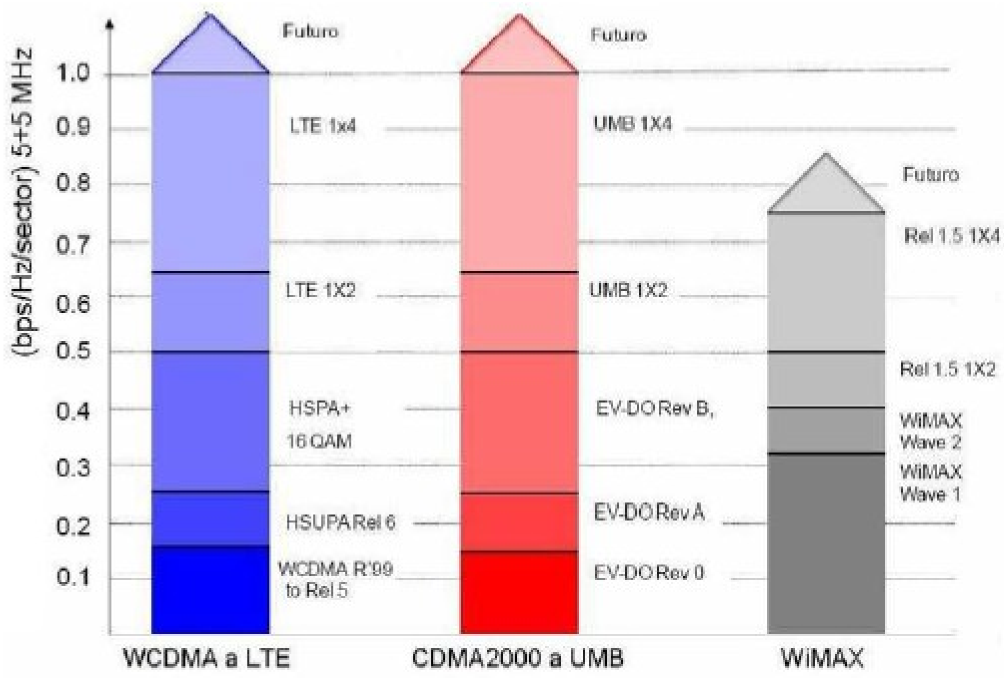


Figure 3.6 Comparasion of Spectral Efficiency Uplink.

Figure 3.6 compares the spectrum efficiency of the up-link of different systems and the efficiency uplink spectral wimax Wave 2, is less than the technologies 3GPP and 3GPP2 using the redemption of interference.

Figure 3.7 compares the spectrum efficiency of the voice. Shows also the coding of voice of UMTS R'99 to AMR (Adaptive Multi-Rate) ambos valores, 12.2 kbps and 7.95 Kb/s. The AMR 12.2 Kbps offers a voice quality in good conditions of the channel. WCDMA has had a dynamic adaptation between the rates for codification of voice, allowing for greater voice quality in comparison with the growth of variable fee (EVRC), where the capacity is limited.

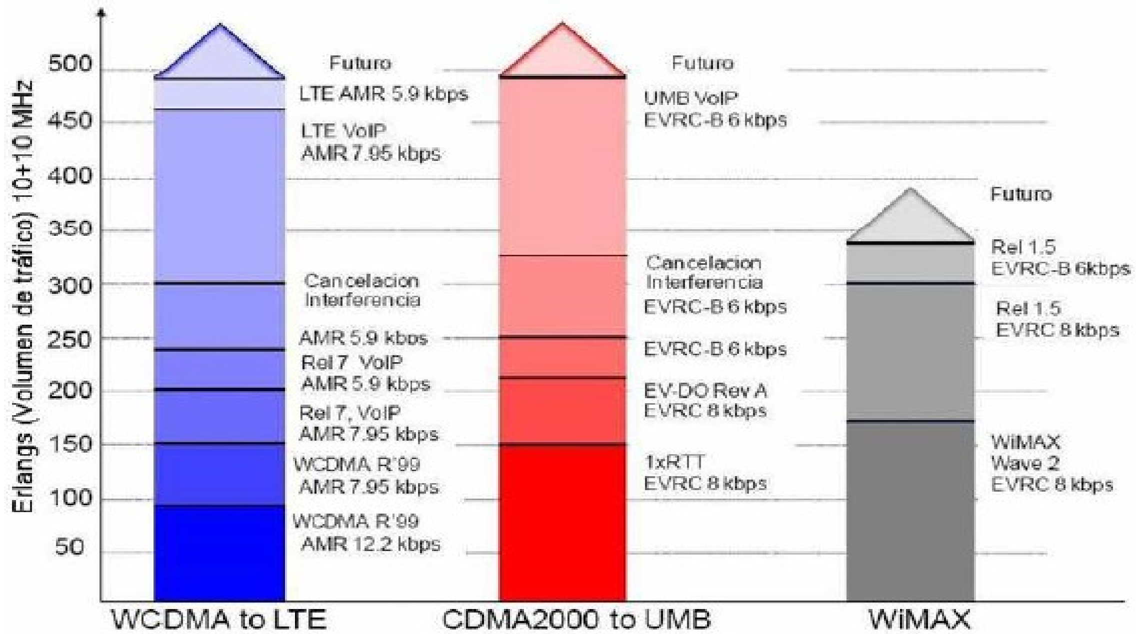


Figure 3.7 Comparasion of Voice Capacity.

Opportunities for improving the ability to voice, the proposed by using VoIP over channels HSPA. Depending on the better, could double the capacity of voice-over systems circuit. It must be understood that the gains are not specifically related to the use of VoIP, but to refer to the advances in radio techniques in data channels. Many of the same progress can also be applied to the current modes of circuit. However, other benefits of the VoIP driving to the migration of data packets. Among these benefits the consolidated a core IP network operators and multimedia applications sophisticated for users.

With regard to the codecs systems in the VoIP, such as LTE, UMB, WiMAX, a variety can be used. The figures show a performance of specific codecs , representing the bit rate by codecs as EVRC. Bit rate is displayed in value.

Although Wimax Release 1.5 has a high spectrum efficiency for VoIP in the link up-down, this is a handicap in relation to LTE, due to the difference in the millisecond borne. The use of the 5 ms limits the number of broadcasting HARQ in each frame of 20 ms. LTE can supports multiple broadcasts of this type in the 20 ms of intervention, on the other hand Wimax only admits one.

3.4 Cost and Market Volume

Many of comparisons have been made on the basis of the technical capacity of the different technologies, which they have been in now that have similar attributes. However , there is a point of comparison where differences between technologies differ tremendously , this refers to the number of players, including the paid and the amount of the infrastructure. This is due to translate to an extreme low-cost for more solutions.

Based on the numbers and projections statistical[13], subscribers networking 3G UMTS at the end of the decade would be hundreds of million (see Figure 3.8), while the number of paid to new technologies and IEEE 802.16e-2005 reach the dozens of millions, in addition to the latter point to lower costs for their services.

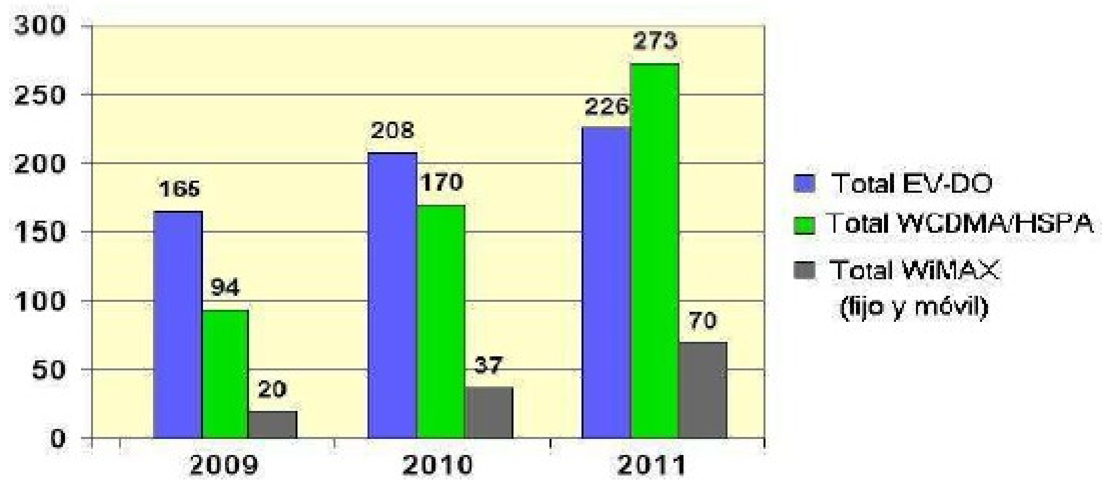


Figure 3.8 Subscribers EV-DO, WCDMA/HSPA and WiMAX in millions.

From the point of view of the deployment, the type of technology (for example, HSPA versus wimax) only applied to him a software support in the digital card of the base station. This cost, however, is only a fraction of the cost of the base station in the balance covering antennas, power amplifiers, cables, behind the scenes, and credit-card radiofrequence. With regard to the rest of the network including the construction, backhaul, core components of network, costs are similar independent of the technology of radio access network. The cost of the spectrum in each technology may vary considerably, depending on the rules of a country and the band of spectrum. As a rule in the majority of the world, the sale of a spectrum , for example of the band of the 3.5 GHz cost less than 850 MHz.

In terms of networks WCDMA/HSPA versus CDMA2000, the largest deployment could be translated into a significant savings for costing. Also, GSM phones considered much less expensive than the telephone and 1xRTT terminals WCDMA, with wholesale price that can be leaders in the market for low-cost.

LTE is still on the road to a wireless solid ecosystem of importants economies of scale. In June of the year 2008, the alliance Next Generation Mobile Network (NGMN) confirmed the selection of LTE. Dr. Meter Meissner, operating officer NGMN notice that, "on the basis of intensive and detailed technology assessment, LTE 3GPP is the first to extensively fulfils its recommendations and approved by the board".

Chapter 4

NETWORK ARCHITECTURE AND PROTOCOLS

The aim of this chapter is to deliver details of the network architecture LTE in order to describe the elements of functional, as well as the interfaces and protocols. A special attention to the work of 3GPP called SAE (System Architecture Evolution). So, to understand where it comes from the architecture of the system SAE, considered as the access network and the core network used by WCDMA/HSPA briefly describing the connections, similarities and differences in relation to the system of LTE. Finally be delivered descriptions of the protocols in the architecture of the interface radio.

4.1 Background

The term "system architecture" describes the assignment of functions for the logic node and the requirements of interfaces between nodes. In the case of a system mobile, as WCDMA/HSPA and LTE, the majority of the functions required for the interface of radio are called normally functions of radio access network. However, in a mobile network number of additional tasks are necessary in order to provide the services of freight needed for the use of the operator, authentication needed to certify that the user is a valid user configuration, service need to ensure that you can connect to an end-to-end, etc. Therefore, there are those not related directly with the radio access technology in itself, but to any radio access technology. These are called normally functions of core network. The fact that there are different kinds of functions in a cell system, has led to the architecture of the system is divided in two parts , in radio access network (RAN) and core network (NC).

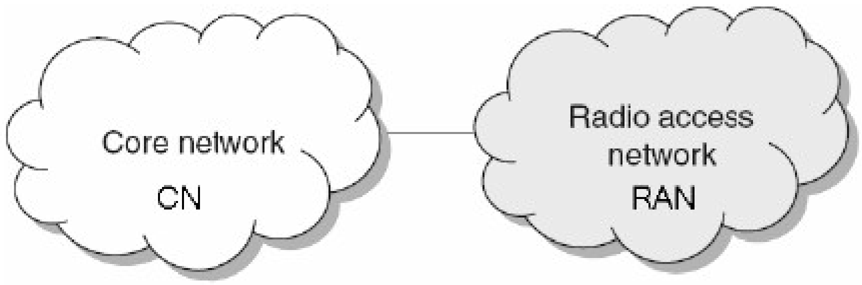


Figure 4.1 Core Network and Radio Access Network.

In addition, similar a WCDMA/HSPA and like most of the other systems of modern media, the processing for specified LTE the structure in different layers of protocol. Several of these layers are similar to the used by the system WCDMA/HSPA, there are some differences, for example because of the differences in the structure of the two general technologies.

Within the structure of protocol LTE there are many actors on the data transmitted, in this case IP packet, before the transmission through the interface radio, which are:

- Packet Data Convergente Protocol (PDCP), done compression of IP header for reducing the number of bits need to be passed by the interface radio.

- Radio Link Control (RLC), is responsible for the segmentation/networking, handling of the retransmission and sequence of delivery to the topmost layers.

- Medium Access Control (MAC), handling HARQ retransmissions and programming for the link up-down. The MAC the RLC in the form of logical channels.

- Physical Layer (PHY), is concerned with the coding and decoding, modulation, and other typical demodulación and functions of the physical layer.

- Radio Resource Control (RRC), is the key element in the lining of the signaling protocol and supports many features between the terminal and the node of the nework architecture LTE/SAE, eNB.

4.2 Division of functions between RAN and CN.

For WCDMA/HSPA, the idea behind the functional division is to keep the heart of knowledge network technology radio access and distribution. This means that la RAN should be in the control of all functionality and optimizing the interface radio and that the cells are expressed in the heart of network. As a result, the core network can be used to any radio access technology to take the same functional division.

To find the origin is necessary to return to the architecture of the GSM system, one of the problems of it is that the node in the heart of network with complete visibility of the cells in the system. Therefore, when it adds a cell in the system, nodes on the core network need to be updated. In WCDMA/HSPA, the core network is not known of the cells. On the other hand , core network knows about the service areas and la RAN prerenders areas of service in cells. As well, to add a new cell in the area of service, the core network does not have to be updated.

The second major difference in comparison with GSM, the location of the protocols of broadcasting and the buffers of data in the heart of red GSM. Since the protocols of retransmission were optimized for interface radio GSM, those were protocols of specific interface, therefore, were not adequate to the interface of WCDMA/HSPA. This was considered as a weakness in the heart of network with all of the buffers and the protocols of retransmission were moved to la RAN for WCDMA. While the radio access network using the same interface of the core network, the user interface Ui, the core network you can connect to access networks based in different access technologies radio.

There are still functional divisions in WCDMA/HSPA that cannot be explained only with the idea of making the core network technology in an independent radio access. The functions of security are an example. Once more, the history goes back to GSM, that has been the security functions in various positions for connections circuit and packet switching. For the connections of circuit switching , the functions of security are in la RAN GSM, while, for the connections of packet switching, the functions of safety at the heart of red GSM. For WCDMA/HSPA, it was considered complicated and a common location of security was coveted. The location was committed by la RAN as the management of resources radio signaling and the need for a safe control[16].

Consequently, the functions RAN WCDMA/HSPA are:

. Coding, patch, modulation, and other typical functions of the physical layer.
· ARQ, squeezing of header and other typical functions of link layer.
· Management of resources radio, traspaso typical functions and other resources control.
· Functions of security (encryption and protection of the integrity).

Functions that were located within the core network are:

· Tariffication.
· Subscriber Management.
· Mobility Management (this is to make the follow-up of users in roaming around the network and other networks).
· Bearer of management and the quality of service in handling.
· Control Policies of the flow of user data.
· Interconnection to external networks.

The division of functions of LTE is the same as the WCDMA/HSPA, however, the key to the design of the radio network access LTE, is to minimize the number of nodes and find a solution when the network consists of a single node type. At the same time , the idea behind the core of red LTE is the most independent as possible to the radio access technology[17].

4.3 Architecture RAN

While in any RAN for any radio access technology and minimum need , is to have a node to connect the antenna of a cell. The different access technologies radio have found solutions for the number of types of nodes e interfaces which ran will have. ARCHITECTURES RAN WCDMA/HSPA and LTE are different for what it appears below the differences and similarities.

4.3.1 Radio Access Network of WCDMA/HSPA.

In essence, an important factor for architecture RAN WCDMA/HSPA is the function of the macro-diversity, which means that the terminal is not communicating with several cells and at the same time is principally used by terminals close to the border of the cell for improving performance. The whole of cells that is communicating with the user terminal (UE) is known as the set active. This diversity requires a anchor point in la RAN that divides and combines data streams, to make it possible to have the anchorage in the node that turned on the antenna in a cell and have other cells with their data streams run through the node, this is not desirable from the point of view of the transport network. The majority of the radio access networks are the limits of the transport network , primarily on the last instalment, which is the last jump to the site of the dish. In addition, the web sites of antenna leaves are generally in an arm of the tree and, therefore, an anchor in fact sheet often involved in the last mile has to be traversed repeatedly as shown in figure 4.2 . Due to this fact, the anchor point was specified to be in a separate node to the node of antenna connection.

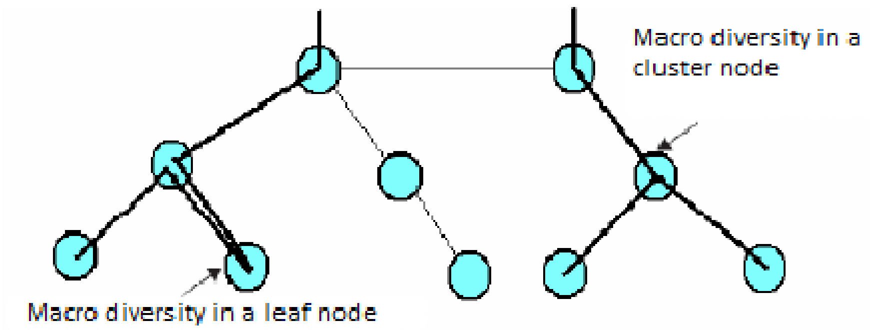


Figure 4.2 Network topology influencing transport assignment.

Like result of the previous, the link layer you need to end in the same node as the macro-diversity, or in a node in the hierarchy echó a correr. Since the only reason to end the link layer in another node would be save resources of transportation and the take them separated cause considerable complexity, it has been decided to have them in the same node. The node he became RNC (Radio Network Controller), as basically controls la RAN.

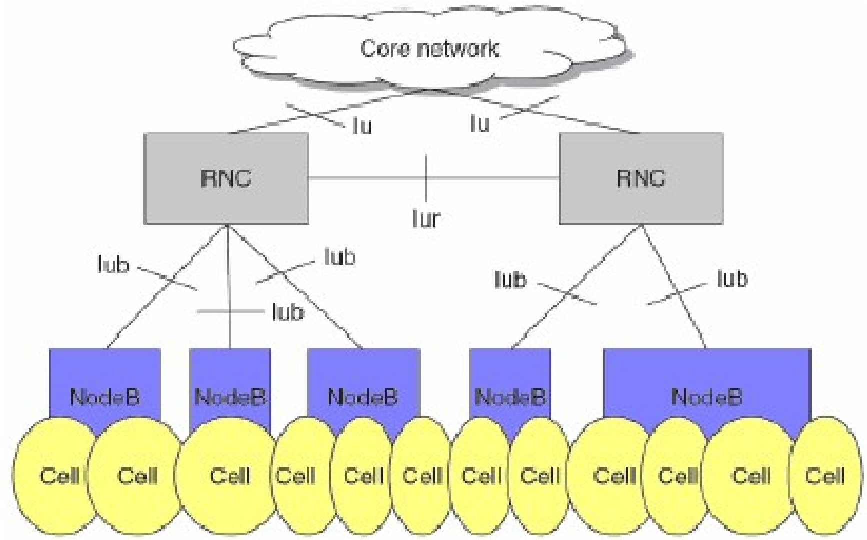


Figure 4.3 Radio Access Network WCDMA / HSDPA: nodes and interfaces.

Figure 4.3 shows an overview of the access network radio WCDMA/HSPA. Each CNR in the network can be connected to any other CNR in the same network using the interface Iur, which is an extensive network interface that makes it possible to keep a RNC as an anchor point to a terminal mobility and hide from the nucleus of network. In addition, the interface Iu can make the macro-diversity between cells of different RNCs. A RNC connects to an NodeB (NB) or more, using the interface Iub, but the NodeB can only be connected to a single RNC the controls. This means that the CNR is the best resource on the radio NodeB.

When you specify which should reside functionalities CORRIÓ, it is necessary for the ownership of the interface of radio WCDMA available a node centralized to operate the macro-diversity, as well as the control of resources radio in several cells. Although the NodoB is a logical node that manages the transmission and reception of a set of cells, the RNC controls a number NodosB and thus the wider area. In addition, the interface Iur makes this possible to have a coordinated approach to the area of coverage of the network.

The CRNC, controlling RNC, provides the frequencies to be used by the NodeB in their cells , on power and the common channel of them, and sets how codes should be used by HS-DSCH (high-speed downlink Shared Channel) and the maximum power to use. In addition, if a user access a RAN the authority to use the radio resources in a cell belongs to one of its NodesB and specify which of them will be. The RNC, in this case, to become the sirviendo RNC (SRNC) for the user.

The SRNC it makes the valuation of the reports on the measurement of the terminal and on the basis of them, decides which one cell will be part of the set active. It is the quality of the terminal, the connection of users to the heart of network and configuration of the terminal with what is allowed the different services to the user you want to use.

During the connection, the terminal can be moved and some time you may need to connect to a cell belongs to another RNCS. In this case, the terminal SRNC needed to make contact with the RNC owner of cells that the terminal has to use requesting permission to add the new cell to the active set. If the owner CRNC accepted , the SRNC dictates that the terminal join the cell a whole, and the CRNC then becomes the drift RNC (DRNC). The drift RNC can be a serving RNC for the other terminal at the same time. Therefore, the serving and drift are two different roles a RNC can take a connection to a terminal (figure 4.4).

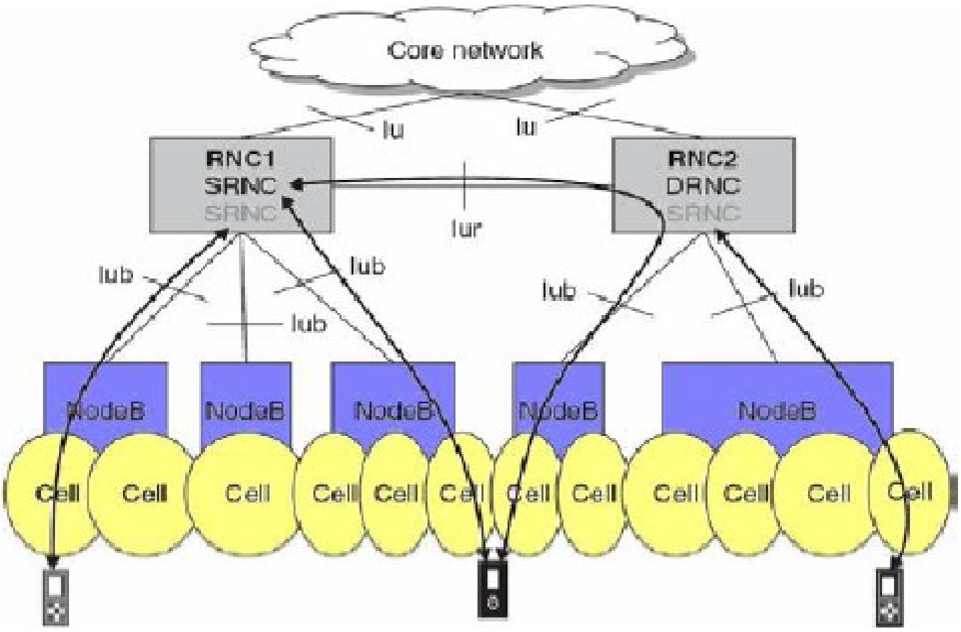


Figure 4.4 Roles of RNC.

For the service of multimedia broadcast and multicast (MBMS), the RNC has a particular role that is to decide if the use of radio channels in the cell or used channels unicast. When using the unienvío channels, the operation is for normal traffic, and when you are using the canal de difusión, the RNC you have the option to make sure that the same data to be transmitted in the environment of their cells. Is why the terminal can make a macro-diversity combine the flow from the different cells and performance of the system cannot be increased.

The basis of using unicast or broadcast to the service MBMS in a cell, it is typically set by the course number of mobile terminals for the reception of content similar at the same time in a cell. If there are a few users in the cell, unicast approach is more efficient than if many users (or in the area of the cell), that is more efficient with the use of broadcast channels.

3GPP has seen the possible migration of architecture ran into an option favorable. There are several proposals, one of them is to move the RNC the NodoB that it is possible with the architecture of the Release 99, but with some considerations.

Another of these, it is the location of the safety functions in the site of the NodeB, which is generally regarded as a remote site and uncollateralised. These functions specify the significance and confidentiality you need to make to the transport of the cryptographic keys to the NodeB. This is in the last section, which you need to be protected by some sort of security, for example, IPSec. However, this is not enough to connect secure, as well as the specific equipment to their needs to the evidence of manipulation, what can be complex and costly. Therefore, if the operator knows that the NodeB is in a safe place, then it can be implemented a network with NodesB RNCs and applications in the same hardware.

Another consideration appear with the functionality of the site RNC NodeB, that is the function of macro-diversity in need by the link to rise of HSPA for a good capacity and quality.

4.3.2 Radio Access Network of LTE

At the time of adopting the architecture of a single node in LTE, the role of macro diversity was put under discussion in 3GPP. Although technically is possible to place the functionality of macro-diversity in the node that corresponds to LTE (ENB or ENB), the fundamental need for this was questioned. Very soon, it was decided that the macro diversity in the downlink is not required for unicast traffic, but with respect to uplink, resolved which was not gains for LTE to motive the rise of complexity. Thus conclude that the macro-diversity among eNBs is not supported in LTE.

For traffic broadcast and multicast was determined thet the eNBs need to be able to transmit data in the same way sync, in order to support the operation of services MBMS. Also the needs of the mobility of the terminal must be considered, since there are two points to the mobility in need of attention: guarantee that no data loss when switching cell and reducing the impact on the core network to switch cell. To solve these, it was agreed that a central anchor in an outer layer retransmission, ENB make this easier for mobility. With this, the 3GPP decided that the added complexity, not having the anchor, was better than the requirement of a RAN node functionality out of the ENB.

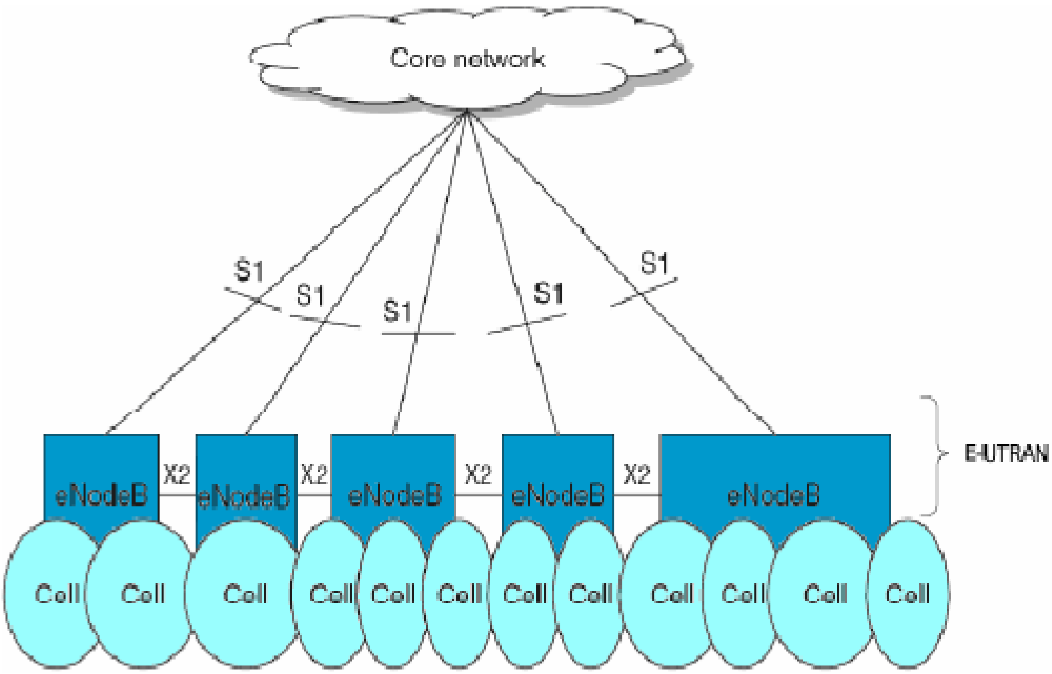


Figure 4.5 LTE radio access network: nodes and interfaces.

Figure 4.5 is a comprehensive approach to LTE radio access network with nodes and interfaces. Contrary to what was seen in the radio access network of WCDMA / HSPA, LTE only has one type of node, the ENB (E-UTRAN NodeB), therefore there is no equivalent of a RNC node to an LTE network. The main reason for this is that there is support for the uplink or down dedicated user traffic and the design philosophy of minimizing the number of nodes.

The eNB is responsible for a set of cells that don't need to be using the same place of antenna, similar to the NodoB in WCDMA/HSPA. The eNB has inherited the majority of the functionality RNC and is a node more complex that the NodeB. It is also in charge of the only cell -making RRM Radio Resource Management), making of handover and programming for users of both in the link up-down. Of course, also makes the functions of physical layer as; codification, decoding, modulation, demodulación, patch and organizes the mechanisms of broadcasting (HARQ).

The ENB is connected to the network core using the S1 interface, which is similar to the Iu interface. There is also an Iur interface similar to the WCDMA / HSPA called X2 interface, it ENB connect any network with any other ENB. However, as the LTE mobility mechanism is somewhat different compared to WCDMA / HSPA, as there is no anchor point in the LTE RAN, the X2 interface between eNBs used only with neighboring cells and is also used to support mobility in active mode. This interface can also be used for multi-cell RRM functions. The control plane X2 interface is similar to its counterpart in WCDMA / HSPA, the Iur interface, but lacks support from the DRNC functionality as the concepts of controlling and drift do not exist here. Instead it provides support for functionality ENB relocation, making it through the handover. The user plane of X2 is used to support the minor loss of mobility of packet forwarding. In addition eNBs that are interconnected by X2 interface are the known E-UTRAN (Evolved Universal Terrestrial Radio Access Network)[17].

For the type of MBMS traffic, LTE access network decides whether to use unicast or broadcast channels as in the case of WCDMA / HSPA. With respect to broadcast channels, increases coverage and capacity will be significant if the operation is used MBSFN (Multicast Broadcast Single Frequency Network). In order for the eNBs be able to send data simultaneously, a MBMS Coordination Entity (MCE) synchronized by a global clock (eg GPS) transmissions of eNBs and data flows.

4.4 CN Architecture.

As mentioned before, the mobile core network needs to perform the functions involved. The core network of WCDMA / HSPA and LTE respectively, is based from the outset, the evolution of network used in GSM / GPRS. The CN used for WCDMA / HSPA is very close to the original GSM / GPRS, whereas the LTE is a radical evolution of Core Network of GSM / GPRS. This is why it has its own name: Evolved Packet Core (EPC).

4.4.1 Core GSM network used by ECDMA/HSPA.

The network core WCDMA / HSPA is based on the same nodes of the GSM network CN, although the functional division of the two technologies is different, this causes the use of different interface between them. WCDMA / HSPA Iu interface is used, while for GSM A and Gb interfaces.

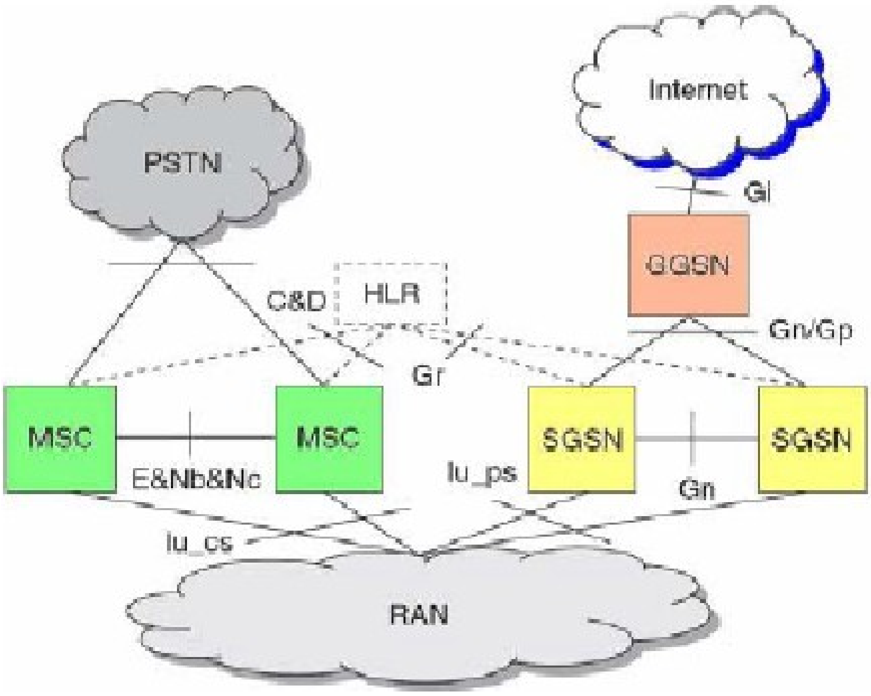


Figure 4.6 Simplified description of the Core Network GSM and WCDMA / HSDPA.

In the figure 4.6 shows an overview of the architecture of the core network used to WCDMA/HSPA. The core network consists of two different domains:

· El dominio de Conmutación de Circuitos (CS), con el Mobile Switching Centre (MSC).

· El dominio de Conmutación de Paquetes (PS), con el Serving GPRS Support Node (SGSN) y Gateway GPRS Support Node (GGSN).

As also seen in the figure above, the Iu interface connects the redWCDMA / HSPA to MSC through the interface and the SGSN *Iu_cs* through *Iu_ps* interface.

Iu_cs interface used to connect the RNC in WCDMA / HSPA to the circuit switch core network domain, ie the MSC that is used for connecting telephone calls to the Public Switched Telecommunications Network (PSTN). MSC and the circuit switched domain, use the functions of the Integrated Services Digital Network (ISDN) as a switching mechanism. Therefore, signaling to the MSC based on ISDN. *Iu_ps* interface is used for connecting the RNC to the packet switch, which connects the SGSN and a GGSN via a *Gn* interface or GP. The GGSN has a *Gi* interface that connects to the external packet network (eg Internet) and to the service operator or the IMS domain.

Common to both domains is the Home Location Register (HLR), a database operator's network origin tracks the operator's subscribers. The HLR contains information about the current location of the subscriber's card SIM / USIM (Subscriber Identity Module / UMTS SIM - Subscriber Identity Module / UMTS SIM). The HLR is connected to the MSC through the interface C & D, and the SGSN via the Gr interface.

The interface supports a feature called Iu flex. This function allows an RNC connected to more than one MSC and SGSN or SGSN and MSC, it is useful to reduce the impact if one of the core network nodes is not available. Iu flex mechanism is used to distribute the connection terminal on multiple nodes SGSN and MSC, if one is not available, the other maintains its assigned traffic and can take all incoming calls or requests for session initiation packages (many of the incoming calls are expected when the core network node is not available, since most of the terminals will try to reconnect when they go offline without notice).

4.4.1.1 MBMS, Multicast, Broadcast.

The MBMS service is used in the packet switched domain core network. Consequently *Iu_ps* interface is used to connect to the RAN's WCDMA / HSPA. For MBMS, the core network is the one who decides if transmission is used broadcast or multicast of the carrier. In the case of broadcast, the network core does not know the identity of mobile terminals receiving the information, while for multicast if known. Thus, the terminals do not need to report to the network core of your intentions when you receive a service that uses the broadcast carrier, whereas when you receive a service that is using a multicast carrier terminals need to report to the network core on these intentions.

By therefore, the RAN may decide whether to use transport unicast or broadcast channels in the cell. Essentially, the ANC asked the user who is in a cell, if you are interested in a specific service, so if there are enough users who are interested, selects the broadcast channel but the channel is used unicast.

4.4.1.2 Roaming

The functionality of roaming in the network core enables a user to use the network of another operator. This is supported by both the circuit switched domain and packet. In both domains there are different possibilities, but in practice traffic is routed through the operators of origin for the PS domain GGSN. For the CS domain, the common case of calls originating terminal (outgoing) is to make the exchange in the visited network. Terminal for receiving calls (incoming calls) is provided through the home network as shown in Figure 4.7.

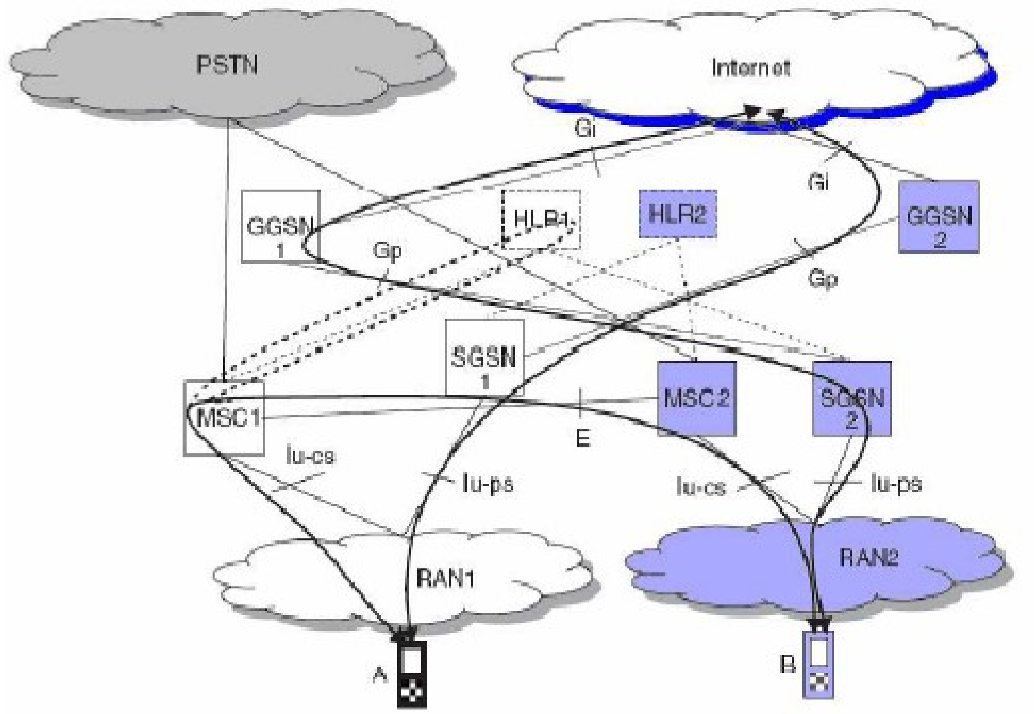


Figure 4.7 Roaming in GSM and WCDMA/HSPA.

The figure shows two terminals belonging to two different operators (A and B). The terminals have roaming in another operator's network and both have connections to packet switching. In addition, the terminal A is called by the terminal B through circuit switched domain. The packet switched connections are routed from the SGSN in the visited network, the GGSN in the home network, using the Gp interface. For circuit switched call, the terminal A (originating call) is connected to MSC of visited network . He realizes that the called terminal in your network, and therefore contact your HLR responds with information that the terminal B is served by MSC in the network 2. MSC1 then contacts the MSC2 which a stable connection to the terminal B.

4.4.1.3 Control Policies and Pricing.

The charging function is very important for the operator who is in the network core. For the circuit switched domain, it takes place in the MSC, while for the packet switched domain, this is handled well in the SGSN or the GGSN. Traditionally, it has become possible pricing for minutes used and charging by volume. The first is used for circuit-switched domain while the latter is more commonly used in the packet switched domain. However, other pricing principles are also possible, for example, single share with or without opening rates. Different rates are used depending on the subscriber's subscription and / or the user uses roaming or not. By manipulating GGSN charging services packet switching, advanced charging systems, is compatible content-based charging or event, allowing the operator charging users depending on the service end.

Policy control is a function that is used in the core network to control the use of packet switched services, and thus ensures that you do not use more bandwidth than is allowed, or the user can access only approved services or Web sites. Policy control is performed in the GGSN and exists only in the packet switched domain.

4.4.2 The core network SAE: Envolved Packet Core.

When it began the standardization of LTE RAN, began the work involved for the CN under LTE System Architecture Evolution (SAE). The core network SAE defined in the system is a radical evolution of the core GSM / GPRS, and it is therefore she has a new name, or EPC Evolved Packet Core (Evolved Packet Core). The SAE system only covers the field of packet switching, not circuit switched. Looking back, the philosophy of minimizing the number of nodes also reigns in the core network standards. Consequently, the EPC network architecture began as a single node with all functions in the same, except the Home Subscriber Server (HSS), which remains outside the node. The HSS is a database node HLR corresponding to the core GSM / WCDMA.

Figure 4.8 is shown as the Evolved Packet Core fits into the overall architecture. The EPC is connected to the LTE RAN through the S1 interface to the Internet through the IMS and the HSS interface via interface S6. S1 is the interface between eNBs and EPC, which is very similar to the interface *Iu_ps*. The S1 and user plane tunnel *Iu_ps* are IP-based transport, they do not know the contents of the packet. The end-user IP packets are placed in the S1 IP tunnel by the EPC or the ENB and recovered at the other end (ENB or EPC).

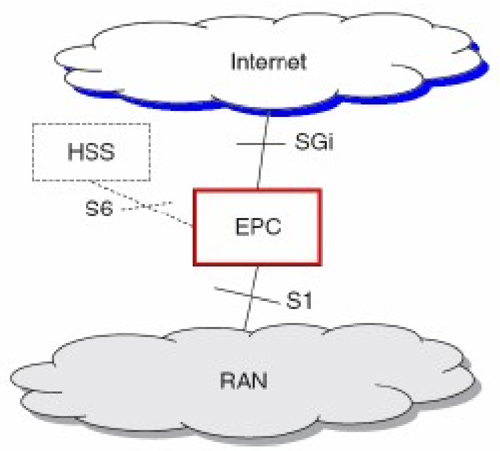


Figure 4.8 Simplified description of the Core Network for LTE SAE.

To control the level of the difference between S1 and Iu is not much, in fact, only in the details of establishing carrier is visible. The difference lies in the way of indicating quality of service assigned on a user's specific flow. For WCDMA / HSPA is through the parameters of Radio Access Bearer (RAB) while LTE is done by means of which points to a specific priority class.

S6 interface is shown connecting the EPC to the HSS. This evolution is a Gr interface used by WCDMA / HSPA to connect to the HLR. Therefore, a combination of HLR / HSS for the Evolved Packet Core, may be the same as that shown in the core GSM network to WCDMA.

Perhaps the biggest difference between WCDMA / HSPA and LTE is the mobility management. In LTE, the EPC serves as an anchor in the SAE core network for mobility, being an EPC node that handles the user plane is not changed during a connection. The EPC takes here the role of a GGSN for GSM / GPRS and WCDMA / HSPA. Due to the flat architecture, the node must be able to connect to each ENB essentially on the network, and updated within it, which should guide the user's packets. This is the big difference compared to the RAN WCDMA / HSPA, where the RNC hides this kind of mobility from the core network.

Tres son las entidades básicas para soportar la movilidad: la MME (Mobility Management Entity), el S-GW (Serving-Gateway) y el PDN-GW (Packet Data Network-Gateway). Por medio de la interfaz S1, éstos se interconectan con la RAN. Dicha interfaz consta del plano de control S1-mme, entre el eNB y el MME, y del plano de usuario S1-u, entre el eNB y el S-GW (ver Figura 4.9).

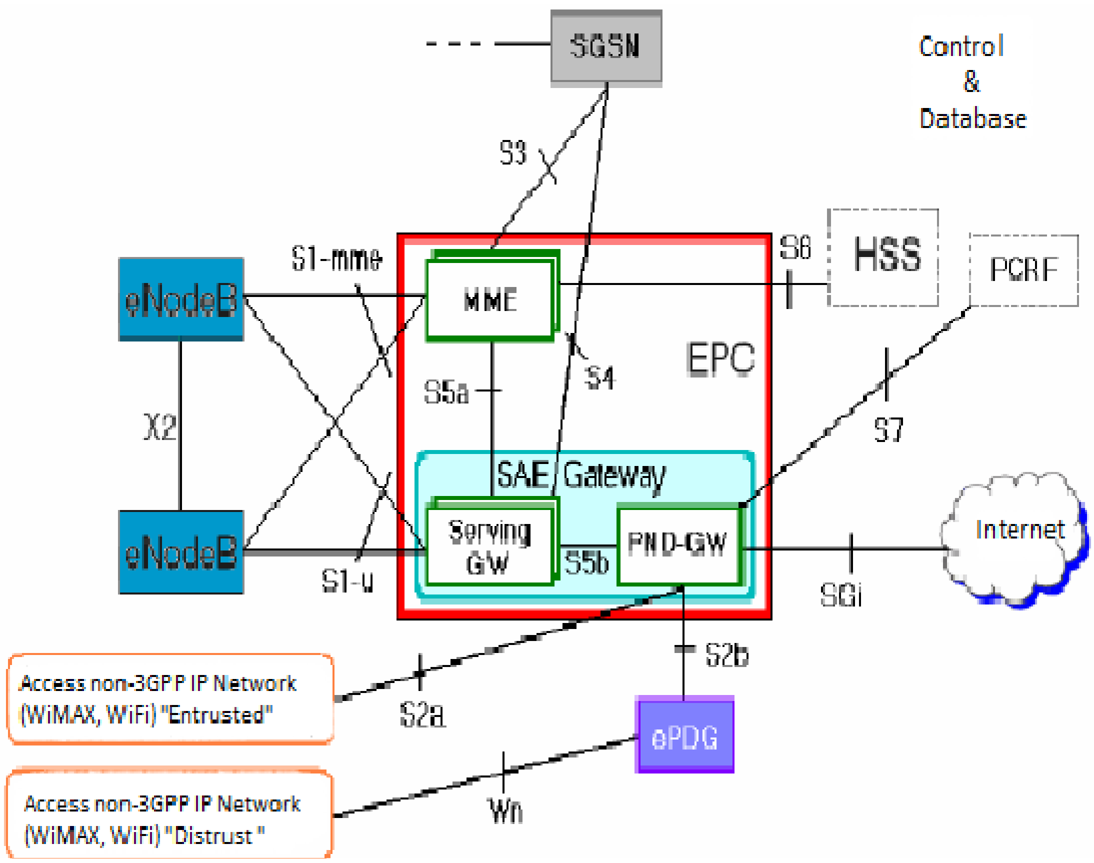


Figure 4.9 Functional elements and interfaces of the EPC.

4.4.2.1 SAE Gateway.

It consists of two logical entities of the user plane, the S-GW and the PDN-GW, and provides an interface between the access network and the various packet networks. In practice both gateways can be deployed as a single network element. The S-GW is responsible for
the following functions:

- Actively involved in the mobility process when a transfer (handover) between eNBs.

- Through the interface S4, based on the protocol GTP (GPRS Tunneling Protocol) is the entity involved in user traffic in case of mobility between 3GPP LTE and other technologies.

- In case of need for user traffic information to a legislative requirement, is responsible for replicating the information.

The PDN-GW is seen as the input / output traffic to / from the user, providing connectivity to the rest of external networks, highlighting the following tasks:

– Through the interface S7 is performed transferring the QoS and pricing policies that apply to user traffic between the PCRF (Policy and Charging Rule Function) and the PDN-GW.

– Facilitate the seamless mobility and continuity in the sessions when the user moves between access networks technologically heterogeneous, i.e, from a network 3GPP (GSM, WCDMA, HSPA) to another network that is not 3GPP (WiMAX or Wi-Fi).

Networks that are not part of the 3GPP, are distinguished in two types of access: Confident and distrustful, and the operator is to decide the type of each network who would allow their connection. The interconnection network considered suspicious, is performed using a ePDG (evolved Packet Data Gateway), which implements IP mobility protocols, being necessary to access the services offered by the operator. The user terminal establishes an IPsec tunnel through the interface ePDG Wn. The interconnection of confidence does not use the ePDG, so PMIP protocols are used directly with PDN-GW by S2a interface.

4.4.2.2 MME.

Is a controlling entity, solely responsible for signaling, and that she did not pass data packets from users. By S3 interface based on the GTP protocol, the control is made for mobility signaling 3GGP networks and interacts with the HSS (Home Subscriber Server), based on the Diameter protocol, which performs the authentication of users. Gives operators the advantage of increasing the capacity of signaling independently of user traffic, and which is a network dedicated to functionally separate signaling and gateways.

4.4.2.3 S1 Flex.

Similar to Iu flex, flex S1 enables more robust core network, with more flexibility in interconnect access nodes and the central system, breaking the usual hierarchical network. If one node EPC is unavailable, another node can take over the loss of traffic. Furthermore, the expansion of the network is easier because the EPC nodes can be added as needed by the traffic demand and not by an increase in coverage.

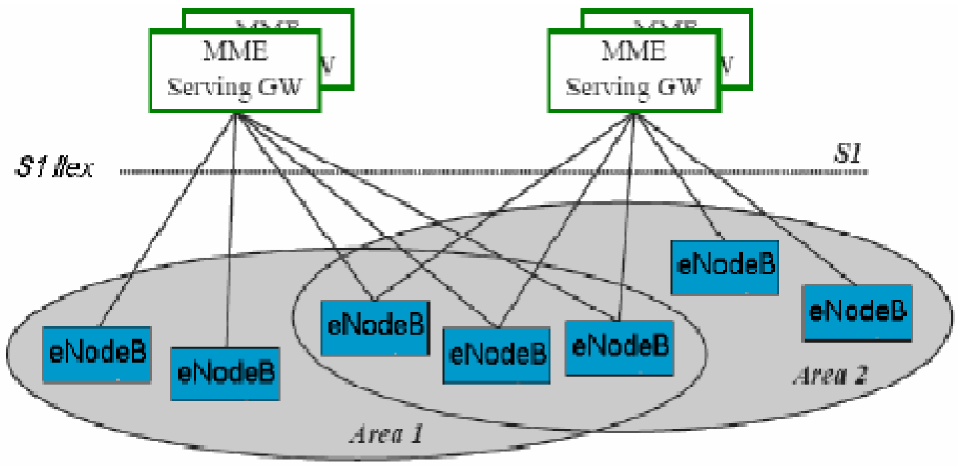


Figure 4.10 S1 Flexibility function.

As shown in Figure 4.10, S1 flex provides redundancy and load sharing, enabling ENB be connected to more than one node or Serving Gateway MME. The application is for both S1 flex independently.

4.4.2.4 Roaming.

Similar to the scenarios considered in today's networks, a distinction depending on whether the user traffic is routed to the home network or not. This latter scenario is called local breakout.

In the case that the user traffic is directed to the Home network, the solution adopted by SAE would make a separation between the S-GW and the PDN-GW. The first, along with the eutrophi and MMES, would be located in the visited network while the PDN GW and the PCRF HHS would be in the home network.

Interface between the S-GW and the PDN-GW would become S8 interface based on the current reference point between the SGSNs Gp and GGSNs. However there are still define some unresolved issues such as the location of the PCRF in the visited network and a possible interaction between the PCRF in the home network and visited network.

The local breakout scenario is applicable in certain situations in which the service can be directly offered by the visited operator, eg is delegated to the visited network operator's Internet access service. Regarding the above scenario, the PDN-GW would be located in the visited network, leaving unresolved the interaction between the PCRF in the home network and visited.

4.4.2.5 Control Policies and Pricing.

In Release 5 and 6 of the 3GPP defines the first architectures for pricing and flow control for IP QoS. The unification of these architectures is finalized in Release 7 on behalf of PCC (Policy Control and Charging). This architecture defines a node, the PCRF, which is responsible for authorizing the services or IP flows that are accessed by a user as well as performing the provision of pricing policies and QoS at the node in charge of run, the PCEF (GGSN in GPRS / UMTS).

Another feature of PCC is the improvement in the standard form of the QoS for "PDP Context", taking a very important step which is to control the QoS, the new data networks, rests with the operator and not the EU.

A key issue for operators is to reuse the long run all the deployed architecture for policy management in the network and the terminal, which is why, in order to ensure a smooth migration to SAE, is taken as a criterion design, reuse of the PCRF interfaces defined for the Release 7.

4.4.3 WCDMA/HSPA connected to the Envolved Packet Core

When the LTE / SAE has been introduced into the network, is necessary the handover to WCDMA / HSPA, and this is solved by connecting to the EPC network. In fact, the SGSN of the core GSM network is used for WCDMA / HSPA is connected to the EPC, which acts as a GGSN when traffic is routed through the RAN's WCDMA / HSPA using S4 interface (based at the interface Gn / Gp used between GGSN and SGSN), and as a normal EPC when traffic is routed through the RAN LTE. This is possible from one end of the user plane in the EPC, thus maintaining the IP address of the terminal. Parts of the plane EPC control are not used when the terminal is connected to the RAN of WCDMA / HSPA, however, the protocols of the core network SGSN if used. With this approach, the required changes are minimal for the core packet network used by WCDMA / HSPA, at the same time must be able to provide fast and seamless handover to and from LTE (Figure 4.11).

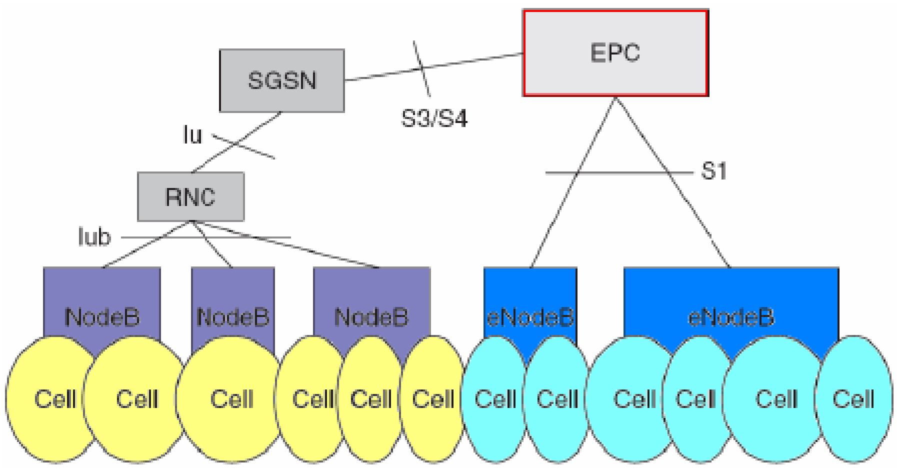


Figure 4.11 WCDMA/HSPA connecting with LTE/SAE.

When is necessary, the handover from WCDMA / HSPA to LTE, the connection is made for the EPC through the SGSN through the S3 interface based on the Gn interface SGSNs used between SGSN relocation. Thus, the handover is about to relocate to a change SGSN user plane in the EPC instead of the GGSN.

4.5 Architecture of the Protocols of Interface Radio.

An overview of the LTE protocol architecture for the downlink is illustrated in Figure 4.12. As will become apparent below, not all entities shown are applicable to all situations. For example, the MAC scheduling, HARQ with a quick combination, are not used for the broadcast system information. In addition, the LTE protocol structure connected to the uplink transmission is similar to falling in Figure 4.12, although there are differences in the selection of transport format and transmission of multiple antennas.

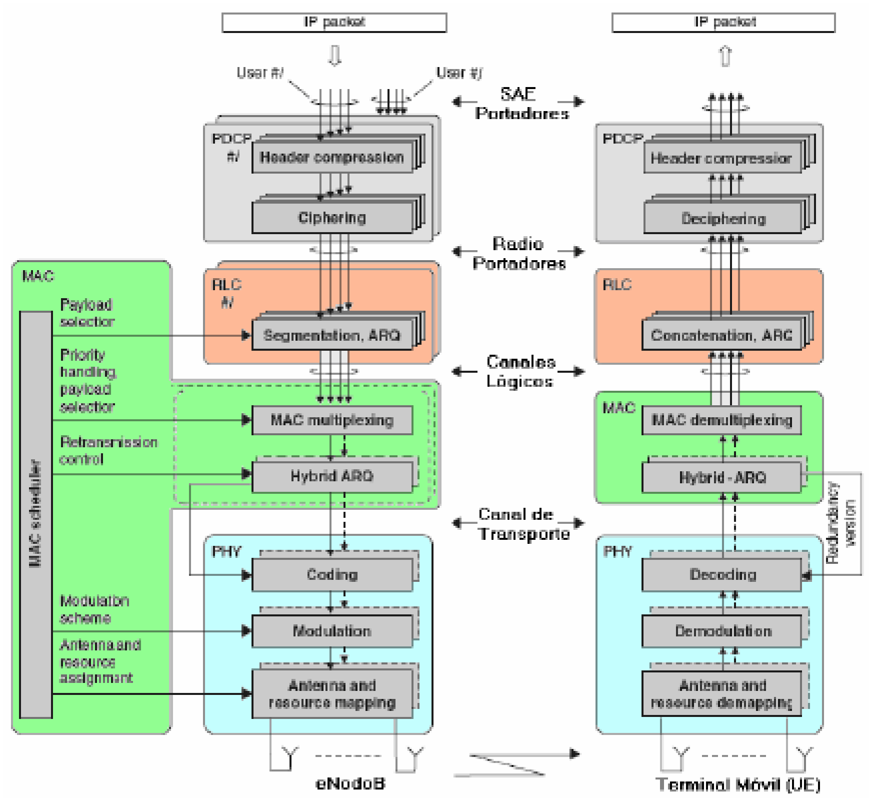


Figure 4.12 LTE Protocol Architecture.

The data are transmitted as IP packets come in one of the carriers SAE. Before transmission via radio interface, IP packets pass through multiple protocol entities.

4.5.1 RLC: Radio Link Control.

The RLC of LTE is responsible for the segmentation of IP packets, known as Service Data Units (RLC SDUs) into smaller units called protocol data units RLC (RLC PDUs). Also responsible for the retransmission of PDUs (Protocol Data Units) received incorrectly and ultimately ensures the sequence delivered SDUs (Service Data Units) to the upper layers.

The RLC retransmission mechanism provides error free delivery of data. To accomplish this, a retransmission protocol operates between RLC entities in the receiver and transmitter. By monitoring the sequence numbers are received, the reception of RLC PDUs can identify missing. For each incorrectly received PDU, the RLC retransmission requests which follows and is transmitted through status reports. When you set the feedback, a status report typically contains information about multiple PDUs and transmitted relatively infrequently. Based on the reception of status reports, the RLC entity at the transmitter can retransmit the missing PDUs if requested. When the RLC is configured to request retransmission, is said to work in AM mode (Mode supported) that is normally used for services based on TCP (Transmission Control Protocol), where data transfer is error free primary interest.

As in WCDMA / HSPA, the RLC can also be configured in UM mode (non admitted) and TM mode (Transparent mode). In UM provides delivery to upper layers in sequence, but no request retransmissions of missing PDUs. UM is often used for services such as VoIP, where error-free delivery is of less importance in comparison with short delivery time. TM mode is only used for specific purposes such as random access.

Although the RLC is capable of handling transmission errors due to noise and unpredictable channel variations, in most cases these are treated by the MAC protocol based on HARQ.

In addition to managing the transmission and delivery sequence, the RLC is also responsible for the segmentation and concatenation as shown in Figure 4.13. Depending on the decision of the programmer, a certain amount of data is selected for transmission from the RLC SDU buffer, and the SDUs are segmented / concatenated to create the RLC PDU. Thus, for LTE RLC PDU size varies dynamically, while in WCDMA / HSPA before version 7, use a semi-PDU size[1]. Therefore, the data transmission speed LTE can vary from a few Kbps to a value well above the hundred Mbps, encouraging support for LTE easy. These coping mechanisms and programming speed are in the ENB.

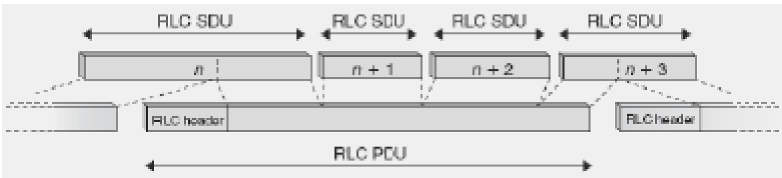


Figure 4.13 RLC segmentation and concatenation.

4.5.2 MAC: Medium Access Control.

The MAC layer is responsible for logical channel multiplexing and scheduling HARQ retransmissions of both links, ascending and descending. This is defined by a cell service, which is the cell of the mobile terminal which is connected to the cell responsible for scheduling and HARQ operation.

4.5.2.1 Logical Channel and Transpot.

The MAC offers services in the form of RLC logical channels. A logical channel is defined by the type of information carried and are generally classified into the control channels used for transmission of control and configuration information necessary for the operation of the LTE system, and traffic channels are used to user data.

The types of logical channels specified for LTE are:

- *Broadcast Control Channel* (BCCH) is used for transmission control system information from the network to all mobile terminals of the cell. Before accessing the system, a mobile terminal needs to read the information provided in the BCCH to find out how the system is configured.

- *Paging Control Channel* (PCCH), used for paging of mobile terminals, whose location in the level of cells is not known in the network and the paging message, therefore, needs to be broadcast in multiple cells.

- *Dedicated Control Channel* (DCCH), used to control transmission of information from / to a mobile terminal. This channel is used for individual configuration of mobile terminals, such as delivering different messages.

- *Multicast Control Channel* (MCCH), used to control transmission of information required for receipt of MTCH.

- *Dedicated Traffic Channel* (DTCH), used for bidirectional transmission of user data to a mobile terminal.

- *Multicast Traffic Channel* (TCM), used for downlink transmission of MBMS services.

The MAC layer also uses the services as transport channels. A transport channel defines how and with what characteristics data is transmitted by the radio interface. Following the notation of HSPA, which has been inherited by LTE, the data in a transport channel between blocks are arranged transport. In each transmission time interval (TTI), at most one block with a certain size, is transmitted through the radio interface. In the presence of spatial multiplexing can be up to two TTI transport blocks.

Associated with each transport block there is a transport format (TF), specified as the block is transmitted, including information about its size and modulation scheme. By varying the transport format, the MAC layer can perform different types of data transmission speeds and therefore carry out its control.

The types of transport channels are specified for LTE:

- *Broadcast Channel* (BCH) has a fixed transport format. It is used to transmit information on the BCCH logical channel.

- *Paging Channel* (PCH) is used to transmit paging information on the PCCH logical channel. The PCH supports discontinuous reception (DRX) to enable the mobile terminal to save battery power when the reception is only in moments of predefined times[3].

- *Downlink Shared Channel* (DL-SCH) is the transport channel used for transmission of downstream data in LTE. LTE supports features like the dynamic rate adaptive channel programming dependent. DRX support, reducing power consumption while still providing mobile an always-on experience.

- *Multicast Channel* (MCH) is used to support the MBMS service. It is characterized by the transport format and programming semi semi. In case of multi-cell transmission using MBSFN, scheduling and transport format configuration is coordinated between cells involved in the transmission MBSFN.

- *Uplink Shared Channel* (UL-SCH) is similar to DL-SCH.

Part of the role of the MAC, is the multiplexing of different logical channels and mapping them to appropriate transport channels. Unlike the MAC in HSDPA, LTE, the MAC supports the multiplexing of RLC PDUs from different radio carriers in the same transport block. An example of mapping the logical and transport channels are shown in Figure 4.14.

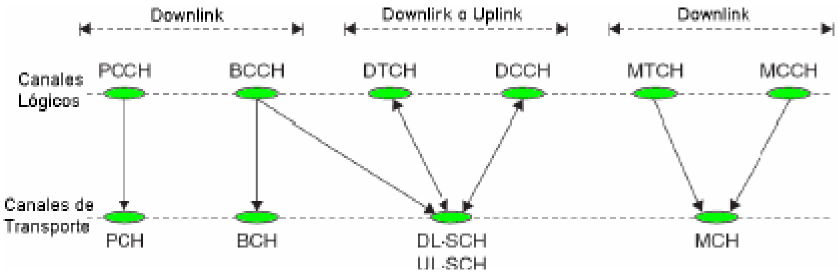


Figure 4.14 Example mapping of logical channels, transport.

4.5.2.2 Downling and Uplink Programming.

One of the basic principles of the LTE radio access, transmission channel is shared on the DL-SCH and UL-SCH, i.e the time-frequency resources are dynamically shared between users on both links. The programmer (scheluder), is part of the MAC layer and controls the allocation of uplink and downlink. Both resources are separated into LTE and their decisions can be taken independently.

Downlink scheduler function is to determine dynamically in each frame of 1 ms, which one terminal is supposed to receive the DL-SCH transmission and what resources do. In each frame, is assigned resource block (time-based unit that covers 180 kHz frequency) to a terminal for receiving the DL-SCH transmission.

The goal of the program is to leverage the channel variations between the mobile terminal, preferably the transmissions to mobile terminals with resources advantages in channel conditions. Due to the use of OFDM as the transmission system in the downlink, LTE can benefit from the channel variations in frequency and time domains, while HSDPA can only take advantage of variations in the time domain. Information on the downstream channel conditions, is fed from the mobile terminal to the NBS via the channel quality reports. In addition to channel quality, high performance programming should take into account the buffer status and priority decisions. It is also the programmer interference coordination, which is to control inter-cell interference.

The basic function of the uplink scheduler is similar to the downlink, i.e dynamically determined for each interval of 1 ms, which are mobile terminals that transmit data on the UL-SCH, and what resources the uplink. For LTE, the uplink is orthogonal and the share is controlled by the scheduler of the ENB. An assigned resource not fully utilized by a mobile terminal can not be partially used by another. Therefore, due to the orthogonal uplink, this represents less gain by letting the mobile terminal selected transport format. Consequently, besides the allocation of resources in time and frequency to the mobile terminal, the NBS is also responsible for controlling the transport format (payload size and modulation scheme) that uses the mobile terminal.

4.5.2.3 HARQ.

The protocol HARQ of LTE is similar to the corresponding protocol used in HSPA, where using multiple parallel processes stop and wait. Upon receiving a transport block, the receiver makes an attempt to decode the block and informs the sender about the outcome of the operation through a single bit ACK / NAK (Acknowledgement / Negative Acknowledgement), which indicates whether the decoding is successful or if required a retransmission of the transport block[3]. To minimize the overhead (header), using a single bit ACK / NAK. For LTE, on the other hand, are designed protocol layers together, which means fewer design constraints.

ARQ mechanism is able to correct most transmission errors due to noise or unpredictable variations of the channel. This may occasionally stop making error-free delivery to the RLC data blocks, causing a difference in the sequence of blocks delivered. This usually occurs due to incorrect feedback signal, for example, a

NAK is incorrectly interpreted as an ACK to the transmitter, causing data loss. The probability of this happening can be 1%, an error probably too high for TCP based services that are virtually error-free delivery of TCP packets. More specifically, for sustainable data transmission rate exceeding 100 Mbps, requires that the probability of packet loss is less than 10-5. To maintain good performance of high speed data transmission, the RLC-AM significantly ensure the delivery of error-free data to

4.5.3 PHY: Physical Layer.

The physical layer (PHY) is responsible for encoding, modulation, HARQ PHY processing, processing of multiple antennas and signal mapping for adequate physical resources of time and frequency. All of them are dynamically controlled by the MAC layer. The physical layer also concerned with the treatment of DL-SCH and UL-SCH (see Figure A2.1), where both are based on a similar process but with some restrictions.

The dissemination of the information system in the BCH, a mobile terminal should be able to receive this information channel as one of the first steps before accessing the system. Indeed, the transmission format must be known in advance terminals and in this case, there is dynamic control of any of the transmission parameters of the MAC layer.

For the transmission of paging messages on the PCH, can be used the dynamic adaptation of transmission parameters. The MAC can control the modulation, the amount of resources and mapping of antennas. However, as in the case of an uplink has not yet been established when a mobile terminal is paged, the HARQ not be used, since there is no possibility that the mobile terminal transmits an ACK / NAK.
The MCH is used for MBMS transmissions, usually with a single frequency network operation through the transmission of various cells in the same resources in the same format simultaneously. Therefore, MCH transmission planning should be coordinated between the cells involved and can not be dynamic selection of transmission parameters for the MAC.

4.5.4 LTE State.

In LTE, a mobile terminal can be in several different states as shown in Figure 4.15. When turn on the mobile enters the state LTE_DETACHED and is not known for the network. Before any new communication between the mobile terminal and network, the terminal needs to register with the network using random access procedure to enter the state or LTE_IDLE LTE_ACTIVE.

LTE_ACTIVE is used when the mobile terminal is activated with the transmission and reception of data. In this state, the mobile terminal is connected to a specific cell within the network. One or more IP addresses have been assigned to the mobile, using the C-RNTI (Cell Radio Network Temporary Identifier). The substates OUT_OF_SYNC IN_SYNC and depend on whether the uplink is synchronized to the network or not. If the uplink is in the state IN_SYNC, it is possible to transmit user data and control signaling. If not, it takes place within a certain window of time, the time alignment is not possible and the link is declared OUT-OF-SYNC. In this case, the mobile terminal needs to perform a random access procedure to restore the link synchronization.

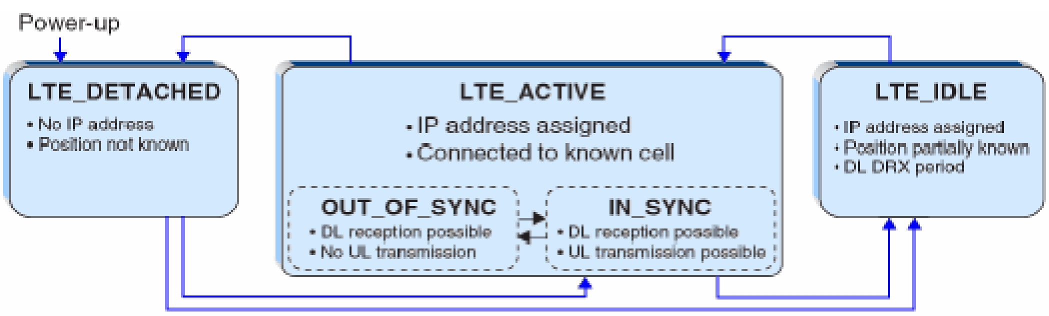


Figure 4.15 LTE State.

LTE_IDLE is a state of low activity in which the mobile terminal sleeps most of the time, in order to reduce battery consumption. Uplink synchronization is not maintained and therefore, the only activity that can be transmitted, it is random access to view LTE_ACTIVE. In the downlink the mobile can wake up periodically to be paged for incoming calls and keeps your IP address to LTE_ACTIVE move quickly when necessary.

4.5.5 Data Flow.

The flow of downlink data across all protocol layers illustrated in Figure 4.16, where there is a case with three IP packet, two radio and one carrier to another carrier radio. The flow of data in the uplink is similar. The PDCP performs IP header compression followed by encryption. A PDCP header is added to the information required to be decoded at the terminal. The output of the ICCPR is directed to the RLC.

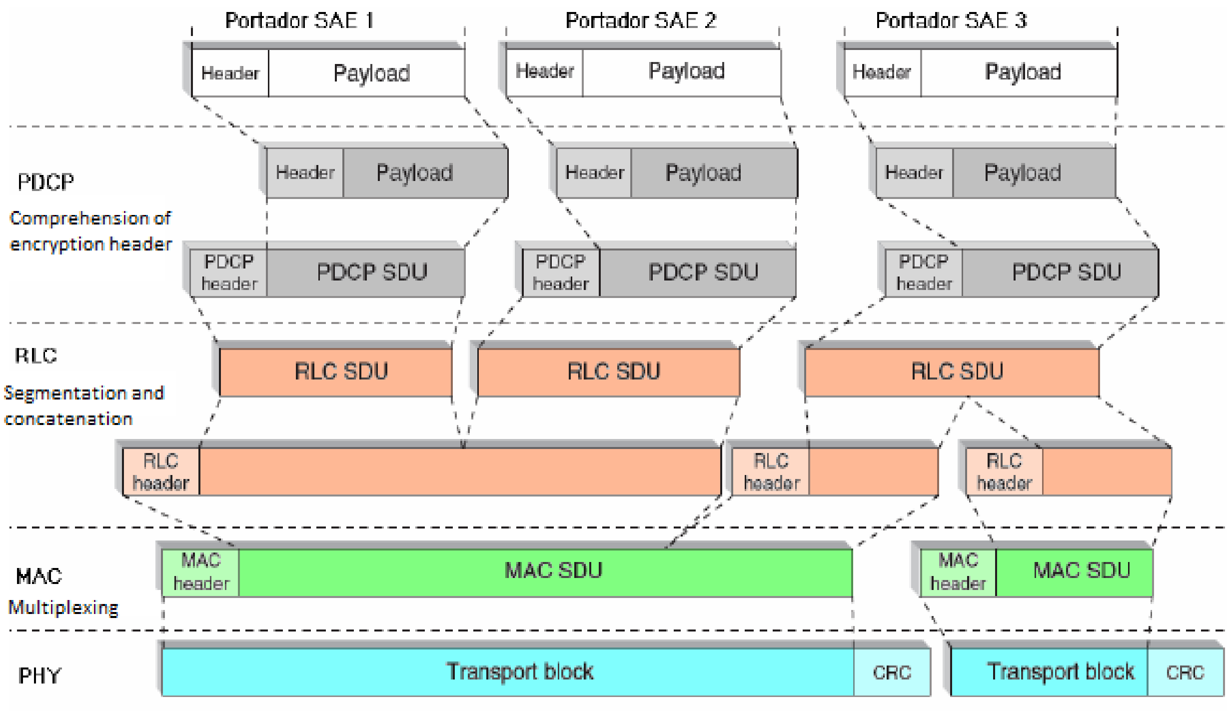


Figure 4.16 Data flow.

The RLC protocol performs concatenation and / or segmentation PSDUs PDC, and adds a RLC header used for the delivery sequence (for logical channel) in the mobile terminal and the identification of the RLC PDUs in case of retransmissions. The RLC PDUs are sent to the MAC layer together in a MAC SDU, and attributing the MAC header to form a transport block. The block size depends on the instantaneous data rate selected by the link adaptation mechanism. Thus, the link adaptation process affects the MAC and RLC. Finally, the physical layer assigns a transport block CRC for error detection, performs coding and modulation, and transmits the resulting signal through the air.

4.5.6 Radio Interface.

The functional architecture of radio interface protocol is, in general, the OSI model and the specific structure of the link layer. Figure 4.17 shows the protocol stack for the user plane and control plane, interacting with the ENB and MME.

In the user plane layers PDCP, RLC and MAC (at the ENB), perform header compression, encryption, scheduling and HARQ.

The control plane protocol is NAS (Network Attached Storage), which is indicated for information only and is part of the communication between the EU and the EPC. The PDCP performs, for example, encryption and integrity protection, RLC and MAC protocols perform the same functions as in the user plane. The RRC performs the broadcast protocol, paging, connection management, radio bearer control, mobility functions, reporting, measurement and control of the EU.

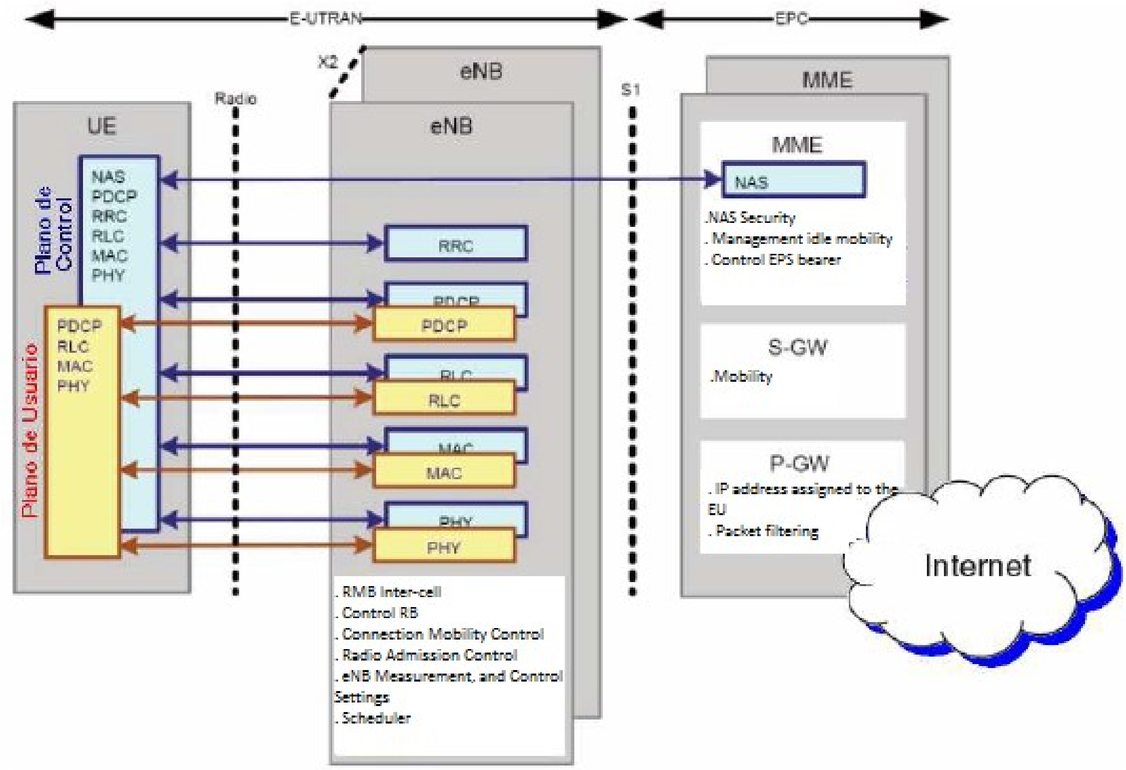


Figure 4.17 Functional division between E-UTRAN and EPC.

4.6 Qos, Quality of Service.

Applications such as VoIP, Web browsing, video telephony and video streaming, have a special need for QoS. Therefore, an important function of any all-packet network is to provide the QoS mechanism for the possible differentiation of packet streams based on QoS requirements. In SAE, called QoS flows SAE bearers are established between the UE and the P-GW as shown in Figure 4.18. A radio bearer transports the packets of a SAE bearer between a UE and an ENB. Each IP flow is associated with a different SAE bearer and the network can prioritize traffic accordingly. When an IP packet is received from the Internet, the P-GW performs packet classification based on certain predefined parameters and shipped in a carrier suitable SAE[2].

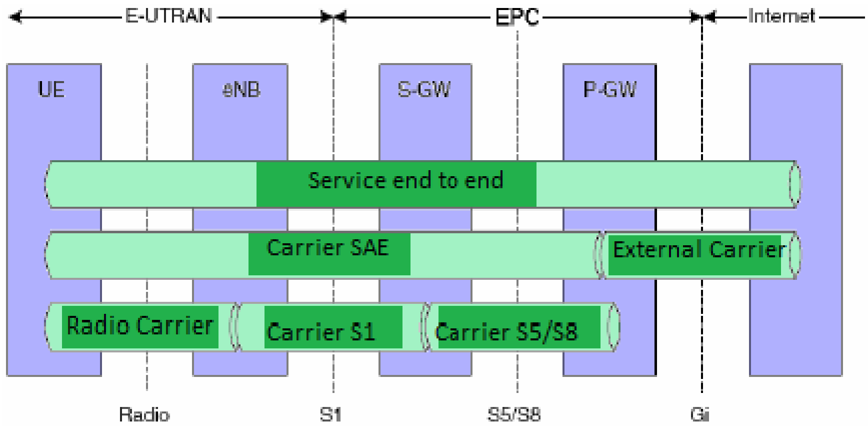


Figure 4.18 Architecture SAE Carrier Service.

An important feature is the simplification in the management and characterization of the parameters that define the QoS associated with each carrier. Although now in definition, it seems likely that each SAE bearer is associated with a label and a value of ARP (Allocation and Retention Priority).

The label is a scalar that defines a QoS profile. This profile would define the characteristics on weights of queues, thresholds for admission, queuing thresholds and would be set by the operator at each node (eg. eNB).

The ARP would determine the possibility of accepting a new activation or modification of the carrier in situations of congestion. In addition, in exceptional situations of congestion, the ARP could be used to determine the carriers to be released.

Another parameter that defines the QoS of each carrier is required transmission speed. On this basis there are two types of carrier, "GBR (Guaranteed Bit Rate) and" Non-GBR ", depending or not they require a guaranteed transmission rate, in order to support streaming services such as IPTV or Radio Internet. It should be noted that the architecture of the Tariff Policy Control allows control not only carrier-grade QoS, but also as an option, control and enforcement of QoS policies by IP flow.

Chapter 5

GLOBAL DEVELOPMENT

This chapter provides an overview of research activities and LTE, providing an update on the results published so far and further development should be for expansion in trade.

5.1 Background.

Now that the standards of 3GPP for LTE / SAE functionally have been stopped, we consider the activities necessary for the implementation of the technology and prepare it for commercial expansion, development of prototypes, interoperability testing and field trials. To ensure the proper development of the next generation, has established a global initiative called LSTI (LTE / SAE Trial Initiative), which consists of operators and equipment providers to coordinatethe activities needed to be taken into account when adopting technology, and reporting on progress in these activities, in order to ensure that everyone has a realistic understanding of the performance and functionality expected from LTE.

LSTI wants to accelerate the commercialization of LTE / SAE, encouraging the adaptation of technology by all participating suppliers. The initiative was officially launched in May 2007 by a small group of network operators with network infrastructure vendors, Alcatel-Lucent, Ericsson, Nokia, Nokia Siemens Networks, Nortel, Orange, T-Mobile and Vodafone, that progressively more operators are joining and measurement equipment manufacturers and terminals (see Figure A4.1). Also concerned with testing the technology on existing implementations of the standard. Compare the measurements of the equipment in the laboratory, field testing requirements and the requirements of the objectives of both organizations NGMN (Next Generation Mobile Networks) and 3GPP.

To demonstrate that LTE / SAE meet expectations, a number of test points were agreed in relation to different aspects of performance and functionality. An activity test (PoC-Proof of Concept) comes with the results of the prototype vendors and outdoor test to see if the technical requirements of performance can be obtained in pre-commercial performances (see Figure 5.1). These PoC tests are:

- Speed of data transmission and spectral efficiency peak.
- Speed of data expected to end users.
- Proof of individual field and multi-cell.
- latency.
- Handover and downtime.
- Voice over Internet Protocol (VoIP) and Quality of Service (QoS) support.

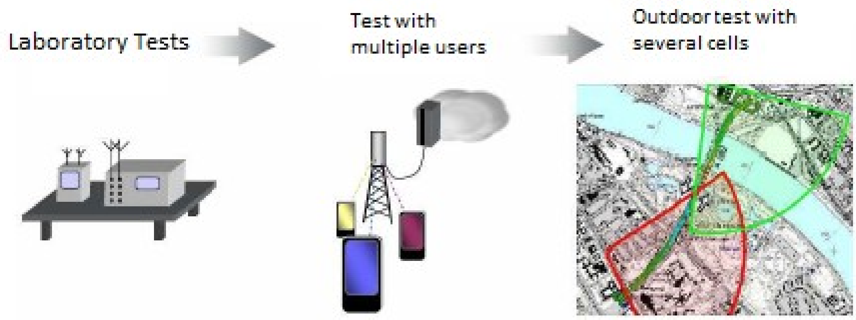


Figure 5.1 Proof of Concept LTE.

The objectives of this activity gives a realistic view of how LTE / SAE will be held, completing this phase in early 2009.

Undoubtedly, this technology has the ability to break the economies of scale typical of the usual networks, offering increased capabilities. Based on this, some governments in several countries have opted to push mobile telecommunications markets to achieve maximum development, encouraging competition among different providers. Having the belief that technology can consolidate through future auctions of radio spectrum, and appropriate regulations that allow the delivery of quality services.

5.2 Data rate.

The data rate of end-user on all mobile broadband systems, will vary depending on the quality of its radio link to base station, and above the number of other users with whom you are sharing a cell. LSTI are looking to achieve optimal conditions, both peak speeds as well as in the rates they can expect end users.

5.2.1 Peak Velocities.

The goals of 3GPP for instantaneous peak data rate is 100 Mbps for downlink (DL) and 50 Mbps for uplink (UL). In 2007, the 3GPP conducted simulations for NGMN and concluded that it is possible speeds of 173 Mbps to 56 Mbps DL and UL. This was taken with the 20 MHz bandwidth, 2 × 2 MIMO in DL and 1 × 2 SIMO in the UL, and with a limited terminal transmissions with 16QAM. Since then, the design has been applied. Figure 5.2 can see a summary of peak data speeds measured for six different suppliers, both in laboratory and field.

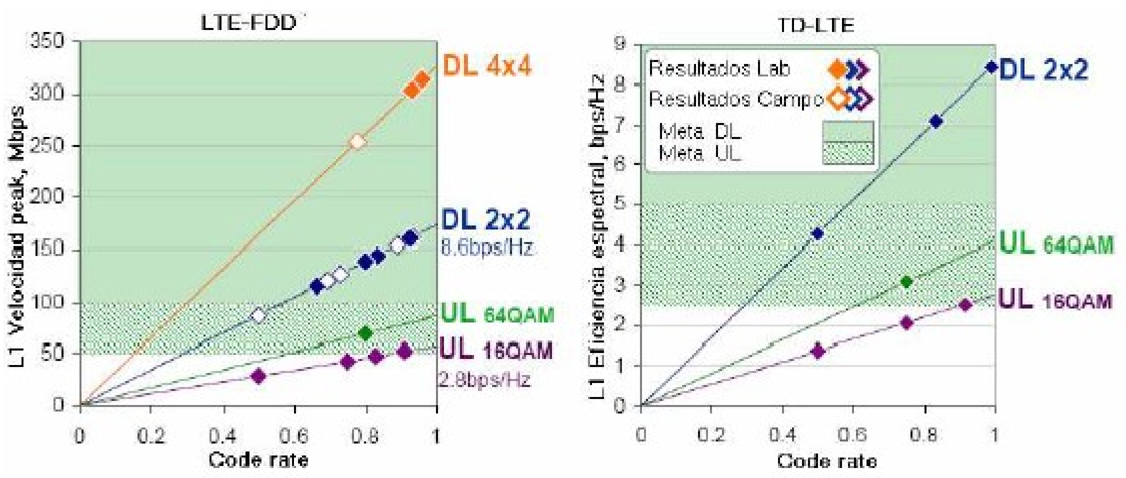


Figure 5.2 Peak data speeds measured at different suppliers LSTI.

The measured results incorporated into the encrypted channel, allowing a flexible exchange between data rate and robustness to bit errors. The results are related on the basis of "code rate " which is the ratio of bits of information bits transmitted. The figure above shows various outcomes, DL finding the original goal of 100 Mbps with MIMO 4 × 4, it can exceed speeds of 300 Mbps DL and UL is more difficult to achieve the goal with 16QAM in terminals available at the time of test, however, the results show that we can achieve. With 64QAM terminals are also included in the LTE standard and in theory can reach up to 86 Mbps in the UL[32].

What impacts the speed users can expect the end?

- There is much discussion about the relevance of the peak speed of data transmission, and if they constitute what in practice will end users. These speeds represent the speed of the air interface, radio taken in optimal conditions and with only one user connected to the cell. The main reason for using them is that they are easily verifiable with a simple laboratory test basis. The current user's speed will depend on the number of users sharing the cell, the type of traffic (web surfing will be different for video streaming), and radio conditions of users. In practice it is very difficult to specify an appropriate combination of such conditions, but that the initiative LSTI has been able to gather the results of actual measured rates experienced by end users, which will be affected by: RF conditions, multiple users in the cell and the headwaters of application.

5.2.2 Impact of RF signal quality and U.E.

The peak speeds are achieved in good condition with high RF signal to noise ratio, usually only experienced by ENB or base station. As the EU moves away from the ENB, reduced speeds. EU speed also reduces the throughput due to the fast speeds of multipath fading. LTE is recommended to support speeds of up to 350 km / h, with minimal attenuation performance up to 120 km / h. Figure 5.3a shows a typical laboratory measurement of these effects of a LSTI providers. Initial results show that it can support up to 350 km / h is very little impact on performance, with speeds up to 120 km / h which is only 10% compared with 3 km / h. Results from other vendors showed similar performance.

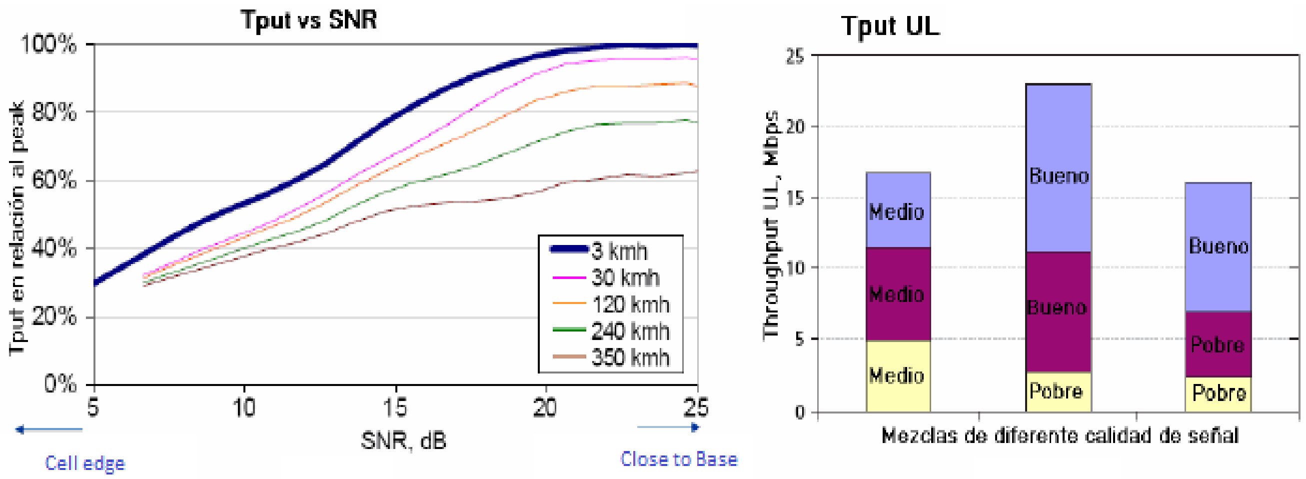


Figure 5.3 Tput impacts on the end user: RF and Exchange Policies cell.

5.2.3 Exchange of throughput of cell among many users.

In the same way that the time taken to get to work depends on the availability of busy highways, the speed of data transmission for LTE end-user depends on how many other people are sharing the cell. The cell is shared only among active users who transfer data at that particular moment and share with users surfing the Web, may have less impact to share with those who are actively using streaming video.

Laboratory results on ideals without fading channels show that the throughput of the cell is simply sharing, therefore, if we double the number of users, then their individual performances are reduced by half. Other tests on fading channels show an increase in frequency selective scheduling, which means the ENB can measure and take advantage of differences in the EU channel to increase the throughput in the cell (see Figure 5.4).

Furthermore, the LTE uplink supports multi-user MIMO, which can match the UEs to use the same resource when their ENAL manage to be "orthogonal" to the ENB. This technique improves the throughput of the cell without any knowledge or processing on the part of the EU.

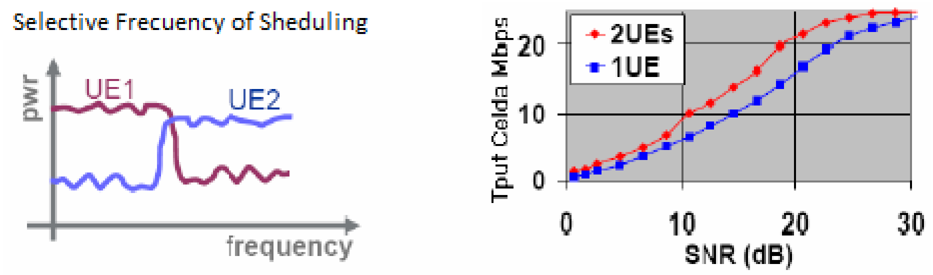


Figure 5.4 Different frequency response and increased tput.

5.2.4 Impact of the head of protocol on the application of throughput final.

The utility for a final application throughput can be regarded as the physical layer throughput (bits of information transmitted over the air), less any retransmission or packet headers added by the upper layers and by the application itself (see Figure 5.5).

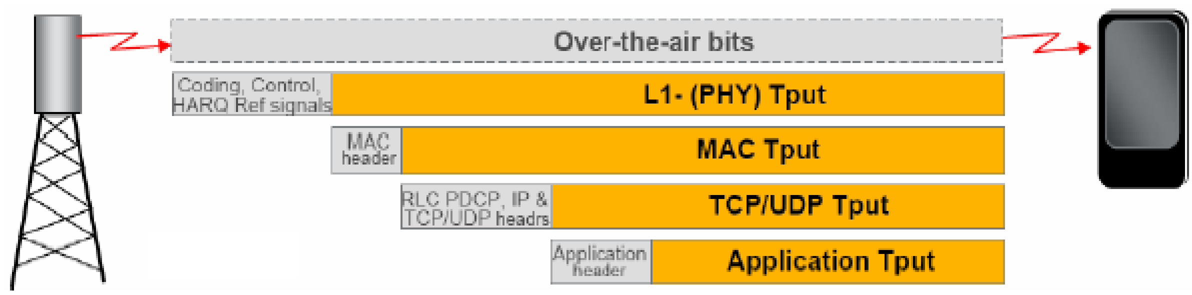


Figure 5.5 Tput in the application layer.

The size of the headers to the data can vary, depending on the type of traffic carried. File transfers tend to use large packets, so the head is relatively small. By contrast, VoIP packets have small payload sizes, and incur more seats without the use of techniques such as Robust Header Compression (ROHC). To give an independent view of traffic throughput LTE capabilities, the requirements of the peak transmission rate is defined at the physical layer, which are the numbers seen in Figure 5.2. The LSTI has also collected results, comparing the transmission rates of the physical layer with the actual download speed of file transfers. The differences are small, usually less than 5%[30].

5.2.5 Data rate of final user.

To characterize the rates of end user data, it requires a large deployment of a fully loaded network, dozens of cells that serve hundreds of terminals using prudent applications. LSTI initiative is working with other agencies such as the NGMN and research project Easy-C, in order to develop new methods to measure end-user speeds representative from a small trial. A key to this is to generate high levels of interference light load during "rush hour ".

Meanwhile, the throughput measured in the laboratory for a single user per cell, have been extrapolated to predict the speed range that can be experienced, as shown by the green area in Figure 5.6.

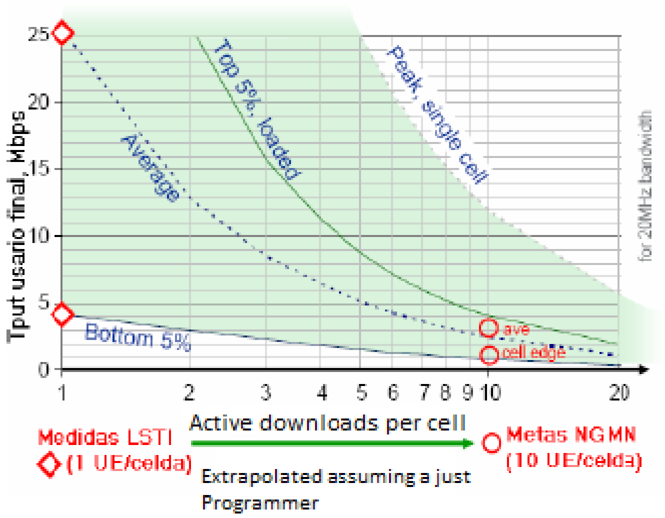


Figure 5.6 Expected data rates based on laboratory measurements.

The edge of the cell indicates 5% below the average and top speeds of 5% are marked by a fully loaded network with reuse of N = 1 (Network of single frecuency). Under conditions of isolated cells or without load, peak speeds can be achieved. In addition, a "fair" scheduler is assumed, by allocating more spectrum resources for users of the cell edge at the expense of giving a good signal quality. These predictions based on measurements LSTI are aligned together with simulations to verify performance of 3GPP[32], and goals of NGMN.

5.3 Latency.

"Speed" is definitely the main extent of broadband experience. Two factors influence the perception of speed: data transmission speed and latency. Their relationship of importance depends on what the user wants to do. When you download a file as an MP3 or a movie, the time required depends very much on the speed of downloads: size / speed data. Also, the connection time is important for instant messaging and / or viewing Web pages. With respect to delay sensitive applications such as VoIP or gaming, is required to be lower from end to end, and is essential for an interactive experience.

There are two types of objectives defined for the latency of LTE / SAE:

- Control plane latency: time to create a connection to a user to enable communication.
- User plane latency: time needed for each data packet to travel from origin to destination.

5.3.1 Latency of the level of control.

For a voice call (circuit switching concept), often takes several seconds for the other part answers the phone, so a few seconds delay in the network to configure the call is not particularly noteworthy. However, for efficient packet-switched communication, such as Web browsing, LTE spectrum resources are only allocated to users when needed, for example by clicking a link. Therefore, delays of even a second here would be very significant. LTE / SAE is designed with a very low idle time-ACTIVE state in order to give an AlwaysOn experience a large number of users without unnecessarily allocate resources to users who do not. Figure 5.7 shows the results measured by LSTI providers demonstrating the time-ACTIVE IDLE state within 100 ms requirement defined by 3GPP.

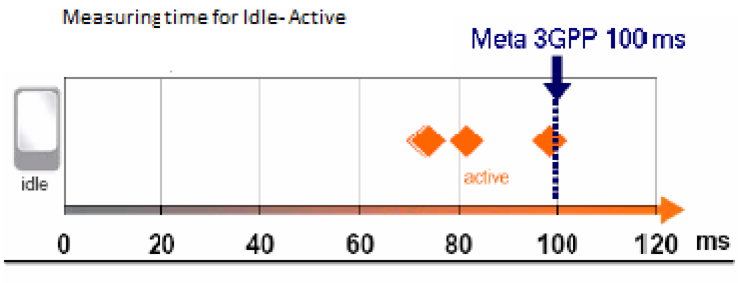


Figure 5.7 Control plane latency.

5.3.2 Latency of the level of user.

The latency of user plane refers to the time of transfer of each of data packets through the network. Figure 5.8 shows the path of these packets traveling from the EU over the air interface to the base station and then through the core network to a server somewhere on the internet. In practice, the latency can be measured by the ping function to the server or network node. 3GPP and NGMN requirements have been established both to the air interface and end-to-end delay.

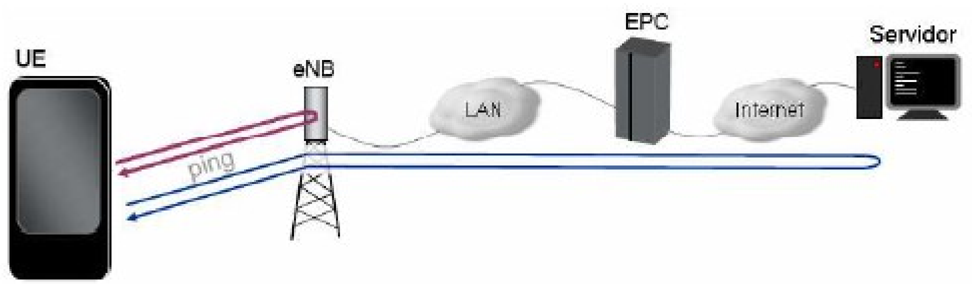


Figure 5.8 User plane latency.

5.3.3 Latency of air interface.

The air interface refers to the radio connection between the UE and base station. This is important, low-latency communication, not only for the user experience, but also to improve the performance of the mechanisms of closed loop control.
Many of these mechanisms in LTE, including power control uplink HARQ, frequency selective scheduling and Closed-Loop MIMO. In all cases, measurements made in the receiver are reported back to the transmitter, so that can be adapted in some way to improve performance in the radio link. Low latency feedback is important to ensure the measures are still valid at the time that you can adapt the transmitter. This becomes more important at high speeds user where radio conditions are changing rapidly.

The latency in the LTE air interface is an important improvement over previous systems and has already been achieved by redesigning the interface with a short transmission time interval of 1 ms. This interval is shorter block the signal, which must be received in full before it can be decoded. The current condition of the air interface latency is 10 ms round trip also takes into account the processing time to encode and decode transmissions at each end. Figure 5.9 shows the measurements show that the latency requirement of the air interface can be fulfilled.

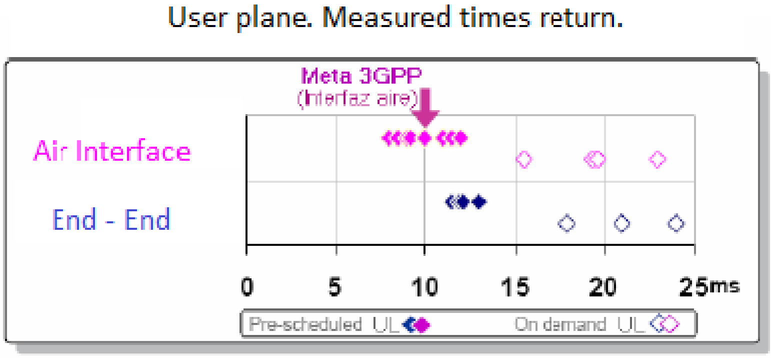


Figure 5.9 Air interface latency, end-to-end user level.

5.3.4 Latency of the user plane end to end.

The latency of end to end epresents the minimum time to send a package from a UE to an external server and receive a response. Figure 5.8 shows several measurements that meet the 20 ms required by the NGMN as the time of return. Apart from the shortest TTI, the end-to-end performance has improved by changing the radio access network and packet core architecture, in particular by removing the node controlled by the base station, and process optimization carrier plane.

5.3.5 Pre-Programming versus programming requiered for the remedy UL.

At best the requirements of peak data rates are defined for a situation easily verifiable. For the user plane latency, we assume a pre-programming of the programming (scheduling) UL, where the EU can be transmitted over the UL as soon as necessary. The latency measures thus apply to VoIP, where a regular pattern for the EU transfers and the BS scheduler can proactively provide UL resources in advance. For the traffic less predictable, such as Web browsing, the EU must first make a request for bandwidth, expected to be issued by the NBS, and then transmit data on the UL in the time allowed. The LSTI found that this process adds about 7 to 12 ms time round.

5.4 Qos and VoIP support.

LTE / SAE is based solely on packages, all-packet network or all-IP. By default, all data is carried on a database called "best effort"as shown in Figure 5.10, where performance varies according to the degree of network congestion. For services such as voice and video conferencing require bit rates unchanged and consistently low latency end to end, despite the load on the cell. LTE supports a flexible set of capabilities to-end QoS, which provides connectivity with guaranteed bit rate and latency.

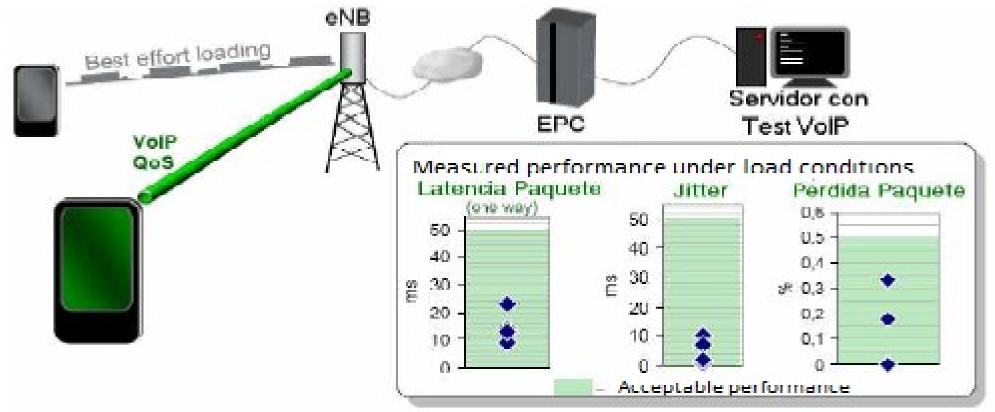


Figure 5.10 VoIP support, best effort service and performance testing.

The first results showed that the services LSTI Guaranteed Bit Rate may be maintained such as IPTV streaming, and is not affected by best effort services such as file transfers that can occur in the same cell. Later, tests have also shown that performance with respect to the delay can be guaranteed. Laboratory tests showed that under ideal conditions LTE / SAE is able to provide IP connectivity with sufficient performance in latency, jitter, and packet loss to support good VoIP quality. LSTI operators have confirmed that this also be achieved through tests run outdoors, even during the handover.

5.5 Handover among many cells.

Hold a call without problems while a user is sharing a cell to another, is one of the key challenges for any cell system. The handover tends to occur when a user is near the edge of coverage and, therefore, a failed handover is often the most likely cause of a missed call. LTE / SAE no longer supports the handover "soft" (make-before-break) used in WCDMA systems that require additional resources, both on the radio communication network and backhaul.
Instead it is implemented, a handover "strong"very fast (break before-make). The new interface X2, attends a direct connection between the source node and destination node, as shown in Figure 5.11. This reduces the load on the core packages and speeds up the process,
reducing the probability of failure and the result of missed calls.

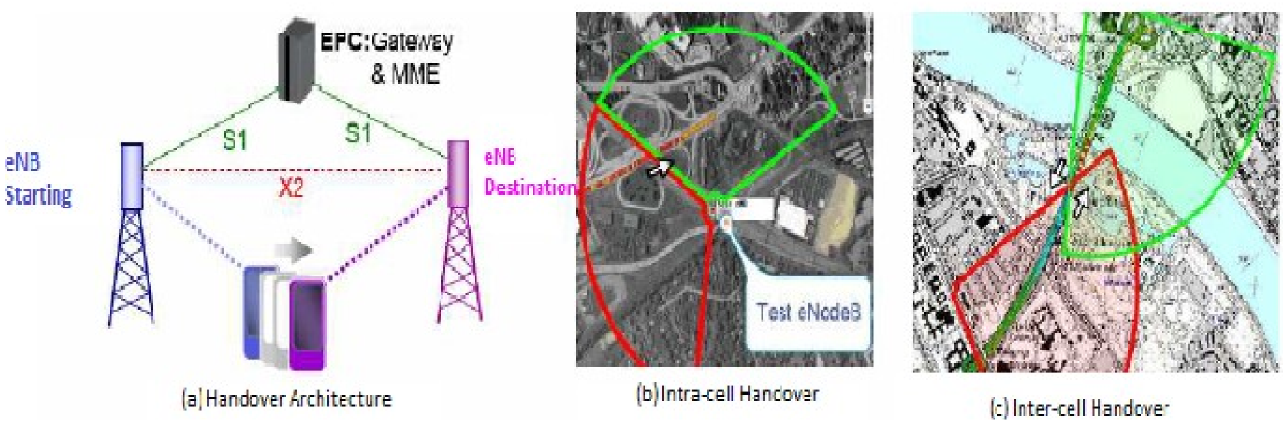


Figure 5.11 Demos LTE Handover.

The results have been consolidated LSTI showing both intra-cell handover (between sectors of the same base station) and the inter-cell handover (between two different base stations). These have been tested in the field with mobile speeds up to 120 km / h.

The data downtime meet the requirement of "real-time service" of NGMN which is 300 ms, shown with times under 50 ms. X2 interface and procedures have shown to work well. In future activity IOT (Inter-Operability Testing) is the one who finds that this interface also works with different X2 ENB providers at each end.

5.6 Interoperability test.

The maturity of the standards can be tested by different vendor implementations operating. The LSTI has an activity called IOTD (Inter-Operability Testing Development), which recommends a core set of air interface features and reports the progress of the tests. A second phase of IOTD extends this set and watch other interfaces that connect the base station and core network.

Essentially, the Interoperability Testing (IOT) check the equipment of different manufacturers working together. This is a method that checks if the standards are correct and have been interpreted in the same way by all manufacturers. Some weaknesses can be resolved and included in the 3GPP standard for members, and then the successful IOT indicates that standards are fully developed. In this initial testing phase, it is not practical to test all the individual features in the standard. Therefore, the LSTI has defined a Minimum Feature Set with the most important, which are tested first.
The IOT is not to be confused with the approved test, because it first tests the standards are correct before checking the approved test that the equipment meets the standard. These tests can not begin until the test has been defined, having to wait that the standards are complete.

5.6.1 IODT.

IODT reports on the first tests of suppliers, are beyond the essential haracteristics air interface. The tests were based on compliant equipment ersion March 2009 standards LTE / SAE. That takes several months for implement the latest version of the standard, the reporting on progress was expected to begin in mid 2009. The IODT focuses on the basic interoperability between handsets and the infrastructure of a third party vendor. Notification of results will be based on commonly accepted test procedures.

5.6.2 IOT.

The Interoperability Testing continues at IODT, but with a larger set of features, and clearly proving the multiple ENB-EU partners. Besides the air interface, the feature set included in the IOT S1 and X2 interfaces as shown in Figure 5.12. These tests are eNBs requirements and the core packages from different vendors. The purpose of IOT LSTI intended to be complete in mid 2010.

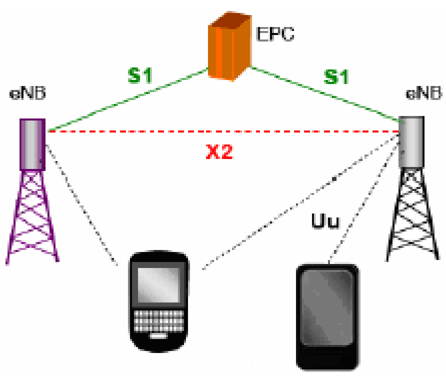


Figure 5.12 Interfaces analyzed in the Interoperability Test.

5.7 Customer Test.

The customer tests are the final stage to test the technology before it is commercially implemented. The users treated will be tested in mobile broadband applications, using pre-commercial terminals, connected to a large group of eNBs and EPCs in the same style. The LSTI is currently working to define a set of test methods, configurations that characterize the operators and key expectations along with the cases of user experience. Good examples of that are the cell capacity and transfer rates of end user data. As demonstrated by the PoC, the results are highly dependent on factors such as RF conditions and the load cell, which should be evaluated before the commercial release of the networks. LSTI testing activities are tailored to the requirements of NGMN and help operators and suppliers to build a realistic interpretation of what is achievable. It is expected that the tests are conducted from mid-2009 to forward, thereby opening the first commercial launch in 2010 as shown in Figure 5.13.

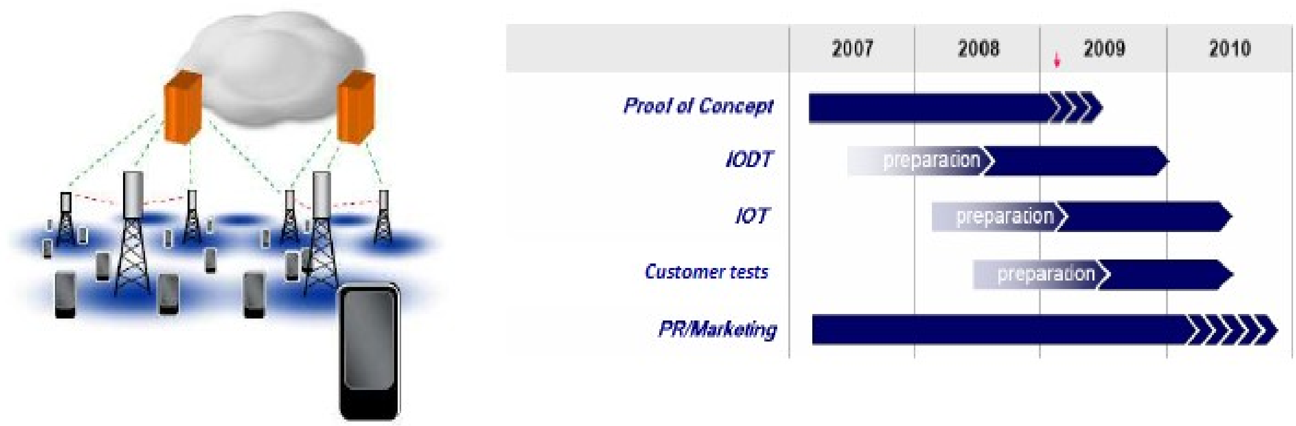


Figure 5.13 Summary of the duration of the activity LSTI.

5.8 The 4th generation in the world.

Mobile operators want to introduce the LTE technology, are seeking advice to optimize and evolve their next generation networks, services and structure to better serve key markets, and need quick answers, as it is considered that the demand for it is very strong.

According to studies, it will reach 136 million LTE users by the year 2014[34], growing at a rate much faster than previous wireless standards. The advantages for consumers and businesses in the form of faster communication, increased productivity, flexibility, innovative services will be key to the adoption of this technology in the world.

The development of LTE at this point, this being supported by major operators around the world (see Figure 5.14). In North America by U.S. companies AT & T and Verizon. In Europe for mobile network operators T-Mobile, TeliaSonera, Movistar and Telenor Group. In China and Japan with SmarTone Vodafone operators, China Mobile, NTT DoCoMo and SoftBank. Finally in Australia with its largest mobile service provider Telstra. Most of these operators are looking to launch their networks in the period 2010-2011.

Figure 5.14 Global drive of LTE.

In addition LTE equipment suppliers have developed network technology prototype to demonstrate more operators to join the process of it. As was the case of the Motorola company mobile to do a tour of LTE for European countries. During the tour the guests were able to verify the performance of mobile broadband and multimedia experience on the move in an urban environment by means of a van with LTE connectivity (see Figure 5.15). The demonstration also included a handover between sectors and a number of video applications running on LTE, which require high bandwidth such as live TV by LTE.

Figure 5.15 LTE Comercial Tour mobil.

The LTE network was deployed and optimized in only 10 days, which is constituted by two eNBs running on commercial hardware, and backhaul products and Motorola EPC operating in the band of 2.6 GHz Inside the van, which successfully toured the streets of Barcelona at the Mobile World Congress, visitors watched streaming video High Definition (HD) video from a server on-demand Motorola, as well as VoIP calls, Web browsing, file downloads Internet applications and other high bandwidth and low latency[35].

5.9 Services and applications.

Here are some typical services and applications that can run in LTE networks. Most of these services are not specific to the technology itself, as they have been adopted in previous technology, an improvement in its implementation. These are:

- **Mobile Push to talk:** it is very similar to the known communication walkie-talkie service. Provides a voice service one-on-one or one-to-many, a group of people in half duplex mode, which means that only one participant can talk at any given time, while others are listening.

- **Presence:** The purpose of this service is to allow a subscriber to have your presence information available to other users of application servers on the network.

– **Wireless Broadband:** LTE technology provides a connection similar to traditional broadband has the advantage of mobility. Thus sufficient to connect the modem LTE to any computer and go surfing the Internet.

– **Broadcast and Multicast:** This is known as MBMS service and the benefit is that several subscribers can receive the same data at the same time, sending only once on each link. Has a much wider range of types and applications, enabling the delivery of multimedia data types. It consists of two separate services: broadcast and multicast (broadcast and multicast)[4]. Some examples of typical applications (see Figure 5.16) suitable for MBMS are:

– **Access to Internet:** Web browsing faster and more efficiently. Search services available on phones and smartphones on 3G, to quickly find blogs, sites, news, etc.. In addition to view maps, find out what the best way to get to a place, or use navigation services.

– **Download music and videos:** Download a complete song or watch a video quickly is a facility more of this type of technology. LTE technology with downloading a song or video takes seconds, while in previous technologies, it takes a few minutes.

– **Video call and conference:** LTE is not only for transmitting data, but can be used on services like Skype to improve audio quality on calls and incorporate video chat.

– **Games Online:** For online play, latency is crucial, because it keeps the game flowing. LTE reduce waiting times to almost zero, allowing users to play instantly.

– **Television Online:** The higher speed of this service will be streaming video services, but also whether they will be in high definition and will be received in life.

– **M-Commerce:** Mobile Commerce is a service dedicated to the electronic transaction through the mobile phone. Allows businesses to extend their market reach, offer better service and lower costs.

Figure 5.16 MBMS Aplications.

5.10 Advantages and disadvantages.

As discussed in this chapter, the great potential of deploying LTE technology is reflected by the following advantages:

- LTE improve the capabilities of network operators, enabling them to provide a faster mobile broadband to more users, which will revolutionize the mobile telecommunications market.

- LTE may bring mobile broadband to less populated regions and contribute to reducing the digital gap between rural and urban areas.

- LTE uses radio spectrum more efficiently, enabling mobile networks to take advantage of the "digital dividend" and use the frequencies freed by the transition from analogue to digital.

- The LTE signals travel further than GSM technology, and actually reduce the number of antennas needed to achieve the same network coverage, with the EU will be preserved landscapes and reduce energy consumption.

- LTE offered through their networks, high performance with peak speeds and lower latencies uploads and downloads. That will allow service providers to offer higher data speeds, providing greater tolerances set of traffic, increase the adoption of mobile data services and improve margins and average revenue per user (ARPU).

- LTE is fully compatible in reverse with GSM / GPRS / EDGE, UMTS (WCDMA), HSPA and CDMA2000, also supporting mobility between heterogeneous networks is not related to 3GPP, for example, WLAN, WiMAX.

- LTE uses OFDM to handle the problems of intersymbol interference caused by multi-step, and greatly simplifies the channel equalization. Being slightly more optimal than CDMA systems.

Regarding the disadvantages, these could be generated based on:

- Technology costs will be high at first, because bids for the new spectrum LTE, renewal of equipment, maintenance costs and operating expenses (sales, marketing, customer management systems, etc.), although this will be solved by through economies of scale.

- Time implementation of the technology. This could lead, if a long time, some doubts about the feasibility of the technology, which was not consistent with the actual dates of implementation.

- The competition from other mobile broadband technologies like WiMAX. In addition to the wide range of technologies, broadband cable modem or fiber, such as ADSL, as this technology is increasingly offering higher speeds to users, so if an operator will compete with this technology, your bid must be much more attractive to the end user.

- A cause of the news services will require the use of the spectrum is the most efficient manner possible, the current spectrum will not be sufficient for future demand, as domestic players are holding a limited range and below the recommended by the GSMA.

Conclusions

Have been studied in depth the needs and requirements of LTE wireless technology, the study focused on comparing it with other 3G technologies, structure necessary to deploy their networks, medium access techniques, implementation within the business scope and identification potential advantages and disadvantages in its future development. Helping in the understanding of an emerging technology that is not yet present in our country, which is very important to be at the forefront in the area of telecommunications.

3G technologies have been developed by different standards bodies, have a lot of common characteristics as they tackle the same type of application and operating under the same conditions and scenarios. However, LTE is distinguished from others by its improved transfer rates, latency, speed, user mobility, coverage, and flexible multicast broadcast spectrum allocation. With this, the technology responds to the technological leap that is required, speeding up the development of a new system more quickly and using as much existing infrastructure, significantly opening the way to 4G mobile communications.

Reengineering the packet core mobile networks today, has been motivated by the rapid growth of IP data traffic as well as the emergence of new wireless technologies that allow to significantly increase data transmission speeds in these networks. SAE is the response of suppliers and operators involved in 3GPP to this need and more as a support network configurations, the high level of service availability and reducing the number of nodes, hoping that this new architecture will ensure competitiveness of mobile technologies over the next decade. However, improvements in the short term such as QoS control and redefining the user plane, allow the migration to SAE is as docile as possible ..

LTE infrastructure is designed to be as simple as possible to deploy and operate, own property to be a flexible technology and can be deployed enn a wide variety of frequency bands, providing scalable band width of less than 5 MHz up to 20 MHz, with the support of the two spectra, FDD and TDD.

The air interface has increasingly more sophisticated features, supported by complex algorithms to optimize performance, efficiency and operating range. OFDMA technology has become accessible to next-generation wireless, to provide a robust data with better spectral efficiency. LTE able to improve this by using schemes such as SC-FDMA, which favors the signal characteristics, because these have lower crest factors OFDMA signals and this results in a simple amplifier stage development of mobile phones. This approach used in LTE capabilities than any other system using OFDMA, and also relies on multiple antennas based technique that seeks to reduce the correlation between the received signals driving modes of diversity, providing wireless technology area extensive most powerful ever developed.

Regulatory bodies should play a role as "promoter / facilitator" on access to innovative technologies such as LTE, and considering measures to stimulate the growth of the mobile broadband market, helping to overcome the obstacles, and to ensure technological benefit to the entire population.

LTE presents a great technical advantage over other potential technologies such as WiMAX and LTE is based on the foundations of its predecessor UMTS being practically a software update, unlike WiMAX must implement their network Full requiring an investment of zero.

In short, LTE is the natural evolution of existing mobile telecommunications systems demand the information society in its continued progress, both for end users and manufacturers and technology providers, telecom operators and companies.

ANNEX I
ITU-R RECOMMENDATIONS

ITU-R, are a series of international technical standards developed by the Radiocommunication Sector (formerly CCIR) of ITU. They are the result of studies undertaken by the Radiocommunication Study Groups on:

- The use of a large range of wireless services, including new mobile communication technologies.
- The management of radio spectrum and satellite orbits.
- The effective use of radio spectrum by all services radio.
- The terrestrial and satellite radio.
- The propagation of radio waves.
- Systems and networks for the fixed-satellite service, for the fixed and mobile service.
- The space operations, service, Earth exploration satellite, meteorological satellite and radio astronomy.

ITU-R Recommendations are approved by consensus among Member States of the ITU. Your application is not mandatory, however, as they are developed by experts from administrations, operators, industry and other organizations dedicated to radio around the world, enjoy a prestigious reputation and applied worldwide.

A list of ITU-R Recommendations on IMT-2000 is shown in Table A1.1, which specifies the number of recommendation and the title he carries.

Recommendation Number	Title
M - 687	International Mobile Telecommunications IMT-2000.
M - 816	Framework for services provided by IMT-2000.
M - 817	Network architecture for IMT-2000.
M - 818	Satellite operation of IMT-2000.
M - 819	IMT-2000 for developing countries.
M - 1034	Requirements for radio interfaces for IMT-2000.
M - 1035	General framework for the study of the radio interfaces and radio sub-system in IMT-2000.
M - 1036	Frequency arrangements for implementation of IMT-2000 in the bands 806-960MHz, 1710-2025MHz, 2110-2200MHz and 2500-2690MHz.
M - 1078	Safety principles for IMT-2000.
M - 1079	Requirements relating to performance and service access networks to IMT-2000.
M - 1168	General framework for management of IMT-2000.
M - 1182	Integration of mobile terrestrial and satellite.
M - 1223	Evaluation of security mechanisms for IMT-2000.

M - 1224	Vocabulary of terms of the IMT-2000.
M - 1225	Standards for the evaluation of radio transmission technologies for IMT-2000.
M - 1308	Evolution of Land Mobile Systems to IMT-2000.
M - 1311	Framework for modularity and radio elements common to the IMT-2000.
M - 1390	Methodology for calculating the spectrum requirements for terrestrial IMT-2000.
M - 1455	Minimum quality and operating conditions for stations in high altitude platforms that provide IMT-2000 in the bands 1885-1980MHz, 2010-2025MHz and 2110-2170MHz in Regions 1 and 3 and 1885-1980MHz and 2110-2160MHz in Region 2.
M - 1457	Detailed specifications of the radio interfaces of IMT-2000.

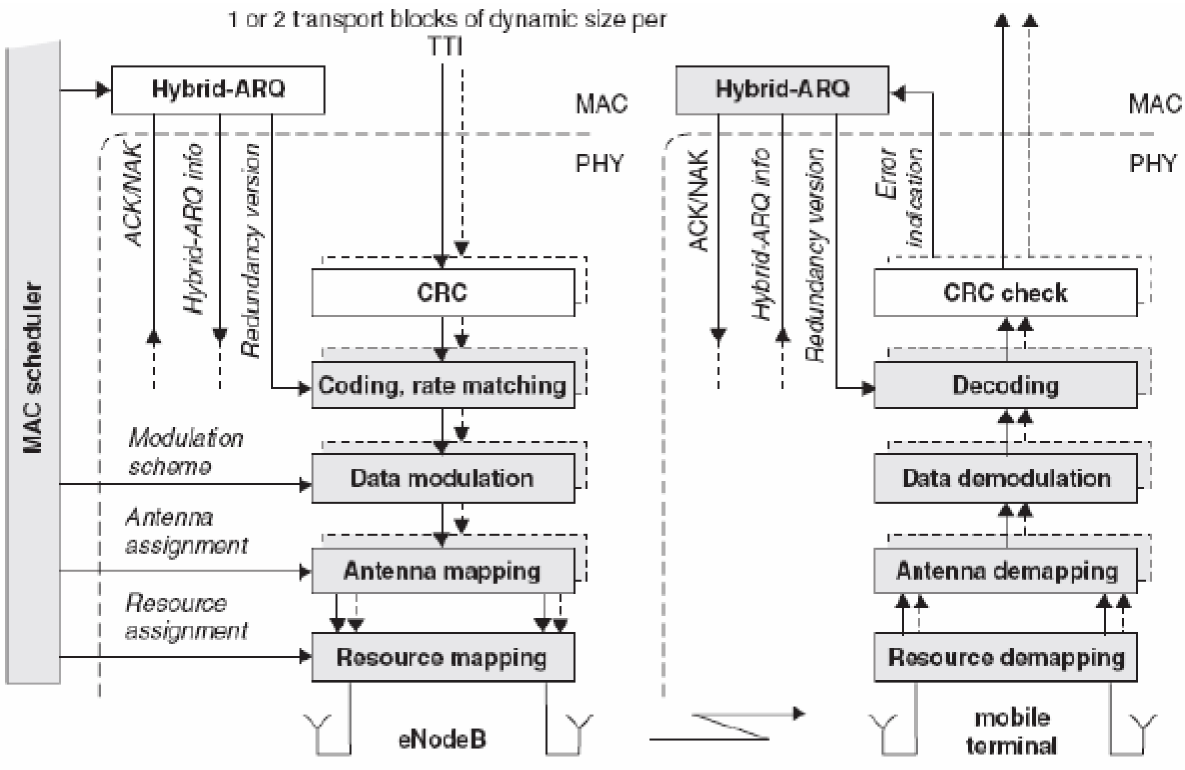
Table A1.1 Recommendations UIT-R of IMT-2000

ANNEX II
PHY: Physical Layer

A simplified view of the process for the DL-SCH is given in Figure A2.1a. The blocks of the physical layer are controlled dynamically by the MAC layer is shown in gray, while the semi-static configuration of physical layer blocks shown in white. When a mobile terminal is scheduled for a TTI in the DL-SCH, the physical layer receives a transport block of data to transmit (two blocks of transportation in case of spatial multiplexing). For each transport block, a CRC is attached and each of these carries an attached CRC block is encoded separately. The channel coding speed is necessarily included in game speed, which is implicitly determined by the transport block size, the modulation scheme and the amount of resources allocated for transmission. All these quantities are selected by the downlink scheduler. The use of redundancy is controlled by the HARQ protocol and affects the processing speed at stake, to generate the correct set of encoded bits. Finally, in the case of spatial multiplexing, mapping of the antenna is under the control of the downlink scheduler.

The scheduled mobile terminal receives the transmitted signal and performs the reverse process of the physical layer. The physical layer in the mobile terminal also informs the HARQ protocol, if the data was successfully decoded or not. This information is used by the part of the MAC HARQ functionally in the mobile terminal to determine whether a retransmission is requested or not.

The process of the UL-SCH at the physical layer closely follows the process of DL-SCH. However, note that the eNodoB programmer is responsible for selecting the transport format of the mobile terminal and the resources to be used for uplink transmission. The process of the UL-SCH at the physical layer is shown in simplified form in Figure A2.1b.



(a) DL-SCH

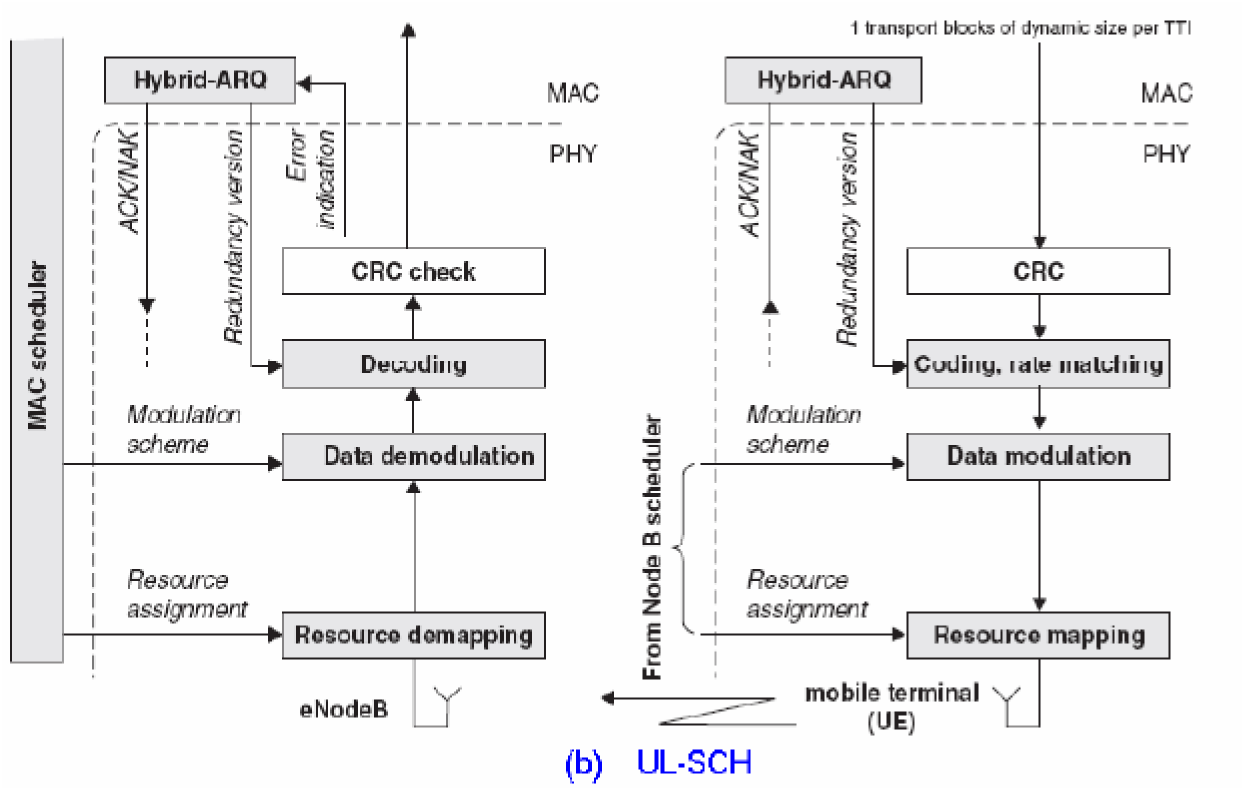


Figure A2.1 Simplified process for PHY layer DL-SCH and UL-SCH.

ANNEX III
Evaluation of 3GPP LTE

Performance requirements.

The performance targets for LTE were defined by 3GPP in 2005 and documented in 3GPP TR25.913. The measures for the performance of the system are:

- Average user: Measured per MHz as the average over all users.
- User performance on the edge of the cell: Measured per MHz in the 5 th percentile of the distribution of users (95% of users have a better performance.)
- Spectrum efficiency: The system performance by sector in bps / MHz / site.
- Coverage: Performance in large cells.

While detailed solutions for LTE technology should not be a basis for performance requirements, the number of Tx and Rx antennas configured for the BS and the EU must be agreed as a prerequisite for the goal. The reason is that an increase in the number of antennas can also be seen as a constraint to the selected solution due to increased complexity. This is theoretically possible as it can get extremely large profits, assuming a number of antennas impracticable. The following settings are uplink and downlink LTE elected to the goals of:

- A LTE downlink with a maximum of 2 antennas at the BS Tx and 2 Rx antennas in the EU.
- LTE uplink with a maximum of a single Tx antenna at the EU and 2 Rx antennas at the BS.

Performance is evaluated in the uplink and downlink separately and objectives are established in relation to the detailed system reference in Release 6. This reference system consists of:

- The HSDPA downlink based on a single Tx antenna at the NodeB with improved performance in the type 1 receptor in the EU (requirements based on dual antenna diversity).
- The uplink based on Enhanced Uplink (enhanced uplink) with a single Tx antenna at the EU and 2 Rx antennas at the NodeB.

The performance goals for LTE agreed shown in Table A3.1. Because it is expected that both the average user performance and spectrum efficiency are benefiting from the increase of 1 to 2 Tx antennas in the downlink, this is the goal of ncreasing user performance on the edge of the cell which would be the challenge in the downlink.

Performance Measures	Goal related to Rel-6 (Downlink) HSDPA	Goal related to Rel-6 (Uplink) Enhanced UL
Average performance of user (MHz)	3-4x	2-3x
User performance on the edge of the cell (MHz, 5 th percentile)	2-3x	2-3x
Effic. spectrum (bps / MHz / site)	3-4x	2-3x
Coverage	Meet the goals to 5 km cell range.	Meet the goals to 5 km cell range.

Table A3.1 Performance Goals for LTE in TR25.913.

Performance 20MHz LTE FDD.

LTE supports a range of different carrier bandwidth of 20 MHz, plus a higher bandwidth transmission and provides increased data throughput for the user. The simulation results of a 20 MHz carrier in the LTE downlink are shown in Figure A3.1. The figures are based on a dynamic simulation in the assessment falling 3GPP.

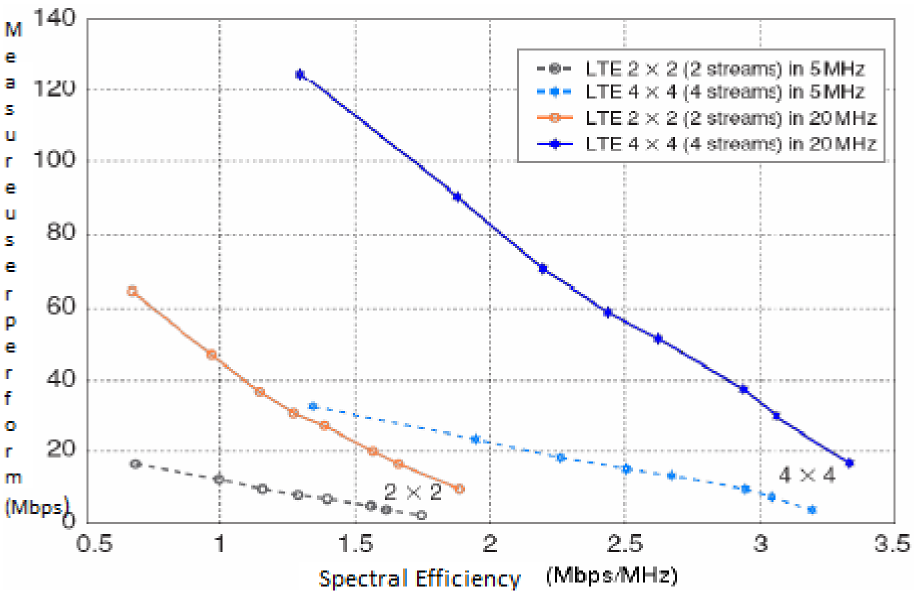


Figure A3.1 Simulation of a carrier of 20 MHz and 5 MHz and MIMO2x4 MIMO2x2.

Is on average performance for a 20 MHz carrier is 4 times larger than a 5 MHz for freight traffic. Although the 20 MHz provide this increased data transmission speed, high spectral efficiency at high loads, is practically the same.

Hypothesis	
Power Base Station (BS)	40W (20 MHz) y 20W (5 MHz)
Propagation model	(Space channel model)
Inter-site distance	500 m
Scheduling	Equity in time and frequency proportional

Table A3.3 Hypothesis for the results on Figure A3.1

ANNEX IV
LSTI

The initiative LTE / SAE (LTE / SAE Trial Initiative) is an initiative to test global collaborative technologies, focused on accelerating the viability of wireless broadband systems interoperable LTE, the next generation. It is formed by a group of operators and suppliers. The initiative was formally launched in May 2007 by leading telecommunications companies Alcatel-Lucent, Ericsson, Orange, Nokia, Nokia Siemens Networks, Nortel, T-Mobile and Vodafone.

Figure A4.1 shows all the participants of the Initiative LSTI now, even reaching total of 32 participants.

Figure A4.1 Providers LTSI

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