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POWER CONTROL FOR WCDMA

TÍTOL DEL TFC: POWER CONTROL FOR WCDMA

TITULACIÓ: Enginyeria Tècnica de Telecomunicació, especialitat Telemàtica

AUTOR: Jose Antonio Puentes Florido

DIRECTOR: Ari Rantala

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Resum

Aquest projecte pretén introduir-se en les implementacions físiques que fan possible la denominada tecnologia mòbil de tercera generació. Així com conèixer a fons el tipus de topologia que fa possible, per exemple, una vídeo trucada en temps real.

En el transcurs d'aquest projecte, es presentaran les diferents fases transcorregudes a partir del moment de la elecció de WCDMA com el mètode de accés per UMTS. S'analitzarà la seva coexistència amb la xarxa anterior de GSM, on la compatibilitat entre sistemes ha estat un dels aspectes més rellevants en el desenvolupament de WCDMA, els organismes d'estandardització involucrats en el procés, així com els diferentes protocols que fan possible les comunicacions mòbils dins d'una xarxa UTRAN. Al llarg de l'estudi es prestarà una especial atenció a la gran aportació que ha ofert WCDMA respecte el control de potencia dels senyals existents.

Es comenten les línies futures que es plantegen en el present, i d'altres que ja estan en la seva última fase de desenvolupament en el camp de la tecnologia mòbil.

UMTS a través de WCDMA pot ser resumit com una revolució de la interfície aire acompanyada per una revolució en el nucli de xarxa de la seva arquitectura.

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Overview

This project tries to introduce itself in the physical implementations that make possible the denominated third generation mobile technology. As well as to know the technology kind that makes possible, for example, a video-call in real time.

During this project, the different phases passed from the election of WCDMA like the access method for UMTS will appear. Its coexistence with previous network GSM will be analyzed, where the compatibility between systems has been one of the most important aspects in the development of WCDMA, the involved standardization organisms in the process, as well as the different protocols that make the mobile communications within a network UTRAN possible. Special emphasis during the study of the great contribution that has offered WCDMA with respect to the control of power of the existing signals will be made.

The future lines that are considered in the present, and other comment that already are in their last phase of development in the field of the mobile technology.

UMTS through WCDMA can be summarized like a revolution of the air interface accompanied by a revolution in the network of their architecture.

Agradecimientos;

Mediante estas líneas me gustaría dar el protagonismo que merecen aquellas personas que de una forma u otra han aportado algo a este proyecto, a todos aquellos que han puesto su esfuerzo o ilusión en que el proyecto llegara a su mejor fin.

En primer lugar, me gustaría agradecer la gran amabilidad, atención y confianza que ha mostrado Ari Rantala, tutor de este proyecto, sobre mi persona durante todo el transcurso de éste. Así como su especial paciencia y compresión con mi carencia lingüística.

No menos importantes han sido los ánimos y muestras de apoyo ofrecidas por parte de mi familia y de mi pareja a lo largo del proyecto, del mismo modo que lo hicieron a lo largo de toda la carrera. Sin los cuales nada de esto habría sido posible.

Por último una especial mención a todos mis compañeros de eramus, quienes en todo momento han compartido de algún modo esta pequeña carga, lo cual siempre la aligeró. Especialmente a toda la gente de Lapinkaari.

Gratefulnesses;

By means of these lines I would like to give protagonism that deserve those people who of a form or another one have contributed something to this project, to all those that have put its effort or illusion in that the project arrived at its better end.

First, I would like to thank for the great amiability, attention and confidence that Ari Rantala, tutor of this project, has had on my person throughout the course of this project. As well as his special patience and compression with my linguistic deficiency.

Less important they have not been the spirits and offered samples of support by part of my family and my girlfriend throughout the project, in the same way that did it throughout the entire academic career. Without which nothing of this would have been possible.

Finally a special mention to all my companions of eramus, who at any moment have shared of some way this small cargo, which always lightened it. Specially to all the people of Lapinkaari.

Chapter 1. Introduction

1.1. Information Society

The evolution of the telecommunications is being a determinant factor in the society of last century ends and the present's beginning. Both the mobile telephony and Internet not only are revolutionizing the way of communicating, but they are helping up a contemporary society, that every time has more information in minor time and Major facility of access to it. Every time there is more used the term "information society" in this century's beginning that promises to bring over us to major advances and facilities in the communications among the men, destined, as last purpose, to get the prosperity and well being that our own nature stimulates us to search it.

In the information society the creation, distribution and manipulation of the information are part important of the cultural and economic activities.

An accepted concept does not exist universally of which "Information Society" is called to it but the majority agrees in which around 1970 a change in the way in which the societies work. This change is referred about basically to that the means of wealth generation step by step are being transferred of the industrial sectors to the service sectors. In other words, one assumes that in the modern societies, most of the uses will not be associate to the tangible product factories, but to the generation, storage and processing of all type of information. The sectors related to the technologies of the information and the communication (TIC), are a particularly important part within this scheme.

Many critical have indicated that the call "Information society" is not but a version updated of cultural imperialism exerted from the rich countries towards the poor men, especially because favour schemes of technological dependency.

Who are in favour of "Information Society" maintains that the incorporation of the TIC in all the productive processes, certainly facilitate the insertion to the global markets, where intense competency forces to reduce costs and to adjust of way almost immediate to the changing conditions of the market.

1.2. The third generation

The third generation systems are created to provide a global mobility with a wide variety of services, wherever and whenever you are. Offering thus a great opportunity of business never sees previously, increasing the mobile internet potential and opening news opportunities of business. The world of the mobile telephony and internet has experimented in the last years a great increase and major yet is preview for next years. In The figure we can see this effect.

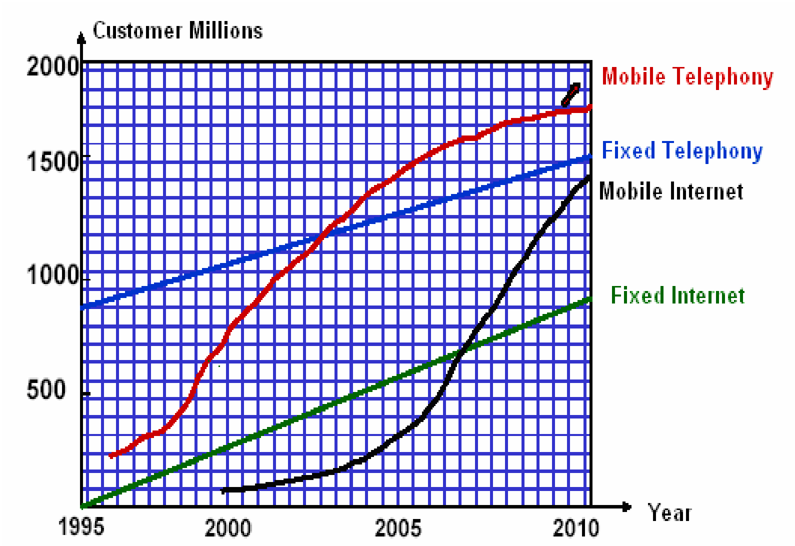


Fig.1.1 world-wide tendencies prediction

Now the consumers demand more services and improved functioning of themselves, the mobile world must cultivate and develop to direct these requests and finally to obtain:

- High bit rates:
  - 384 kbit/s in high mobility.
  - 2 Mbit/s in low mobility.

- Variable bit rate under demand according to the characteristics of each service.

- Multiplexed capacity of services with different calls of quality inside of a same connexion, like for example voice, video or packet mode data transfer (e-mail, files transfer…).

- Support capacity a great number of delays needed, to offer from real time service even best effort data services (without quality of service guaranteed).

- Support capacity qualities needed from a 10% of frame error rate even a 10^{-6} of bit error rate.

- Second generation system and Third generation systems are coexisting, with possibility to do handovers between different systems.

- Support capacity asymmetric traffic between up-link and down-link, like would be the case of Internet.

- High spectral efficiency.

- FDD and TDD modulation modes must to coexist.

The 3G systems are being developed to offer a wide range of services in comparison to the previous systems of second generation like GSM. These improvements increase in the services need news amendments in the actual networks, for finally to offer all the awaited things for users. These improvements were done by evolution's route of the systems of second generation to third generation in Europe, Japan and North America.

About interoperability 2G-3G, has must to have in mind several requirements as the following ones:

- The progressive and soft migration of second generation to third generation is very important for success.

- To get this migration is necessary to enable interconnectivity between second generation-third generation.

- Third generation is beneficiary of second-generation's wide coverage.

- Second generation is beneficiary of a migration to packets switching[1] architecture, being of this form more near proposed architecture for 3GPP R5 of All-IP network.

The transition to third generation capacities must to be based in a feasible migration way, it defines a form of to integrate multimedia, packets switching and radio access of wide band to the dominant systems of second generation. In this way was GPRS the pass to the third generation, in that without modifying almost GSM is using packets switching.

The third generation radio access must to give in addition full area coverage (same that voice's service of second generation), services of high rate of bits (full area coverage of 384 Kb/s, 2 Mb/s of local coverage), and any type of mixture of service. And finally, the third generation radio access must to use the radio spectrum and the network resources with an effective cost.

[1] Packets switching. These provide connections for packet data services. The internet is one example of a packet switching network.

The scope of performance of the third generation systems it is tried to show in the following figure, as a form to include under an only system the different existing surroundings, based on the offered cover, from the systems via satellite to the most reduced to systems interiors, with objective to allow a universal mobility of terminals able to support customized applications of very varied nature.

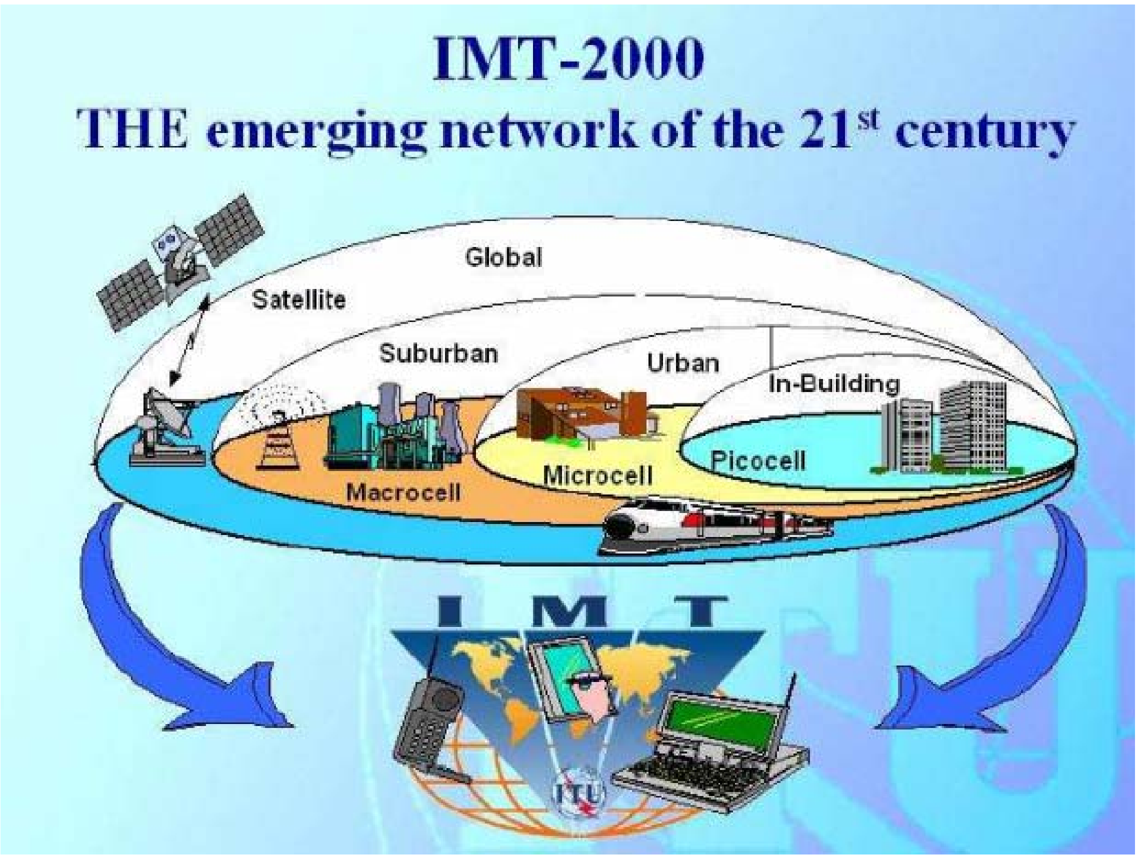


Fig.1.2 Different surroundings in a unique system

In order to carry out the project 3G, the International Telecommunication Union (ITU) began in 1985 to specify the minimum requirements that the services 3G would have to render to be considered like such. They called to the systems group that fulfilled these requirements IMT2000 (International Mobile Telecommunications 2000), because, the 2000 indicated date was the year for the launching of the services of third generation. During the last years, this technology has been object of intensive investigation and development anywhere in the world.

Commercial and political reasons are those that they cause that doesn't exist a single technology unified for the services of third generation. IMT 2000 group contain all these technologies. In Europe the system of third generation is called UMTS (Universal Mobile Telecommunication System), and it is based on the technique Wideband Code Division Multiple Access, WCDMA.

In the standardization forums, WCDMA technology has emerged as the most widely adopted third generation air interface. Its specifications have been created in 3GPP (the 3rd Generation Partnership Project), which is the joint standardization project of the standard bodies from Europe, Japan, Korea, the USA and China. Within 3GPP, WCDMA is called UTRA (Universal Terrestrial Radio Access) FDD (Frequency Division Duplex) and TDD (Time Division Duplex), the name WCDMA being used to cover both FDD and TDD operation.

Functionally the network elements are grouped into the Radio Access Network (RAN, UMTS Terrestrial RAN = UTRAN) that handles all radio-related functionality, and the Core Network, which is responsible for switching and routing calls and data connections to external networks. To complete the system, the User Equipment (UE) that interfaces with the user and the radio interface is defined. To complete the system, the User Equipment (UE) that interfaces with the user and the radio interfaces is defined.

1.3. The most popular candidates

The most popular candidates for providing 3G services include CDMA2000 and Wideband Code Division Multiple Access (WCDMA). Both these schemes are based on the DS-CDMA. The main difference between WCDMA and CDMA2000 is that WCDMA supports *asynchronous* base stations whereas CDMA2000 relies on synchronized base stations.

Synchronous CDMA systems need an external time reference at all the base stations. For instance, a Global Position Systems (GPS) clock can be used by all the base stations to synchronize their operations. This allows the mobile station to use different phases of the same scrambling code to distinguish between adjacent base stations. Figure 1.3 illustrates a *synchronous* CDMA system. In an *asynchronous* CDMA system, each base station has an independent time reference. The mobile station does not have prior knowledge of the relative time difference between various base stations. The advantage of an asynchronous operation is that it eliminates the need to synchronize the base stations to an accurate external timing source.

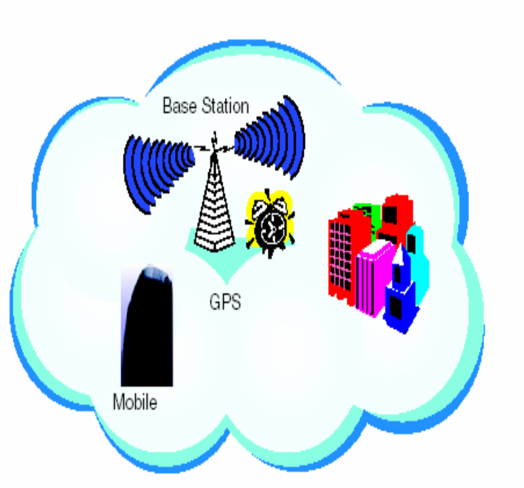


Fig.1.3 Synchronous CDMA system

1.4. Categories of services in the third generation

In the near future, any content will be able to reach cellular, Internet or broadcasting users regardless of the transport path and delivery mechanism. This will create a single, seamless mass medium that will combine the reach, quality and emotion of information with the needs of the network user.

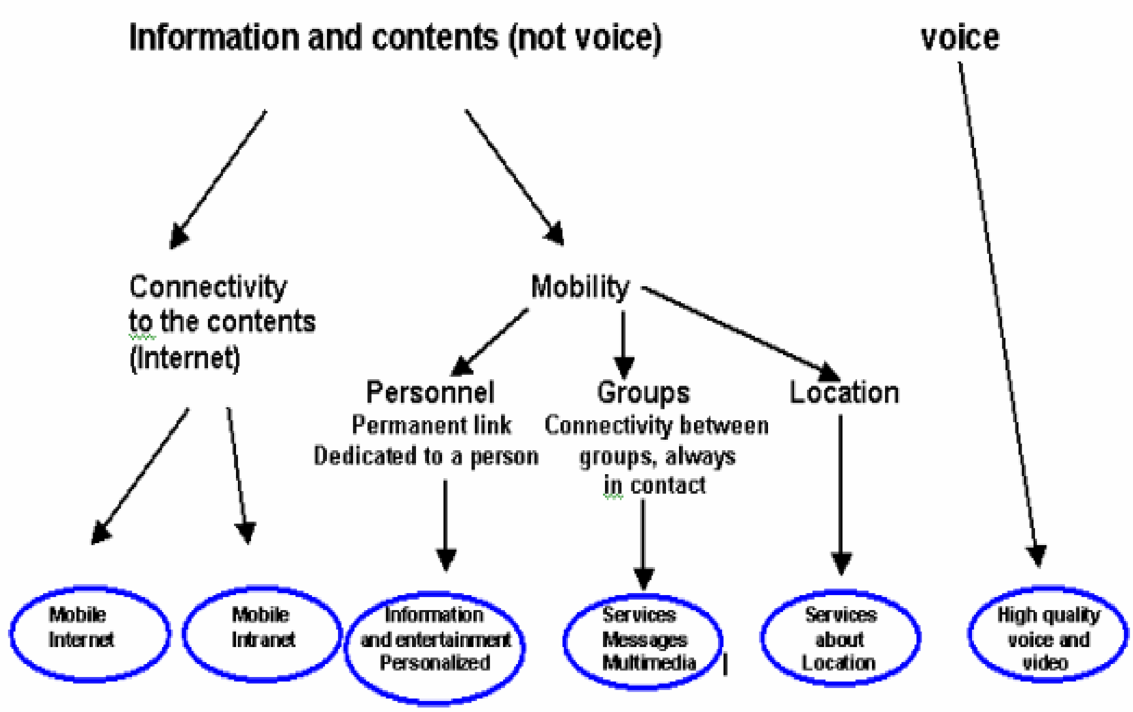


Fig.1.4 Categories of services in the third generation

It is not tried to show in the previous figure better or worse services, but the greatness of coexistence between different categories of services.

1.5. Nokia

Nokia allowed the accomplishment of the first voice call of Third Generation, made from the center of Nokia in Finland thanks to the mediation of Finnish operators Radiolinja and Sonera, by means of the use of a compatible network with the standard 3GPP (The 3rd Generation Partnership Project), and the first commercial versions of the mobile terminals WCDMA and GSM.

This call, the first of Third Generation, supposed the most important step within the development of Nokia in the sector of the mobile telephony, it demonstrates the synchrony between the elements of the network of Third Generation of Nokia and the first version of the dual terminal GSM / WCDMA with the standard 3GPP Release 99, presented in December of 2000.

Most significant of this call has been that has been carried out in an update commercial network GSM that supports the transferences from WCDMA. This demonstrated clearly that service WCDMA was prepared for its installation in real networks.
Nokia is worldwide leader in the sector of the mobile communications, with a quota of 35% in the worldwide market of mobile telephony, according to data facilitated by the independent consultant DataQuest. Supported by its wide experience and its search of simple, safe and innovating solutions, the company has become leader supplier of mobile telephones and networks, fixes and IP (Internet Protocol). When adding mobility to Internet, Nokia offers to the companies' new opportunities of business, simultaneously that facilitates the life to all its clients. Nokia is one of the companies with greater stock exchange presence, quoting in six of the most important stock exchanges anywhere in the world.

Chapter 2. CDMA SYSTEMS

UMTS mobile systems are WCDMA systems, WCDMA is based in CDMA systems.

The spread spectrum technology, that is the base of CDMA technology, specially was used in military applications, in order to resist the effect of jamming[1] and to hide the transmitted signal to possible spies.

The great attraction of CDMA technology was from the beginning its great capacity to increase the benefits of the communications and to reuse frequencies.

In 1991, the promising results obtained in the first tests demonstrated that CDMA technology could work actually equal of good like in the theory. In 1993, the CDMA system was adopted by the TIA (Telecommunications Industry Association). In 1995, the first service of CDMA was launch in Hong Kong, followed of a launching in Korea and another one in Pennsylvania.

2.1. Multiple access techniques

In a mobile communications system the users do not connect directly with another user, something that sometimes the distance among them would make impossible. The communication is made through of a station base, which will cover the transmissions with a delimited area called cell. The set of the stations of the system composes a cellular structure, which does that to the systems of mobile telephony are called cellular systems to them.

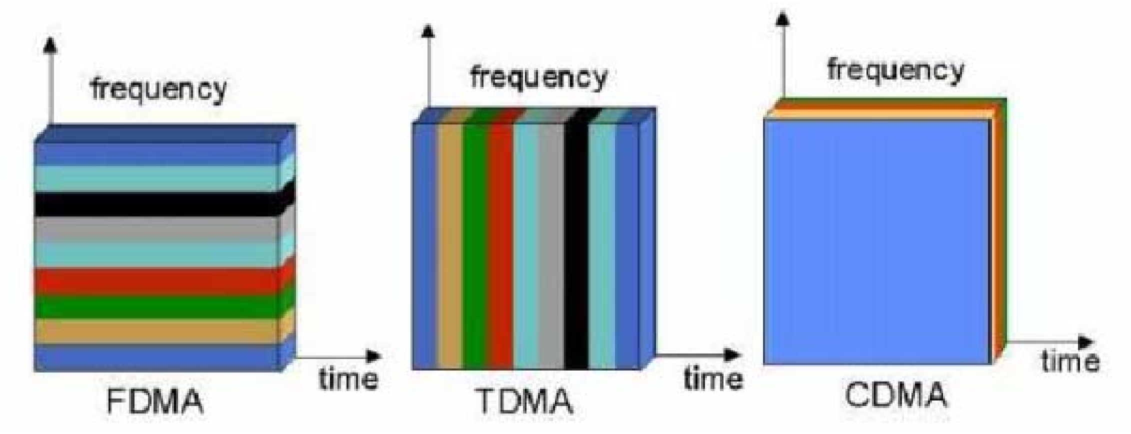


Fig.2.1 Multiple access Techniques

[1] Hostile interference with the purpose of disturbing the communications. Well interrupting the transmission and/or blinding the receiver.

Frequency Division Multiple Access (FDMA). This technique divides the spectrum in frequency and each user uses a carrier different to communicate with the station bases throughout the time.

Time Division Multiple Access (TDMA). This technique divides each carrier frequency in different time slots, in each one of which a user uses to accede to the station bases.

Code Division Multiple Access (CDMA). This technique throughout the time uses the same carrier frequency and for all the users. The users codify their signal by means of a unique code, before transmitting it, so that it is possible to separately later each one of the signals, although they share the same spectrum frequency. This technique has been the one that will mainly prevail for the systems 3G.

2.2 How CDMA works

Imagine a room with several interlocutors, with crossed conversations and all speaking simultaneously. Surely it would be a chaos. Nevertheless, imagine that the interlocutors use different languages. In that case each one could catch the message that is transmitted in his language and extract it of the others. So that the conversations in different language form it’s would be simply noise or interference. That is the fundamental principle of the Multiple Access by Division of Code or CDMA.

In the communication systems with spread spectrum, the bandwidth of the signal is expanded, commonly to several orders of magnitude before its transmission. When there is an only user in a widened channel, the use of the bandwidth is inefficient. However, in a multi-user atmosphere, the users can share the same channel and the system gets to be efficient.

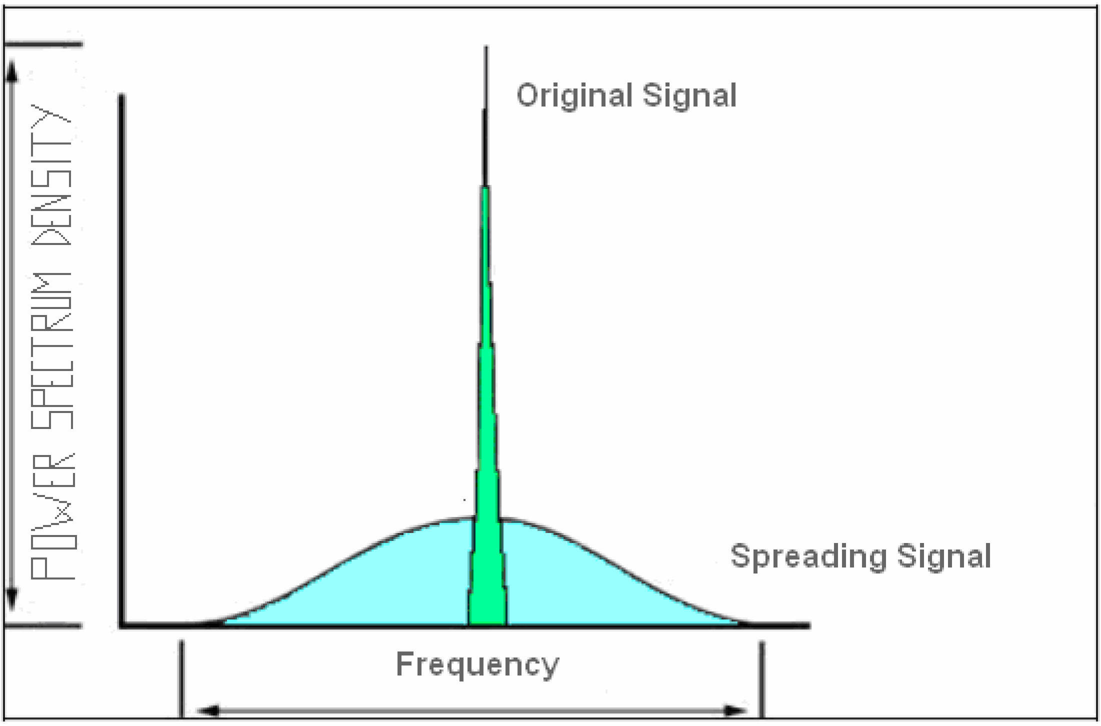


Fig.2.2 Signals with the same power, but with different bandwidth

In this technique, the signal that contains the information, in forward data signal, is codified multiplying this one by a pseudo-random code similar to the noise or code PN (Pseudo-random Noise-like Code, PN-Code).

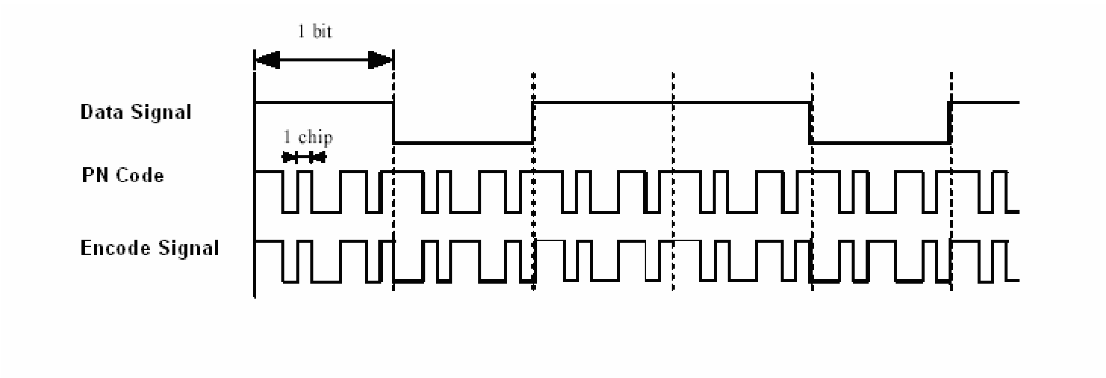


Fig 2.3 Codified Multiplying

This code is made up of a number N of symbols, to which we will call *chip* to distinguish them of the symbols pertaining to the data signal to transmit. The previous figure shows this process to us for a signal in which the code is made up of N Chip. In this each one of the symbols of the data signal is multiplied by all the complete code, that is to say, the N Chips. This means that the chip rate must be N greater than the bit rate, that is to say, greater N times in a general case.

The resulting signal also will have bit rate N grater or equal than the chip rate. Bandwidth busy it will be also greater N times and, because the transmitted power it cannot increase, its power spectrum density[1] will be distributed, and the power of the resulting signal contained in a small margin of the spectrum will be very low.

This method to codify signals by means of the multiplication of sequences code, being obtained a signal of spread spectrum is known with the name of DS-CDMA.

2.3 Spreading codes

There exist two families of WCDMA codes, the PN codes and the orthogonal codes. The PN codes are pseudorandom sequences generated by a feedback shift register and are used for the users or B nodes[2] differentiation. The most used in W-CDMA are generated using a linear shift register. The cross-correlation theoretical between orthogonal codes is zero in a synchronous transmission. The Walsh sequences are the orthogonal codes commonly used for the spectrum spread and the separation of channels or users in W-CDMA systems.

In a W-CDMA transmission the information signal is modulated by means of a CDMA code, and in the receiver the received signal is seen its correlation with one replica of the same code. Due to this, is important that exists a low cross-correlation between the wished signal and the interferences signals of the other users, to be able to suppress the multi-user interference. Also it is required that they have a good autocorrelation for a good synchronization. In addition, the good autocorrelation is important to eliminate the interference due to the propagation multiway.

2.3.1 M-Sequences

In many cases the spread codes are generated with a linear registry of displacement beside to appropriate logic operators. These operators feedback to the entrance of the registry a combination of the states of two or more of its registries as it is possible to be seen in Figure.

[1] The power spectrum density represents the amount of power of the signal in each component of frequency.
[2] A logical node responsible for radio transmission / reception in one or more cells to/from the User Equipment.

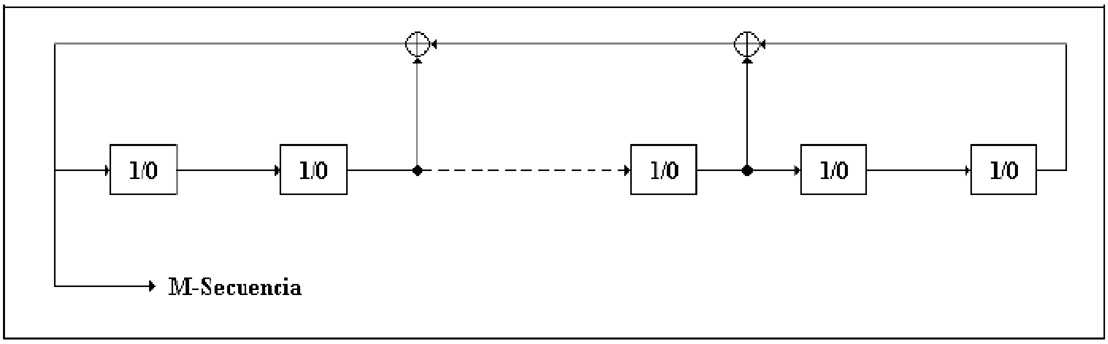


Fig.2.4 Scheme of a generator of M-sequences

The connections of the registries to the module sum are determined by the generating polynomial from the sequence PN, which is of the form:

$$G(X) = 1 + A_1X + A_2X^2 + ... + A_NX^N \quad \textbf{(2.1)}$$

A_i is “1” or “0” depending if there is connection or not with the module sum. The initial estate of the registers is called seed of the code. Logical adders make one XOR of the registries to be feedbacks**.** For the case of binary codes the operation of module-2 sum is equivalent to operation XOR. It is necessary to consider that all the generating polynomials do not produce a sequence PN of maxima length, reason why is necessary to consult tables standard where are the specifications. M-Sequences are codes that have the maxima attainable length with a shift register of N squares, for this reason its name Maxima-Sequence. This length is:

$$L=2N – 1 \quad \textbf{(2.2)}$$

M-Sequences are defined by the denominated irreducible or primitive polynomials. For different initial values from the squares, obtained M-Sequence is always same, the only difference is that begins with a displacement in the time called phase of code.

Table.2.1 Number of M-Sequences for different larges

N	3	5	7	11	15
L	7	31	127	2047	32767
Number of M-Sequences	2	6	18	167	1800

Next an example of the generation of a sequence PN can be seen:

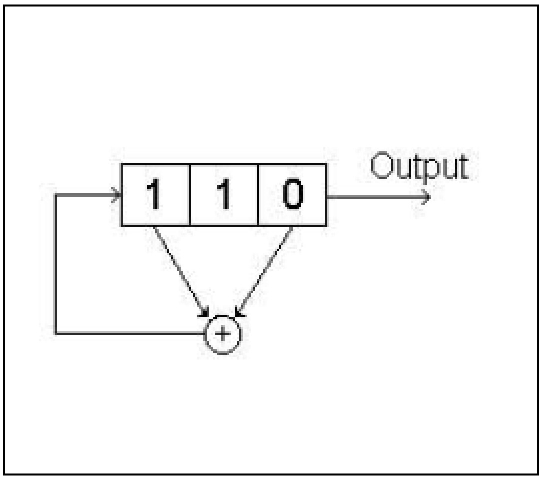


Fig.2.5 Scheme of a linear registry of displacement with seed 110

In that:

- N = 3
- Seed = 110
- G(X) = 1 + X^2 + X^3
- L = 7

Making a pursuit of the circuit it is possible to be seen as exit sequence PN is the following one:

0 1 1 1 0 1 0 0 1 1 1 0 1 0…

It is possible to be seen as each 7 chips the sequence PN is repeated.

2.3.2 Gold sequences

The Gold sequences are generated by means of the module-2 sum of two M-Sequences of equal length as it is possible to be seen in Figure 2.6.

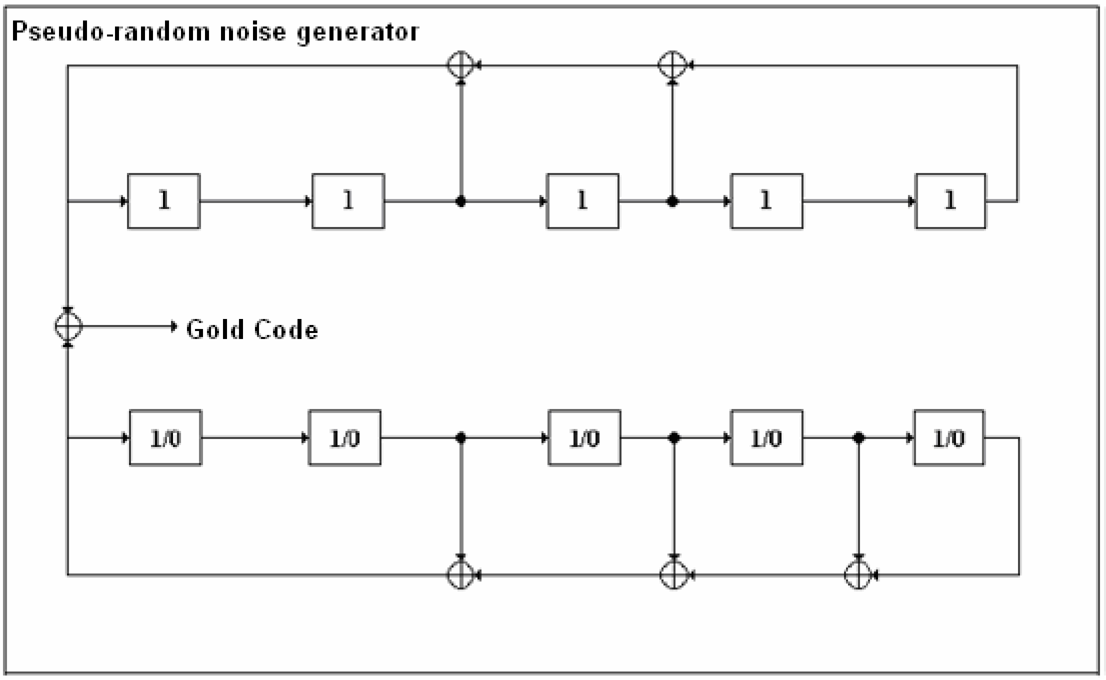


Fig.2.6 Scheme of a generator of Gold codes

Two M-Sequences can have even 2N-1 different relative displacements among them, and each displacement is a different Gold sequence.

An example of communication CDMA with a user can be seen:

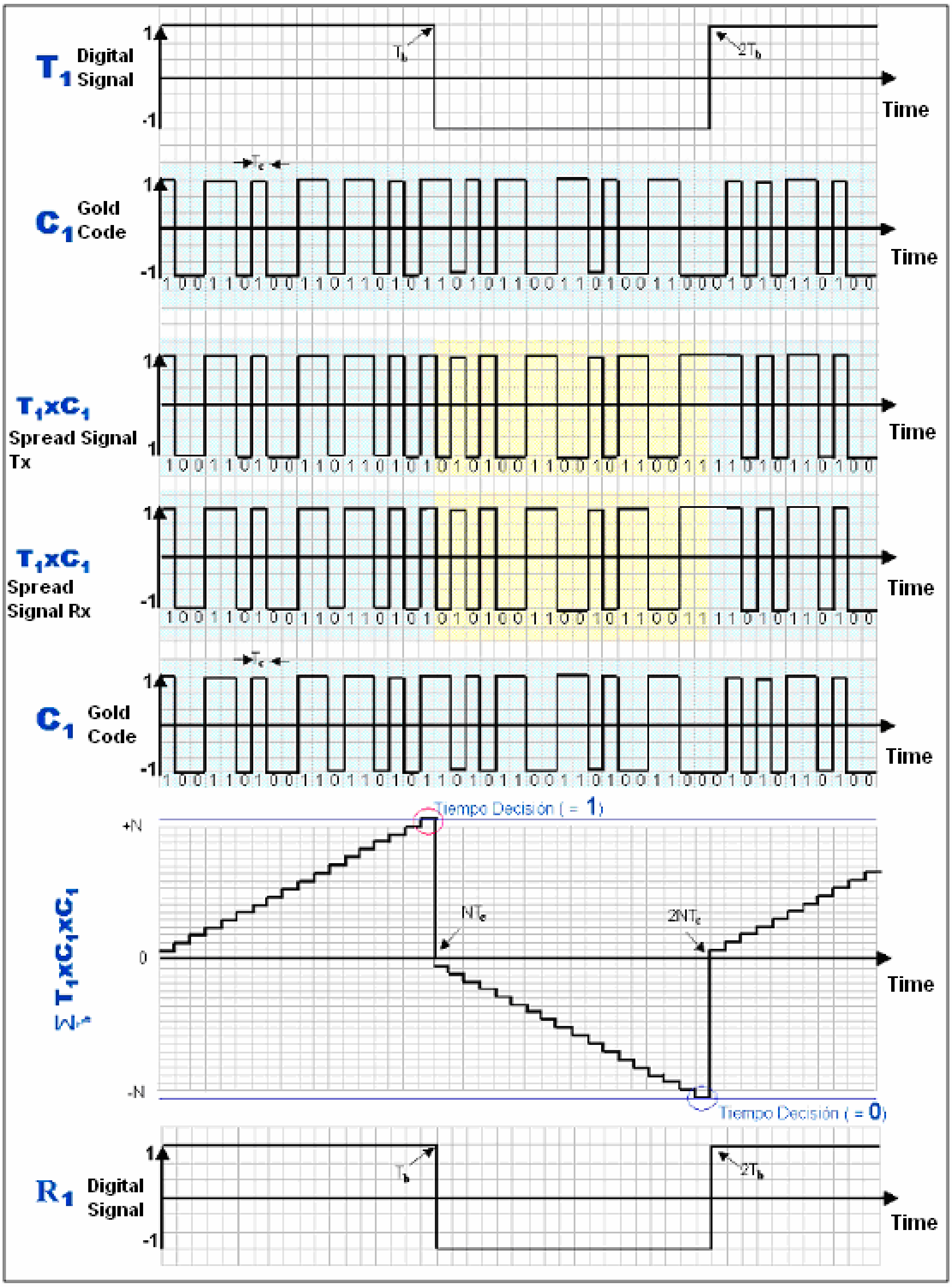


Fig.2.7 Example of CDMA communication with a transmitted signal (T_1), a Gold code (C_1), a matched filter in reception ($\sum T_1 * C_1 * C_1$), and a signal without spreading (R_1).

If in the previous example, instead of multiplying in reception by the code of Gold C1, it is multiplied by a code of Gold C2 equal to the initial code, but displaced a sample would be obtained:

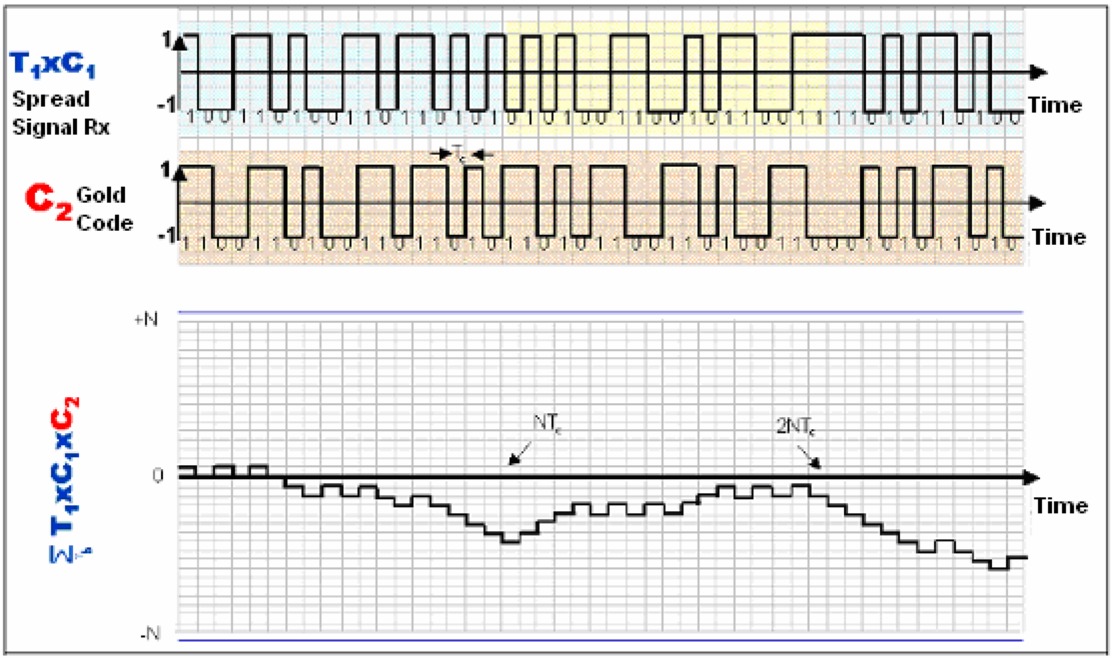


Fig.2.8 Example of CDMA communication with a transmitted signal (T1), a erroneous Gold code in reception (C2), and a matched filter in reception ($\sum T_1 * C_1 * C_1$).

The previous example corresponds with the case that the transmitter and the receiver are not synchronous. In Figure 2.8 it is possible to be seen as to the output of the matched filter the level of the signal in the periods of sampling is almost despicable.

In multi-user surroundings, where each user has his own code of Gold, it would be possible to recover the signals in reception multiplying them by the code of the user of who it is wanted to recover the signal.

2.3.3 Orthogonal codes

In 1923, J.L Walsh defined a system of orthogonal functions. The most important characteristic of the codes of Walsh is the perfect orthogonal between the codes, and is for that reason, that is used in applications of communications. The sequences of Walsh are used in UMTS like codes of canalization in the Uplink and the Downlink.

The sequences of Walsh can be generated through denominated Hadamard matrices, which are symmetric matrices. Each row or column of Hadamard matrices is a sequence of Walsh. The matrices of Hadamard can be calculated using the following recursive rule:

$$H_1 = [1]$$

$$H_{2i} = \begin{bmatrix} H_i & H_i \\ H_i & -H_i \end{bmatrix}$$

Or what is the same.

$$H_2 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

$$H_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix}$$

$$H_8 = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \end{bmatrix}$$

It is possible to be seen with facility that all the columns and the rows are mutually orthogonal. The following properties can be derived if is defined the Walsh sequence W_i like the row or column ith of a Hadamard matrices:

- The sequences of Walsh are binary sequences with values of +1 and -1.
- The length of the sequences of Walsh is always power of 2.

- Always there is L sequences different of length L.
- The sequences of Walsh are mutually orthogonal if they are synchronous.

- All the sequences of Walsh begin by +1.

Another method to generate codes orthogonal is using tree structures:

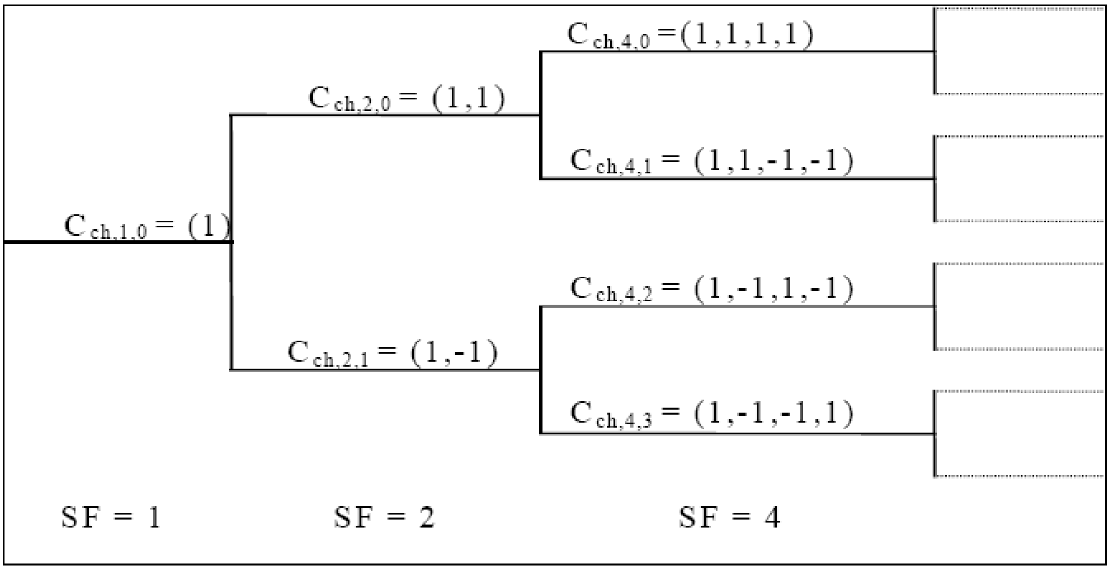


Fig.2.9 Tree of canalization codes

Where C_{2n} is a set of orthogonal codes of size 2n and SF is the Spreading Factor.

The creation of these codes is based on an algorithm, which produces trees of codes where each level defines a code of canalization with length SF (Spreading Factor). In UTRAN is used the SF (Spreading Factor) from 4 to 512, from 4 to 256 are used in the uplink, and the 512 is added for the downlink. A SF of 4 (that is a very low SF, the lowest that is possible to use in UTRAN) for example, it means that for each data of the signal exists four chips in the spread code, and that the resulting bandwidth it is four times greater than the original one.

All the codes inside of the tree can't to be used at the same time within a cell; this is because a code in a cell can be used if and only if this it does not belong previously to the same route towards the root of tree of another code in use. That is to say, two codes that belong to the same route cannot be used simultaneously, reason why there will be a limited number of codes of canalization dependents of the speed and the SF of each physical channel.

Example of the use of the orthogonal codes, in which two spread signals by different orthogonal codes are transmitted and one of them is recovered in the receiver.

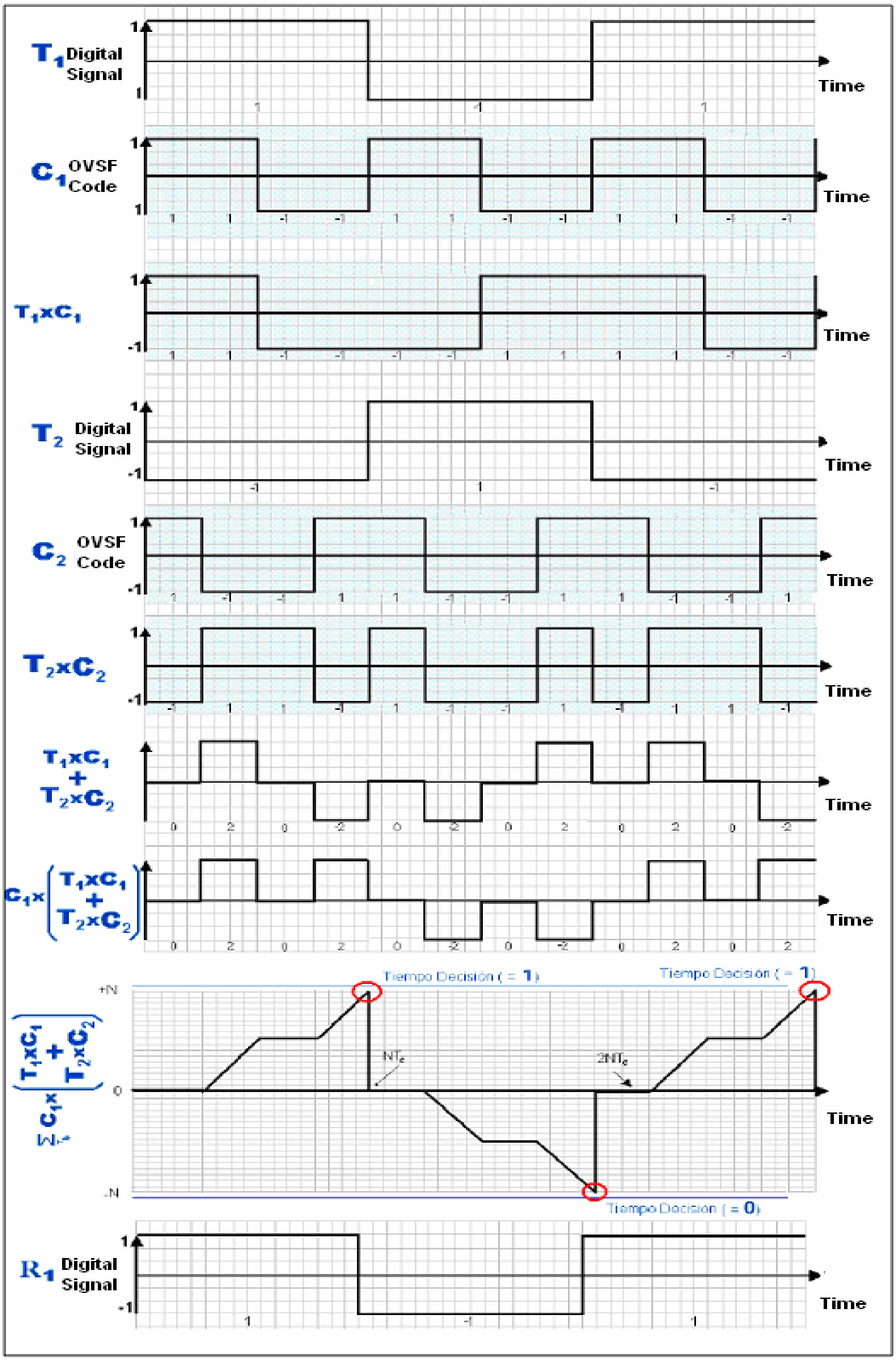


Fig.2.10 Example of use of orthogonal codes

In conclusion this type of signals of spread spectrum, offers a series of advantages to us at the time of making the mobiles communications, as they can be the following ones:

Low interception probability: When multiplying the signal by a code, only is known by the emitter and the receiver, we avoided that the signal can be listened by a third. In addition, the low power spectrum density makes its detection very difficult.

Rejection to the interferences: Being signals of broadband and low power spectrum density, seemed to the one of the noise, also makes impossible deliberate interference of the signal.

Capacity of Multiple Accesses: When a signal of spread spectrum is received, this is multiplied again by same code and of that form it is recovered. For a signal received by that receiver and that has not been codified by means of that code, that process it would again generate a signal with the same binary regime and equal to the chip rate, with which the signal would be seen like noise in front of the recovered signal.

2.4. Example of modulation of spread spectrum of a signal:

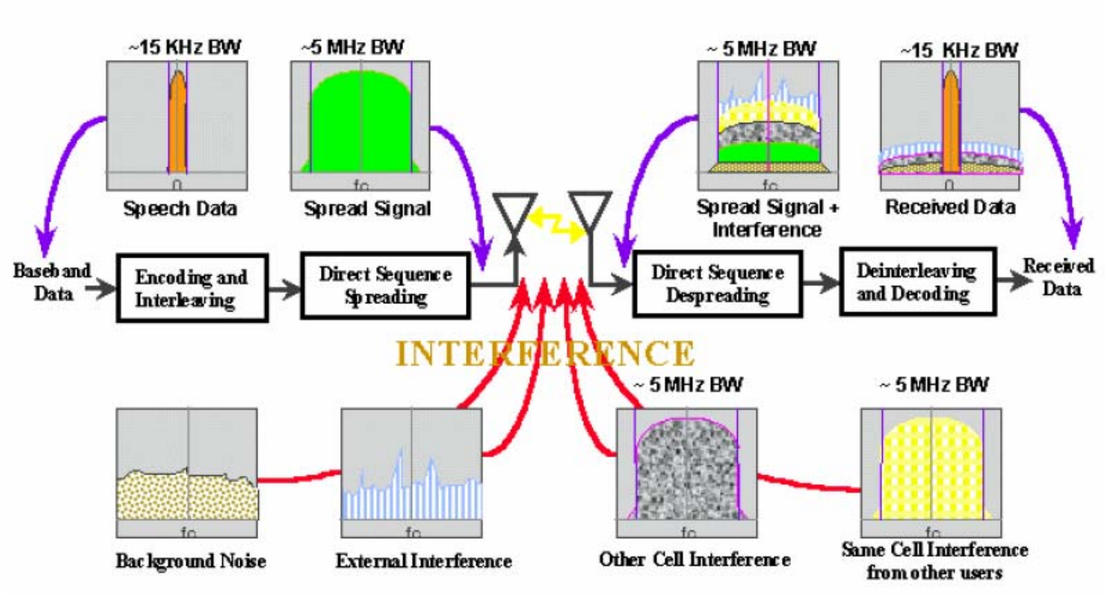


Fig.2.11 Spreading process

In the previous figure we can see as several interferences will be added to the spread signal. This is because the communications always will have to be done through a hostile channel, like is the own air, in addition shared by other users.

Chapter 3. WCDMA

The W-CDMA System (Wideband-Direct Sequence-Code Division Multiple Access) is the system that takes advantage the bandwidth of more efficient form in multi-user surroundings. Therefore, the W-CDMA system becomes an ideal election for metropolitan zones with great density of users.

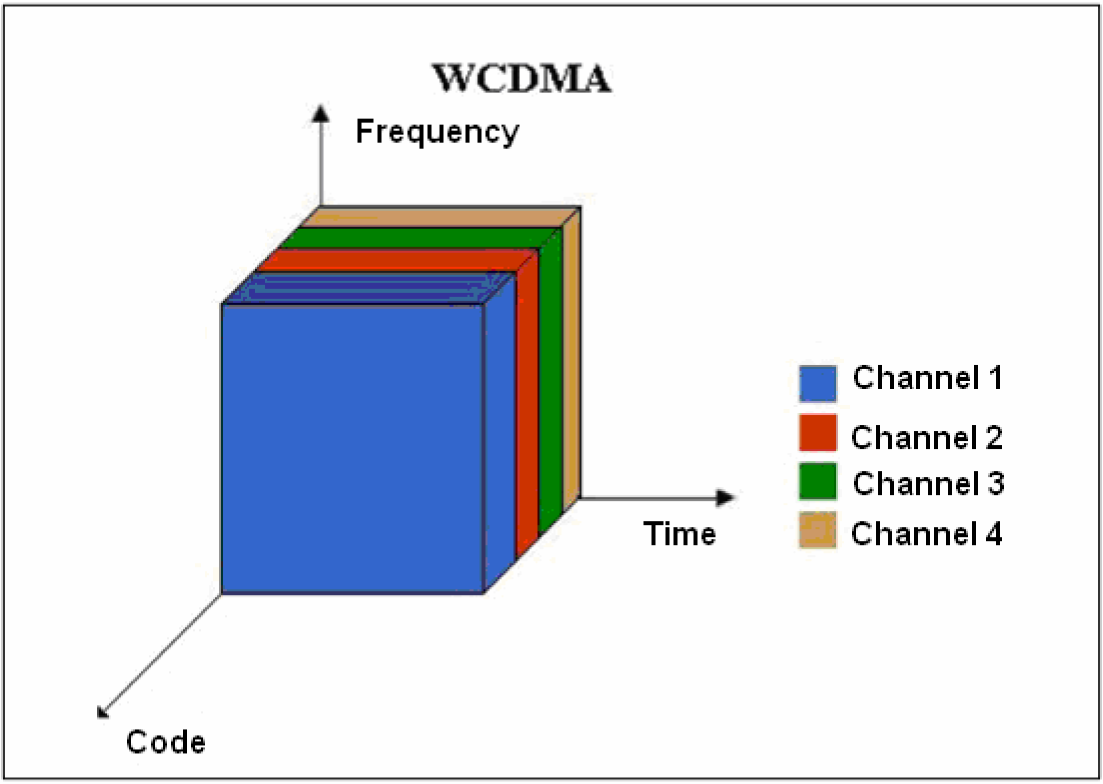


Fig.3.1 Scheme of multiple access by division of code of broadband

Its use in UMTS follows a norm developed by the 3GPP (3rd Generation Partnership Project). This standardization organization defines parameters like the chip rate, the types of modulation in uplink and downlink, the type of power control, the spreading factors used or the method to generate codes PN.

If we pay attention to the network architecture of the system, in the physical layer we found common channels, that they are transmitted and received by all the users, and dedicated channels, that are exclusive for each one of the users. Each UE will know exclusively the codes the common channels and the dedicated ones to him, but not know them codes of the channels dedicated to the rest of UEs.

3.1. Characteristics and Benefits

Next a summary of the technical benefits of this new infrastructure technology:

Flexibility in the service: WCDMA allows in each channel of 5MHz, to handle mixed services with speeds from 144 Kbps to 2 Mbps. In others words the concept of obtaining Bandwidth on Demand (BoD) is well supported. Each user is allocated frames of 10 ms duration, during which the user data rate is kept constant. However, the data capacity among the users can change from frame to frame.

Modes of operation TDD and FDD supports: WCDMA support Frequency Division Duplex (FDD) and Time Division Duplex (TDD). In the FDD mode, separate 5 MHz carrier frequencies are used for the uplink and downlink respectively, whereas in TDD only one 5MHz is time-shared between uplink and downlink.

Multiple services in a single connection: WCDMA fulfils the IMT-2000 requirements, because services of circuits and packages switching[1] can be combined with different bandwidth, and are released to the same user and with specific quality levels. Each terminal WCDMA can accede to different services of simultaneous form. This could be voice in combination with services like Internet, email, etc.

Economy in the network system: Wireless access WCDMA can coexist with the previous cellular digital network (GSM in Europe), because the same structure of network nucleus is used, of the same form that the stations bases are reused. WCDMA uses a structure of network protocol (signalling) similar to GSM; therefore, it allows the use of present network GSM like the structure of network nucleus. WCDMA provides the opportunity for the global development and offers to the existing operators in GSM the opportunity to construct services of wireless access of third generation with the existing investment.

Superior capacity of voice: Although the main intention of the wireless accesses of third generation is the traffic handling multimedia of bits high rate, this also enable a mechanism of efficient use of spectrum for voice traffic.

Transparent access: Terminals of dual way, will allow access is transparent and roaming[2] between systems GSM and networks UMTS, with the changed of the services between both access systems.

Transparent global: The European selection of standard WCDMA offers a unique opportunity to create a global standard for services of third generation. This is translated in assuring roaming global between the operators of radio network.

[1] Circuit switching. These provide circuit-switched connections, like the existing telephony service. ISDN and PSTN are examples of circuit switching networks.
[2] The ability for a user to function when the serving network is different from their home network.

Table 3.1 Main WCDMA parameters

Multiple access method	DS-CDMA
Duplexing method	Frequency division duplex/time division duplex
Base station synchronisation	Asynchronous operation
Chip rate	3,84 Mcps
Frame length	10 ms
Service multiplexing	Multiple services with different quality of service requirements multiplexed on one connection
Multirate concept	Variable spreading factor and multicode
Detection	Coherent using pilot symbols or common pilot
Multiuser detection, smart antennas	Supported by the standard, optional in the implementation

3.2. Multipath Radio Channels

Radio Propagation in the land mobile channel is characterised by multiple reflections and attenuation of the signal energy. There are caused by natural obstacles such as buildings, hills, and so on, resulting in so-called multipath propagation.

In Figure 3.2 we can observe the temporary characteristic of this type of channels. Great precise fading exist that could finish cutting the connection. Nevertheless, using trajectories different, originating of different points from reflection or different stations bases, and combining the signals these cuts are avoided. The possibility of listening to several stations bases, all simultaneously, also makes the Handover Soft possible, that it is not another thing that a soft transition between cells and which improves the quality of services, mainly those of voice, avoiding inopportune cuts in the communications.

The dynamics of the radio propagation suggest the following operating principle for the CDMA signal reception:

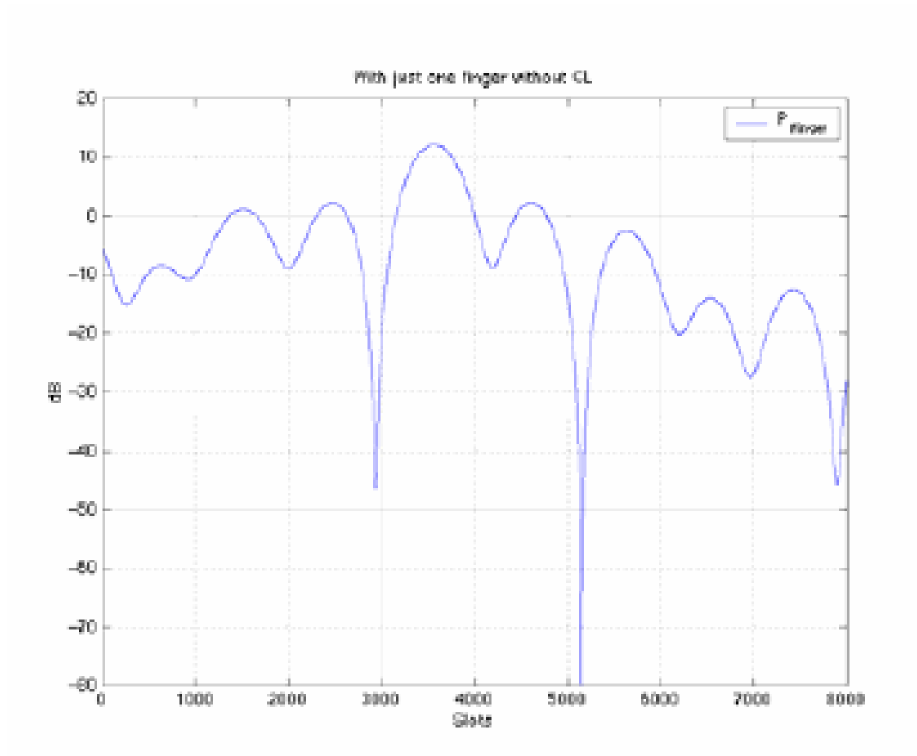


Fig.3.2 Fast Rayleigh fading as caused by multipath propagation

We see that the received signal power can drop considerably (40-50 dB) when phase cancellation of multipath reflections occurs.

A user terminal will be able listen 2 or 3 stations base simultaneously, because all the users share the same portion of spectrum. This way is possible to avoid the injurious effects of Rayleigh fading channel.

3.3. IP multimedia subsystems

The IP Multimedia Subsystem (IMTS) is an open, standardized, operator friendly, and Next Generation Networking (NGN) multi-media architecture for mobile and fixed IP services. It's a VoIP implementation based on a 3GPP variant of SIP, and runs over the standard Internet protocol (IP). It's used by telecom operators in NGN networks (which combine voice and data in a single packet switched network), to offer network controlled multimedia services.

WCDMA supports connectivity IP (Internet Protocol); allowing faster accesses in Internet, the connection to Internet will be faster with WCDMA than the values reached with fixed workstations.

The evident relation between the mobile communications and the access to Internet has stimulated that these are integrated.

The aim of IMS is not only to provide new services but to provide all the services, current and future, that the Internet provides. In addition, users have to be able to execute all their services when roaming as well as from their home networks.

3.3.1. What is mobile IP?

- Mechanism at level of network designed to allow the mobility of host in Internet so its original direction IP stays at any moment. In addition, the connections or sessions that it had established.

- The change of station place takes dynamically and of transparent form at the superior levels. The sessions stay even during the change of station, as long as the communication stays at any moment, although the speed of movement can influence in this factor.

- Mobile IP is designed to solve the problem of “macro” mobility, which is between different networks. “Micro” mobility (between cells in a radio network) is solved better with mechanisms at data link level.

3.4. High-speed Downlink Packet Access

High-speed Downlink Packet Access (HSDPA) is the key new feature included in Release 5 specifications. The HSDPA has been designed to increase packet data throughput by means of fast physical layer (L1) retransmission and transmission combining as well as fast link adaptation controlled by the Node B (Base Transceiver Station (BTS)).

The Key idea of the HSDPA concept is to increase packet data throughput with methods known already from Global System for Mobile Communications (GSM), enhanced data rates for global evolution (EDGE) standards, including link adaptation and fast physical layer retransmission combining. The physical layer retransmission handling has been discussed earlier but the inherent large delays of the existing Radio Network Controller (RNC)-based Automatic Repeat reQuest ARQ architecture would result in unrealistic amounts of memory on the terminal side. Thus, architectural changes are needed to arrive at feasible memory requirements as well as to bring the control for link adaptation closer to the air interface. The transport channel carrying the user data with HSDPA operation is denoted as the high-speed Downlink-shared Channel (HS-DSCH). A comparison of the basic properties and components of HS-DSCH and DSCH is conducted in Table 3.2.

Table 3.2 Comparison of fundamental properties of DSCH and HS-DSCH

Feature	**DSCH**	**HS-DSCH**
Variable spreading factor	Yes	No
Fast power control	Yes	No
Adaptive modulation and coding (AMC)	No	Yes

Multi-code operation	Yes	Yes, extended
Fast L1 HARQ[1]	No	Yes

A simple illustration of the general functionality of HSDPA is provide in Figure 3.3. The Node B estimates the channel quality of each active HSDPA user on the basics of, for instance, power control, ACK/NACK ratio, Quality of Service (QoS) and HSDPA-specific user feedback.

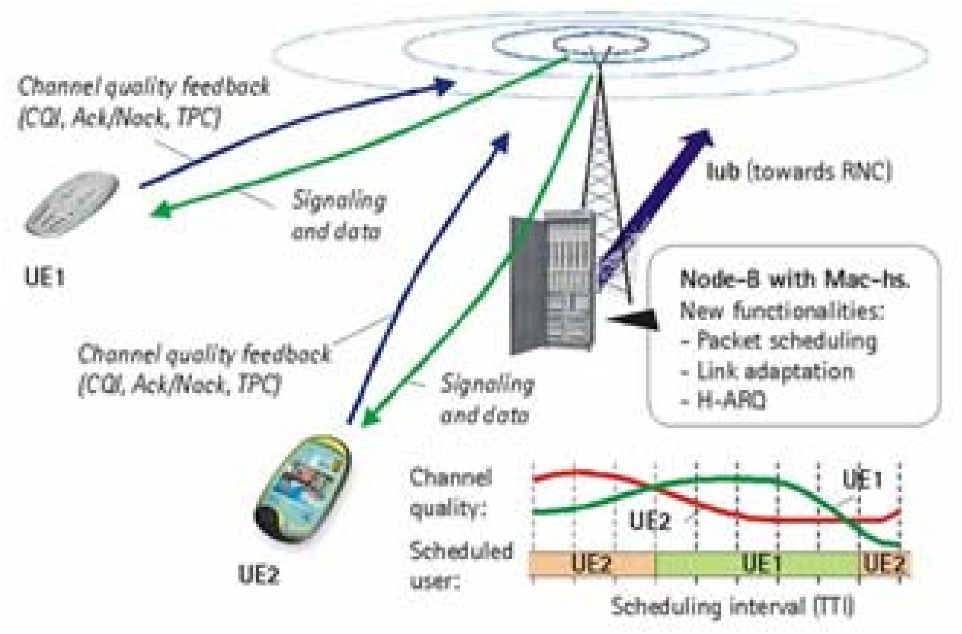


Fig.3.3 General operation principle of HSDPA and associated channels.

With HSDPA, two of the most fundamental features of WCDMA, variable SF and fast power control, are disable and replaced by means of adaptive modulation and coding (AMC), extensive multi-code operation and a fast and spectrally efficient retransmission strategy. In the downlink, WCDMA power control dynamics is in the order of 20 dB compared to the uplink power control dynamics of 70 dB. The downlink dynamics is limited by the intra-cell interference (interference between users on parallel code channels) and by the Node B implementation. This means that for a user close to the Node B, the power control cannot reduce power maximally, and on the other hand reducing the power beyond 20 dB dynamics would have only marginal impact on the capacity. With HSDPA, this property is now utilised by the link adaptation function and AMC to select a coding and modulation combination that requires higher Ec / Ior, which is available for the user close to the Node B (or with good interference/channel conditions in short-term sense).

[1] HARQ (Hybrid Automatic Request). An advanced retransmission strategy, which allows to perfom possible retransmissions directly at physical / MAC layer, without involving higher layer mechanisms and so reducing the delay.

3.5. High-Speed Uplink Packet Access

HSUPA, High-Speed Uplink Packet Access, is a data access protocol for mobile phone networks with extremely high upload speeds up to. Similar to HSDPA (High-Speed Downlink Packet Access), HSUPA is considered 3.75G or sometimes 4G.

The specifications for HSUPA are still under development and will be included in UMTS Release 6. It is published on www.3GPP.org.

HSUPA is expected to use an uplink enhanced dedicated channel (E-DCH) on which it will employ link adaptation methods similar to those employed by HSDPA, namely:

- Shorter Transmission Time Interval enabling faster link adaptation.
- HARQ with incremental redundancy making retransmissions more effective.

Similarly to HSDPA there will be a packet scheduler, but it will operate on a request-grant principle where the UEs request a permission to send data and the schedular decides when and how many UEs will be allowed to do so. A request for transmission will contain data about the state of the transmission buffer and the queue at the UE and its available power margin. In addition to scheduled transmissions the standards also force a self-initiated transmission mode from the UEs - this mode can for example be used for VoIP services for which even the reduced TTI and the Node-B based schedular will not be able to provide the very short delay time and constant bandwidth required.

The standard forces two basic scheduling methods: Long term grants are issued to several terminals which can then send their data simultaneously. The grants are increased or decreased according to the current load of the cell and the requirements of the terminals. Short term grants on the other hand are an alternative scheduling method to allow multiplexing terminals in the time domain instead of the code domain as is done for the long term scheduling. In order to allow multiplexing uplink transmissions of several terminals in both code and time domain the scrambling and channelisation codes are not shared between different terminals like this is done in HSDPA on a shared downlink channel.

Because in the uplink the DPDCH and DPCCH are code-multiplexed and transmitted simultaneously in time the ratio of their transmit powers is important for the achievable pay-load bit rates. The greater part of the UE's power is assigned to DPDCH the higher the pay-load bit rate achievable on that channel but the less power is left for DPCCH and the less reliable the signalling in the link. In UMTS Release'99 the ratio between the power of DPDCH and DPCCH was set to a constant. In HSUPA this ratio will be controlled by the Node-B.

In HSUPA, unlike in HSDPA, soft and softer handovers will be allowed for packet transmissions. The control of UE's transmit power in soft/softer handover on E-DCH will be slightly different from that specified in Release'99 for DCH, namely: the main serving Node-B will be able to issue both power-up and power-down commands but all other Node-Bs participating in the handover will be able to issue only power-down commands. A power-down command will always have precedence over a power-up command.

Chapter 4. Spectrum Allocations for Third Generation Systems

In the standardization forums, WCDMA technology has emerged as the most widely adopted third generation air interface. Its specifications has been created in 3GPP (the 3rd Generation Partnership Project), which is the joint standardization project of the standardization bodies from Europe, Japan, Korea, the USA and China. Within 3GPP, WCDMA is called UTRA (Universal Terrestrial Radio Access) FDD (Frequency Division Duplex) and TDD (Time Division Duplex), the name WCDMA being used to cover both FDD and TDD operation.

Work to developed third generation mobile systems started when the World Administrative Radio Conference (WARC) of the ITU (International Telecommunications Union), at its 1992 meeting, identified the frequencies around 2GHz that were available for use by future third generation mobile systems, both terrestrial and satellite. Within the ITU these third generation systems are called International Mobile Telephony 2000 (IMT-2000).

In addition to WCDMA, the other air interfaces that can be used to provide third generation services are EDGE and cdma2000.

In Europe and in most of Asia the IMT-2000 (or WARC-92) bands of 2 x 60 MHz (1920-1980 MHz plus 2110-2170 MHz) will be available for WCDMA FDD. The availability of the TDD spectrum varies: in Europe it is expected that 25 MHz will be available for licensed TDD use in the 1900-1920 MHz and 2020-2025 MHz bands.

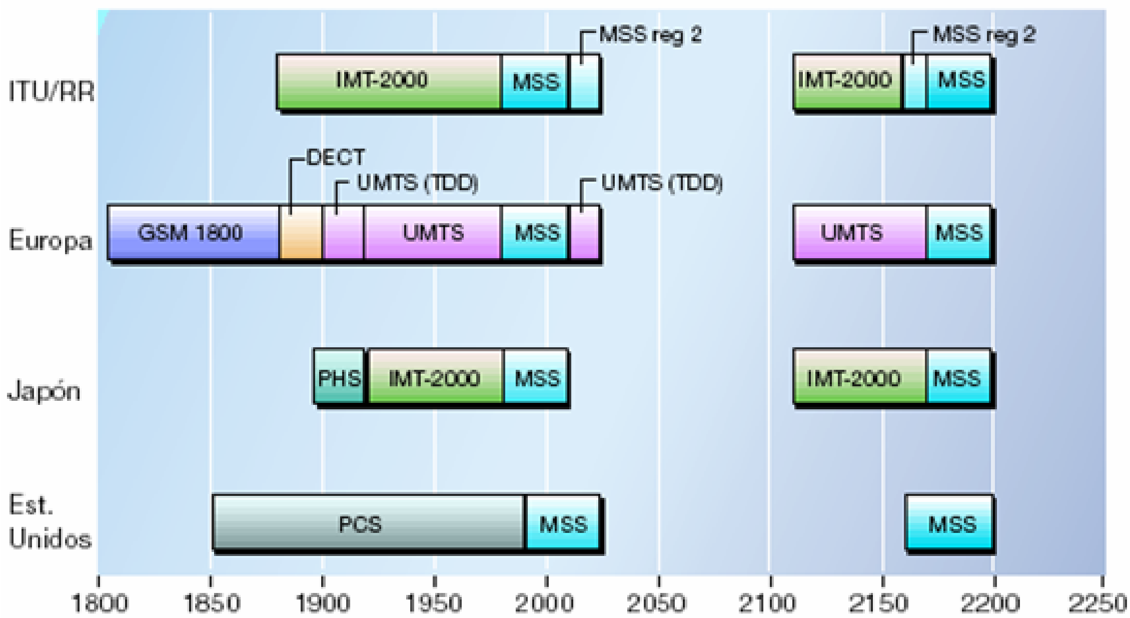


Fig 4.1 2 GHz band spectrum in Europe, Japan, Korea and USA (MSS = Mobile satellite spectrum)

The demand for even higher data rates and potential need for wider bandwidths in cellular evolution raise even further questions on spectrum needs. However, before this need can be defined, a much better vision of the next generation will be needed. For example, if WLAN is combined with WCDMA, the additional spectrum is already the current WLAN spectrum, and something more is needed to justify even higher spectrum requirements. There are many discussions ongoing, for example, about reallocating analog TV bands for mobile systems. On the other hand, administrations seem to prefer more flexible air interfaces where globally harmonized spectrum would not be needed.

The first IMT-2000 licenses were granted in Finland in March 1999, and followed by Spain in March 2000. No auction was conducted in Finland or in Spain. Also, Sweden granted the licenses without auction in December 2000. However, in other countries, such as the UK, Germany and Italy, an auction similar to the US spectrum auctions was conducted.

4.1. The standardisation organisations

4.1.1. Creation of 3GPP

The standardisation organisations involved in the creation of the 3rd Generation Partnership Project (3GPP), it's a collaboration agreement that was established in December 1998. 3GPP is a co-operation between ETSI (Europe), ARIB/TTC (Japan), TTA (Korea), T1P1 (USA), and CWTS (China).

The partners agreed on joint efforts for the standardisation of UTRA, now standing for Universal Terrestrial Radio Access, as distinct from UTRA (UMTS Terrestrial Radio Access) from ETSI, also submitted to 3GPP.

3GPP2 was focused on the development of cdma2000 Direct-sequence (DS) and Multi-carrier (MC) mode for the cdma2000 third generation component. This activity has been running in parallel with the 3GPP project, with participation of ARIB, TTC and CWTS as member organizations.

4.1.2. IMT-2000

IMT-2000 (International Mobile Telecommunications-2000) is the global standard for third generation (3G) wireless communications as defined by the International Telecommunication Union (ITU).

In 1999 ITU approved five radio interfaces for IMT-2000 as a part of the ITU-R M.1457 Recommendation. The five standards are:

- IMT-2000 CDMA Direct Spread
  Also Known as W-CDMA or UTRA-FDD, used in UMTS

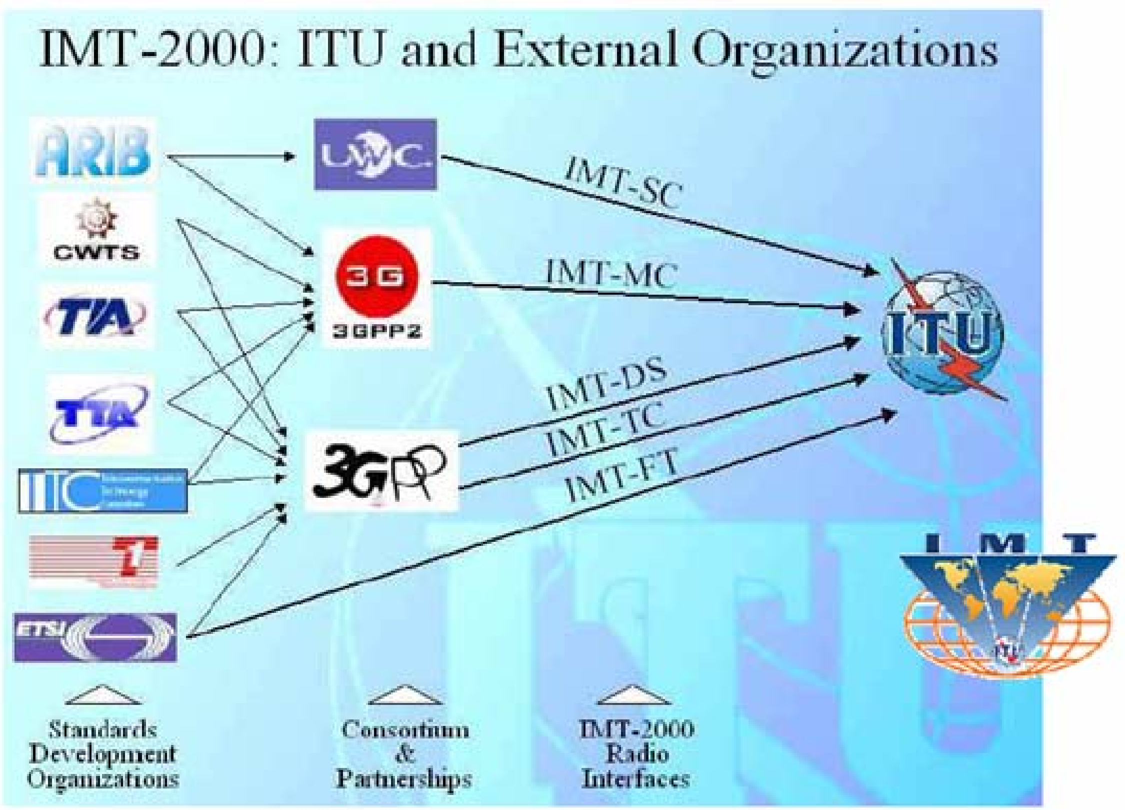
- IMT-2000 CDMA Multi-Carrier
  Also Known as CDMA2000, the successor to 2G CDMA

- IMT-2000 CDMA Time-Code
  This summarises UTRA-TDD (standardised in UMTS)

- IMT-2000 TDMA Single Carrier
  Also known as EDGE, an intermediate 2.75G technology

- IMT-2000 FDMA/TDMA
  Also Known as DECT

The ITU Radio-communication Sector (ITU-R) has been an important external motivation and timing source for IMT-2000 activities in regional standard bodies. The ITU-R interaction between regional standardization bodies in the IMT-2000 process in reflected in the next figure:



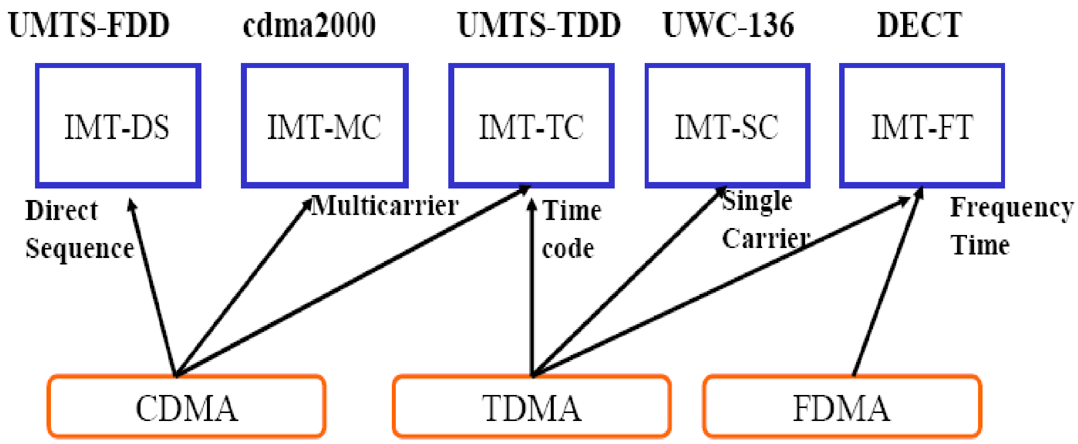


Fig.4.2 The ITU-R interaction between regional standardization

Chapter 5. WCDMA Background

It is often the case with new technologies that technical committees, standardization organizations, company R&D departments, etc. have been working on their specification and development long before they hit the headlines in the news. With respect to 3G technology, the work with developing the specifications started even before the 2G solutions had reached the markets. Work has been performed in several organizations and parts of the world in parallel and cooperation.

ITU had started working on 3G specifications already in 1986 - at that point of time it was called Future Public Land Mobile Telecommunication System (FPLMTS), and also the ITU terminology being called IMT-2000. However, ITU has not had a decisive role in the processes of 3G standardization. The most important organizations in this field are 3GPP and its counterpart 3GPP2 (organizing the proponents of cdma2000 technology) and the regional standardization organizations behind these two conglomerates and the different equipment manufacturers and telecommunications operators. The ITU-R IMT-2000 process was finalized at the end of 1999, when the detailed specification (IMT-RSCP) was created and the radio interface specifications were approved by ITU-R. The detailed implementation of IMT-2000 will continue in the regional standards bodies. The ITU-R process has been an important external motivation and timing source for IMT-2000 activities in regional standard bodies. The ITU-R interaction between regional standardization bodies in the IMT-2000 process is reflected in Figure 5.1.

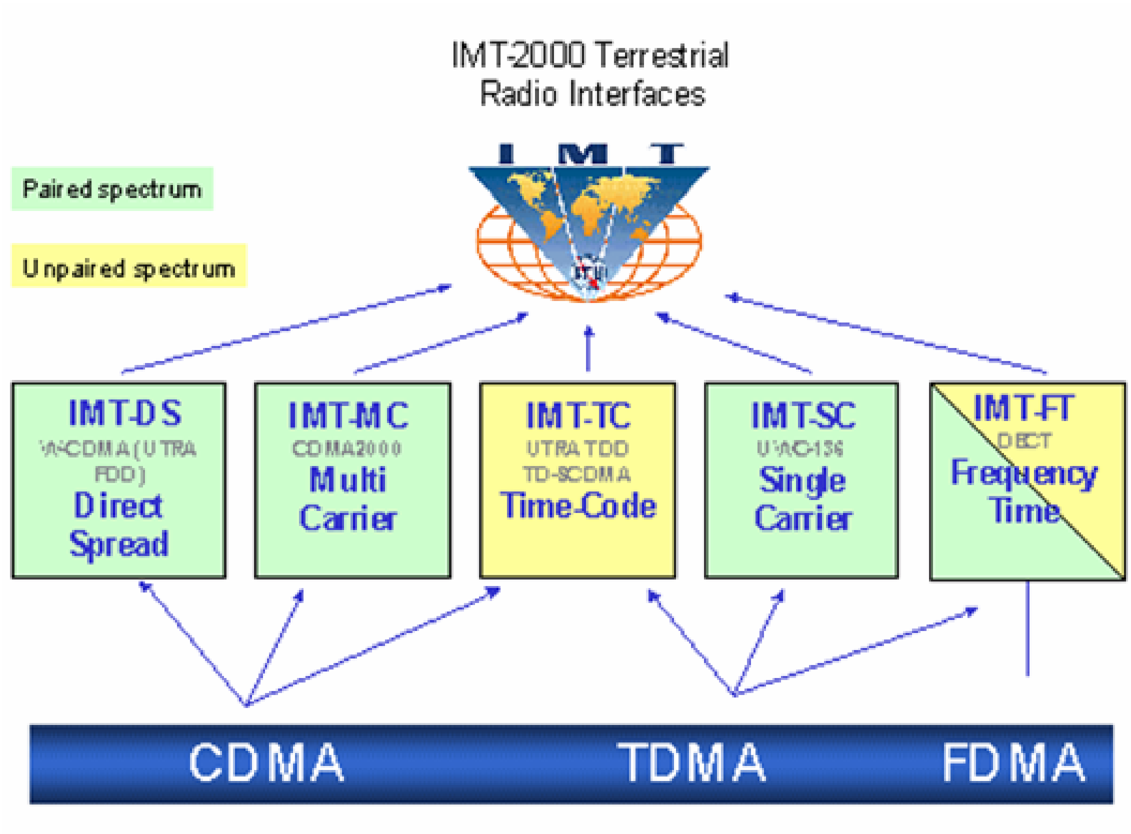


Fig.5.1 ITU-R IMT-2000 grouping

5.1 Background in Europe

Work in the EU context on 3G technology started in 1988 in relation to the first communication technology research programme RACE I (Research of Advanced Communication Technologies in Europe) with participation from European based equipment manufacturers, telecommunication operators and universities. Work continued in the RACE II programme and the subsequent ACTS (Advanced Communication Technologies and Services) programme, and results from this work were submitted to the European standards institute ETSI as candidates for UMTS air interfaces and to ITU as IMT-2000 submissions. The proposals for air interfaces were in 1997 grouped by ETSI in 5 different categories: WCDMA, WTDMA, TDMA/CDMA, OFDMA and ODMA. At that point of time, there was no definite decision as to which air interface technology would eventually be favoured by ETSI. It was still not a closed game; however, with the decision of ARIB (The Association for Radio Industries and Businesses) in Japan later in 1997 to support WCDMA, it was decided in ETSI (in 1998) to select WCDMA as the preferred air interface for 3G. Ericsson and Nokia already favoured WCDMA, which was part of the background for the Japanese decision. Therefore, there were, actually, already strong indications that WCDMA would be given priority. And, to continue working together in a broader international context, ETSI in 1998 took part in the establishment of the so-called 3GPP with participation from Europe (ETSI), Japan (ARIB and TTC), South Korea (TTA) and USA (T1P1) and later in 1999 CWTS from China.

The proposals for the UMTS Terrestrial Radio Access (UTRA) air interface received by the milestone were grouped into five concept groups in ETSI in June 1997, after their submission and presentation during 1996 and early 1997.

The following groups were formed:

- Wideband CDMA (WCDMA)
- Wideband TDMA (WTDMA)
- TDMA/CDMA
- OFDMA
- ODMA

The evaluation of the proposals was based on the requirements defined in the ITU-R IMT-2000 framework.

Wideband CDMA

The WCDMA concept group was formed around the WCDMA proposals from FRAMES/FMA2, Fujitsu, NEC and Panasonic. Several European, Japanese and US companies contributed to the development of the WCDMA concept.

The main characteristics of system are:

- Wideband CDMA operation with 5 MHz
- Physical layer flexibility for integration of all data rates on a single carrier

- Reuse factor equal to 1 operation

Also some optative additional advantages were considered:

- Transmit diversity
- Adaptive antenna operation
- Support for advanced receiver structures

The great flexibility of the physical layer of WCDMA caused that this radio access proposal received a great support on the part of all the technical committees.

5.2. Background in Japan

In Japan, ARIB (the Association for Radio Industries and Business) evaluated possible third generation systems around three different main technologies based on WCDMA, WTDAM and OFDMA. The WCDMA in Japan was very similar to that being considered in Europe in ETSI; indeed, the members of ARIB contributed their technology to ETSI's WCDMA concept group. Details of FRAMES/FMA2 were provided from Europe for consideration in the ARIB process.

The outcome of the ARIB selection process in 1997 was WCDMA, with both FDD and TDD modes of operation. Since WCDMA had been chosen in ARIB before the process was completed in ETSI, it carried more weight in the ETSI selection as the global technological alternative. In Japan, work on higher layer specifications is the responsibility of TCC (the Telecommunication Technology Committee), which has also shifted the activity to 3GPP.

5.3. Background in the United States

In the US, T1P1 worked on GSM related standardization and submitted WCDMA N/A (N/A for North America) as their IMT-2000 proposal. The WCDMA N/A proposal had many similarities with the WCDMA proposals from ETSI and ARIB, as several of the contributing organizations had been involved and active in the ETSI and ARIB standardization work as well. Furthermore, a cdma2000 air interface proposal was submitted by the TIA TR45.5 working group. The proposal was based partly on the IS-95 standard as a migration road towards 3G cdma systems. This US based cdma2000 proposal has a high degree of similarity with the South Korean cdma proposal.

5.4. Background in Korea

In South Korea, TTA selected two 3G air interface standards, TTA 1 and TTA 2 (later renamed Global CDMA 1 and 2 respectively) were based on synchronous and asynchronous wideband CDMA technologies respectively. TTA 1 is based on WCDMA and is similar to the standards chosen in Europe and Japan, while TTA 2 is similar to the US version of cdma2000.

Chapter 6. Radio Access Network Architecture

From a specification and standardization point of view, both UE and UTRAN consist of completely new protocols, the design of which is based on the needs of the new WCDMA radio technology. On the contrary, the definition of Core Network (CN) is adopted from GSM. This gives the system with new radio technology a global base of known and rugged CN technology that accelerates and facilitates its introduction, and enables such competitive advantages as global roaming.

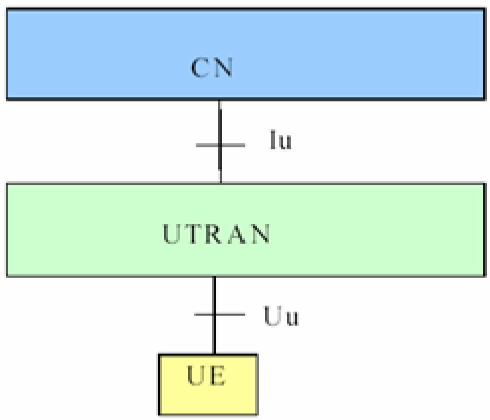


Fig.6.1 UMTS high-level system architecture

The UMTS system is modular in the sense that it is possible to have several network elements of the same type. The possibility of having several entities of the same type allows the division of the UMTS system into sub-networks that are operational either on their own or together with other sub-network and that are distinguished from each other with unique identities. Such a sub-network is called a UMTS PLMN (Public Land Mobile Network).

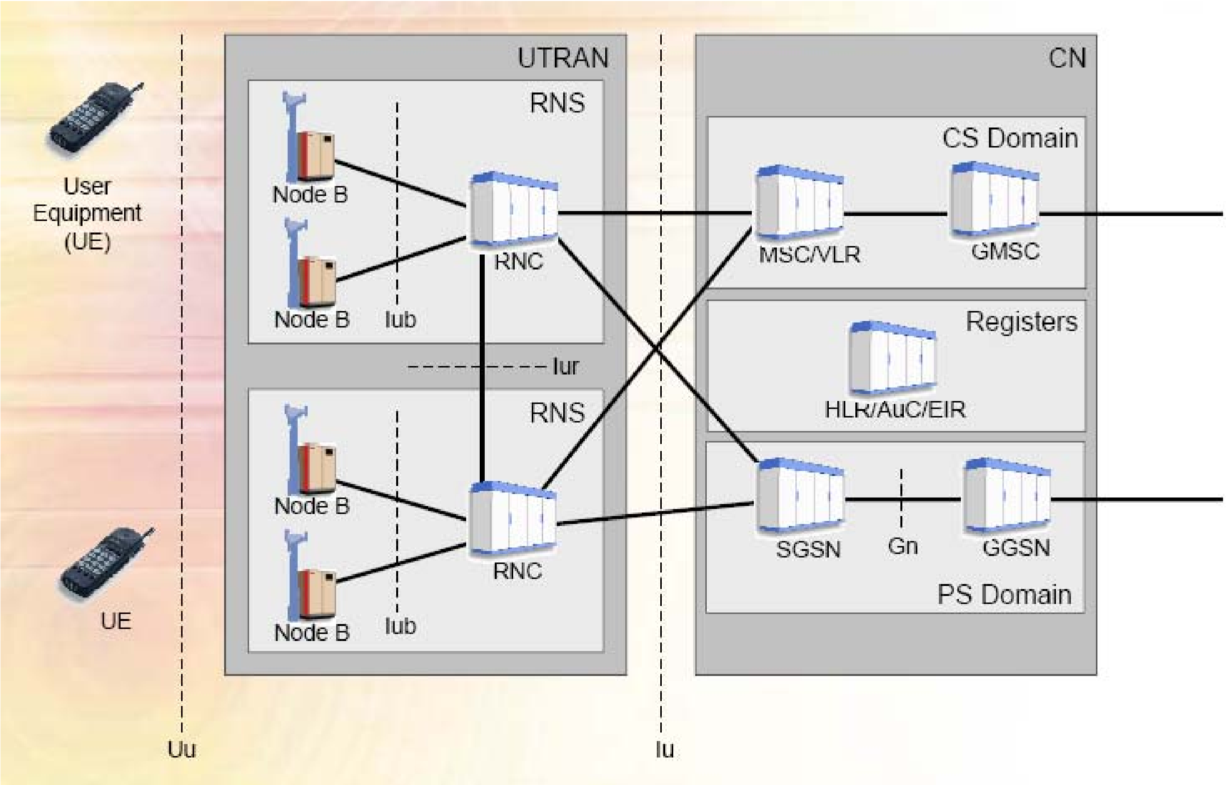


Fig.6.2 Radio Access Network Architecture

6.1. UE (User Equipment)

It is the equipment that the user uses to obtain the communication with a station bases on the moment and the place that wish it, as long as cover exists.

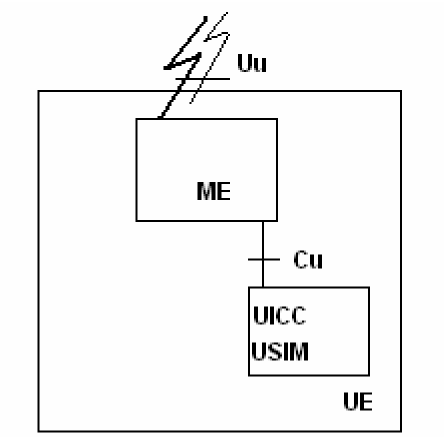


Fig.6.3 User Equipment Architecture

The UE consists in two parts:

The mobile equipment (ME) is the radio terminal used for radio communications over Uu interface.

The UMTS subscribe Identity Module (USIM) is a smartcard that holds the subscriber identity, performs authentication algorithms, and stores authentication and encryption keys and some subscription information that is needed at the terminal.

6.2. UTRAN elements

It has two interfaces that connect it with the central network and the team of user. The Iu interface and the Uu interface respectively.

UTRAN also consists of two distinct elements, Node B and RNC (Radio Network Controller):

- The **node B** converts the data flow between the Iub and Uu interfaces. The enigmatic term “Node B” was initially adopted as a temporary term during the standardisation process, but then never changed. Node B is the equivalent one in UMTS to the BTS of GSM (Base Transceiver Station).

Briefly it is a logical node responsible for radio transmission / reception in one or more cells to/from the User Equipment. It does operations with the Iub interface towards the RNC.

- ✓ Functions of the Node B:

- o Forward Error Correction (FEC)
- o Rate Adaptation
- o W-CDMA spreading / dispreading
- o QPSK modulation
- o Management of the macro diversity
- o Measurements of quality in radio link, for the handover process
- o Power Control (PC)

- The **RNC** will receipt much important information through Node B, in order to carry out its functions correctly.

The RNC owns and controls the radio resources in its domain (the Node Bs connected to it). RNC is the service access point for all services UTRAN provides the CN (Core Network), for example management of connections to the UE.

The RNC is in charge of the soft handover, this one along with its respective nodes B form a RNS[1]. RNCs may be connected to each other via an Iur interface, and may too be connected to node B with an Iub interface.

Logical Role of the RNC

The RNC controlling one Node B (i.e. terminating the Iub interface towards the Node B) is indicated as the Controlling RNC (CRNC) of the Node B. The Controlling RNC is responsible for the load and congestion control of its own cells, and also executes the admission control and code allocation for new radio links to be established in those cells.

Serving RNC. The SRNC is in charge of the connection between a mobile unit and the RNC, there is a SRNC by mobile that has a connection with the RNS. The functions of the RNC in this role are: mapping of the parameters for the radio link, outer loop power control, macro diversity and handover decision.

Drift RNC. A DRNC helps to a SRNC with resources of radio in the case of connections with macro diversity. If a connection between a mobile and its SRNC arrives by means of another connected node B at a different RNC, this RNC is known like DRNC.

6.3. The main elements of the CN (Core Network)

HLR (Home Location Register) is a database located in the user's home system that stores the master copy of the user's service profile. The service profile consists of, for example, information on allowed services, forbidden roaming areas, and Supplementary service information such as status of call forwarding and the call forwarding status. Its created when a new user subscriber to the system, and remains stored as long as the subscription is active.

MSC/VLR (Mobile Services Switching Centre/Visitor Location Register) is the switch (MSC) and database (VLR) that serves the UE in its current location for Circuit Switched (CS) services.

- ✓ Functions of MSC/VLR:
    - Functions of interoperability with another type of networks
    - Handling of the processes of Handover (specially the complex process of Handover between systems)
    - To store data for the invoicing centre
    - Handling of the parameters for the encryptation
    - Signalling between different interfaces
    - Control and operation of the echo cancellation

[1] RNS. The UTRAN (UMTS Terrestrial Radio Access Network) consists of one or more RNS (Radio Network Subsystem). Each RNS control the allocation and the release of specific radio resources to establish a connection between a UE (User Equipment) and the UTRAN. A RNS is responsible for the resources and transmission/reception in a group of cells.

GMSC (Gateway MSC) is the switch at the point where UMTS PLMN is connected to external CS networks. All incoming and outgoing CS connections go through GMSC.

SGSN (Serving GPRS (General Packet Radio Service) Support Node) functionally is similar to MSC/VLR but is typically used for Packet Switched (PS) services. The part of the network that is accessed via the SGSN is often referred to as the PS domain.

GGSN (Gateway GPRS Support Node) is the switch at the point where UMTS PLMN is connected to external PS networks.

6.4. UTRAN Interfaces

The UMTS standards are structured so that internal functionality of the network elements is not specified in detail. Instead, the interfaces between the logical network elements have been defined. The following main interfaces are described:

Cu Interface. This is the electrical interface between the USIM smartcard and the ME.

Uu Interface. This is the WCDMA radio interface, the Uu is the interface through which the UE accesses the fixed part of the system, and is therefore probably the most important open interface in UMTS.

Iu Interface. The open Iu interface gives UMTS operators the possibility of acquiring UTRAN and CN from different manufacturers.

Iur Interface. This interface allows soft handover between RNCs from different manufacturers, and therefore complements the open Iu interface. The protocol stack of the RNC to RNC interface is RNSAP Signalling. Although this interface was initiallt designed in order to support the inter-RNC soft handover, more features were added during the development of the standard and currently the Iur interface provides four distinct functions:

- Support of Basic Inter-RNC Mobility → Iur1
- Support of Dedicated Channel Traffic → Iur2
- Support of Common Channel Traffic → Iur3
- Support of Global Resource Management → Iur4

Iub Interface. The Iub connects a Node B and an RNC. Several “Nodes B” are controlled by a single Controller of the Radio Network through the Iub interface. UMTS is the first commercial mobile telephony system where the Controller-Base Station interface is standardised as a fully open interface.

6.5. Utran and GSM network Comparison

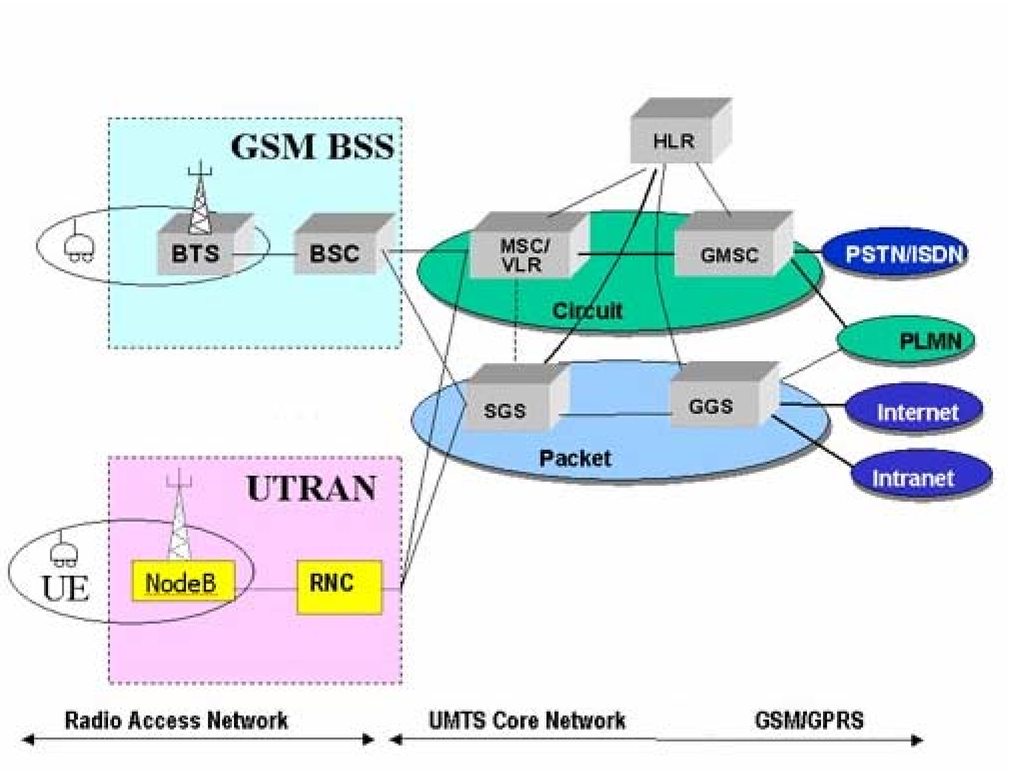


Fig.6.4 UTRAN and GSM network Architecture

1. In GSM MSC can take part in radio resource management. For example MSC takes part in the inter MSC handovers or GSM can be configured so that MSC can perform inter BSC handovers. But in the UTRAN RNC's are responsible for all radio resource management, they don't take any help from the core network.

2. RNC's can communicate each other via Iur interface (communication between RNCs). With this functionality RNC's can do all Radio resource management without the help of core network. This allows the first implementations of Utran to be interoperable with GSM network with the help of protocol converters that covert the signaling of Iu (UMTS) and A (GSM) interfaces.

6.6. Evolution of the Access Network

Next to the main characteristics of the network of access UTRAN and the CN for different releases are described:

Release-99

- ✓ Radio Access Network builds on ATM
- ✓ Core Network GSM + GPRS

Release-4

- ✓ Radio Access Network builds on ATM
- ✓ CS domain independent of the transport
- ✓ Voice/ATM and Voice/IP
- ✓ IP Architecture

Release-5

- ✓ Radio Access Network builds on IP
- ✓ IP header overload
- ✓ Traffic multiplexing of several users
- ✓ Data packets segmentation
- ✓ Supports of mechanisms of QoS on IP
- ✓ Total integration

Release-6

UMTS Release 6 takes a radical approach to the introduction of conversational and real time interactive multimedia services over an end to end IP transport provided by an enhanced general packet radio service in the packet switched domain.

It specifies a voice and multimedia services network called the Internet protocol Multimedia Subsystem Core Network (IMS CN). The IMS CN comprises all the CN elements for provision of IP multimedia applications over IP multimedia sessions.

The main reasons for the introduction of the IMS CN are to enable new real time interactive services, to provide flexibility to the user and to reduce cost. Examples of the services that will be supported by the IMS CN are: voice telephony (VoIP); real time interactive games; multimedia conferencing; video telephony.

Chapter 7. Protocols Architecture in the UMTS Access Network

Protocol structures in UTRAN terrestrial interfaces are designed according to the same general protocol model. This model is shown in the next figure. The structure is based on the principle that the layers and planes are logically independent of each other. Therefore, as and when required, the standardisation body can easily alter protocol stacks and planes to fit future requirements.

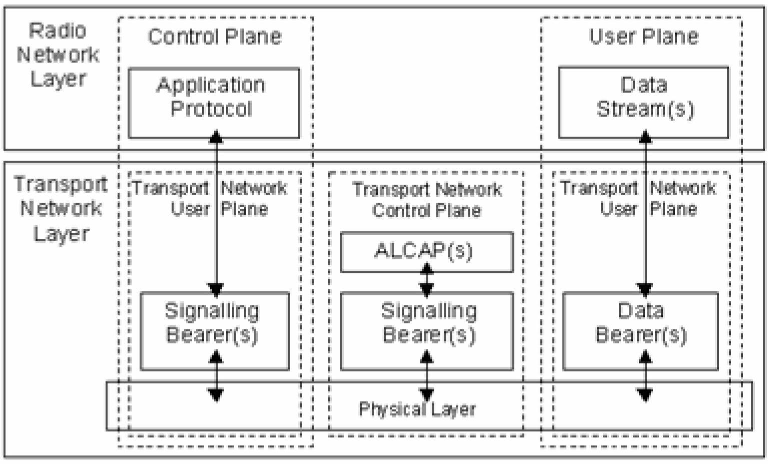


Fig.7.1 General Protocol Mode for UTRAN Interfaces

Horizontal Layers

The Protocol Structure consists of two main layers, **Radio Network Layer**, and **Transport Network Layer**. All UTRAN related issues are visible only in the Radio Network Layer, and the Transport Network Layer represents standard transport technology that is selected to be used for UTRAN, but without any UTRAN specific requirements.

Vertical Planes

The **Control Plane** includes the Application Protocol (i.e. RANAP in Iu, RNSAP in IUr and NBAP in Iub), and the Signalling Bearer for transporting the Application Protocol messages. The Application Protocol is used, among other things, for setting up bearers to the UE (i.e. Radio Access Bearer in Iu and subsequently the Radio Link in Iur and Iub).

The **User Plane** transports all information sent and received by the user, such as the coded voice call or the packets in a Internet connection. The user plane includes the Data Stream(s) and the Data Bearer(s) for the Data Stream(s). The Data Stream(s) is/are characterised by one or more frame protocols specified for that interface.

The **Transport Network Control Plane** is used for all control signalling within the Transport Layer. It does not include any Radio Network Layer information, and is completely in the Transport Layer. It includes the ALCAP protocol(s) that is/are needed to set up the transport bearers (Data Bearer) for the User Plane. It also includes the appropriate Signalling Bearer(s) needed for the ALCAP protocol(s). This is a plane that acts between the Control Plane and the User Plane. The introduction of Transport Network Control Plane is performed in a way that the Application Protocol in the Radio Network Control Plane is kept completely independent of the technology selected for Data Bearer in the User Plane. Indeed, the decision to actually use an ALCAP protocol is completely kept within the Transport Network Layer during real-time application.

At the **Transport Network User Plane** belong the Data Bearer(s) in the User Plane and the Signalling Bearer(s) for the Application Protocol. The Data Bearers in the Transport Network User Plane are directly controlled by the Transport Network control Plane during real-time application, but the control actions required for setting up the Signalling Bearer(s) for the Application Protocol.

A division of the network can be made in two stratums from a point of view of grouping of functions. A stratum is a grouping of protocols (communication flows) associated to one or more aspects of service. It is distinguished then:

Access Stratum: it represents the communication between the UE and the UTRAN. It includes layers 1, 2 and part from the 3 of OSI model. It is considered that it is the carrying layer of the functions of the stratum of non access. It is independent of the technology of access used in the radio interface.

Non Access Stratum: it represents the communication between the UE and the CN and is considered that it includes part of the layer 3 and layers 4 to the 7 of OSI model.

The protocols architecture of the radio interface is composed by three protocols.

- Physical Layer L1
- Link Layer L2
- Network Layer L3

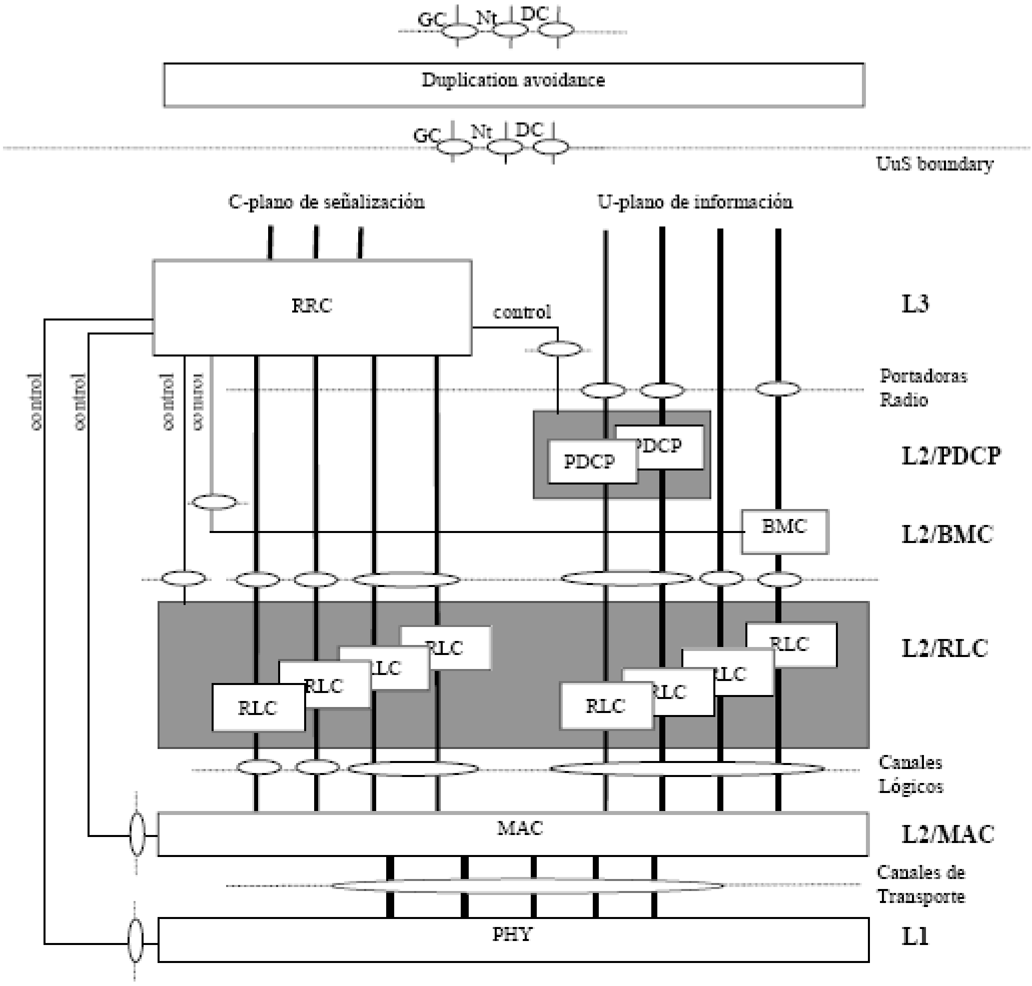


Fig.7.2 Protocols Architecture of the Radio Interface

The Link Layer L2 is made up of 4 sub-layers: MAC (Medium Access Control), RLC (Radio Link Control), BMC (Broadcast/Multicast Control Protocol) and PDCP (Packet Data Control Protocol). These two last sub-layers only affect the User Plane. The PDPC exists for the dominion of packages and its function is of compression of heads. The BMC is used to send on the radio interface, messages originating by the center of Diffusion.

The Network layer L3 is divided in two parts: Access stratum and non Access stratum. The part of access to the layer is formed by organization RRC and the organization "duplication avoidance". The part of the access is not formed by the parts of control of calls CC and management of mobility MM. All the messages of signaling of the superior layers (signaling of Non Stratum Access) and of the own layer are encapsulations in messages RRC for their transmission on the interface radio. The organization "duplication avoidance" is in charge to guarantee the protection of the data when it changes the point of connection in the Iu Interface changes.

In figure each block represents an instance of the protocol and the circles the joining points the service. The layers of the model are related to each other through control connections that are employees of the implementation (in the standards they are not described). These connections of control allow the RRC layer to configure the low layers of the model:

- Configuration of the layer 1 for a reconfiguration of a radio carrier and shipment of commands to make measures
- Exchange of information on volume of traffic between MAC and RRC, this allows to switch between transport channels (for example of FACH to DSCH)
- Report of measures of layer 1 to the RRC
- Report of statistics of errors of transmission of layer RLC to the RRC, this gives rise to changes of transport formats
- To configure the layer PDPC to make the compression of heads

7.1. Physical Layer

7.1.1. Introduction

Taking care of the network architecture of the system, in the physical layer we found common channels, that they are transmitted and received by all the users, and dedicated channels, that are exclusive for each one of the users. Each UE will know exclusively the codes the common channels and the dedicated ones to him, but not them codes of the channels dedicated to the rest of UEs.

UMTS uses technique WCDMA where the chip rate of the spread signal is fixed and equal to 3,84 Mcps which leads to a bandwidth 5 of Mhz. To each user is assigned to him frames of duration 10 ms during which its bit rate is constant, although it can be varied from a frame to another one (varying the SF). In the following figure is this characteristic and that the services with high rates of user bits require a greater power than those of low speed.

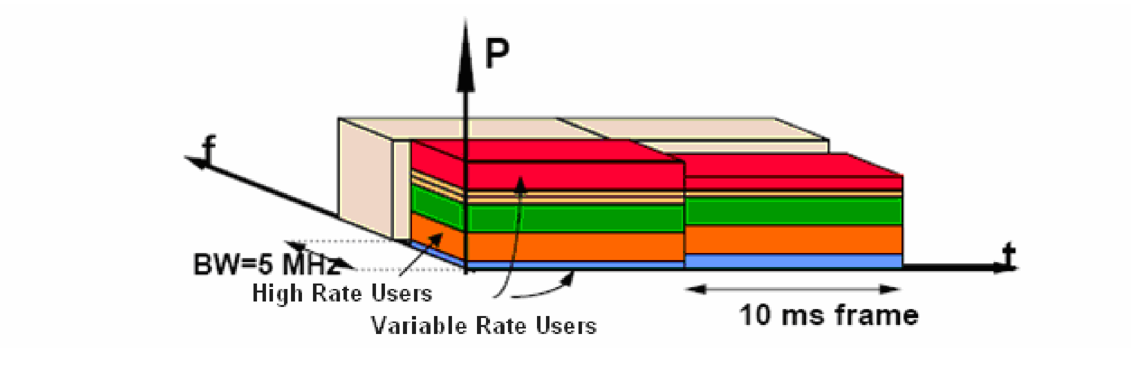


Fig.7.3 Allocation of Codes in the time-frequency region

In WCDMA the codes of spreading are made up of two codes:

Scrambling: They are used to separate users in the UL and cells in DL. These codes can be long (38400 Chips) or short (256 Chips) in the UL and are long in the DL. The long codes are codes of Gold while the short ones belong to the family of extended codes.

Channelisation: They are used to separate the physical channels of data and of control of a same UE, and in the DL to separate the connections of different users within a cell. They are short codes of 256 Chips (in DL 512 Chips is possible) and belong to family OVSF.

Table.7.1 Functionality of the channelisation and scrambling codes

	Channelisation code	**Scrambling code**
Usage	Uplink: Separation of Physical data (DPDCH) and control channels (DPCCH) from same terminal Downlink: Separation of downlink connections to different users within one cell	Uplink: Separation of terminal Downlink: Separation of sectors (cells)
Length	4-256 chips (1.0-66.7 µs) Download also 512 chips	Uplink: (1) 10 ms = 38400 chips or (2) 66.7 µs = 256 chips Option (2) can be used with advanced base station receivers Downlink: 10 ms = 38400 chips
Number of codes	Number of codes under one scrambling code = spreading factor	Uplink: Several millions Downlink: 512
Code family	Orthogonal Variable Spreading Factor	Long 10 ms code: Gold code Short code: Extended code family
Spreading	Yes, increases transmission bandwidth	No, does not affect transmission bandwidth

WCDMA supports two basic ways of operation:

FDD Frequency Division Duplex: where uplink and downlink uses separated different frequencies 190 Mhz.

TDD Time Division Duplex: where uplink and downlink uses the same frequency but is separated in the time.

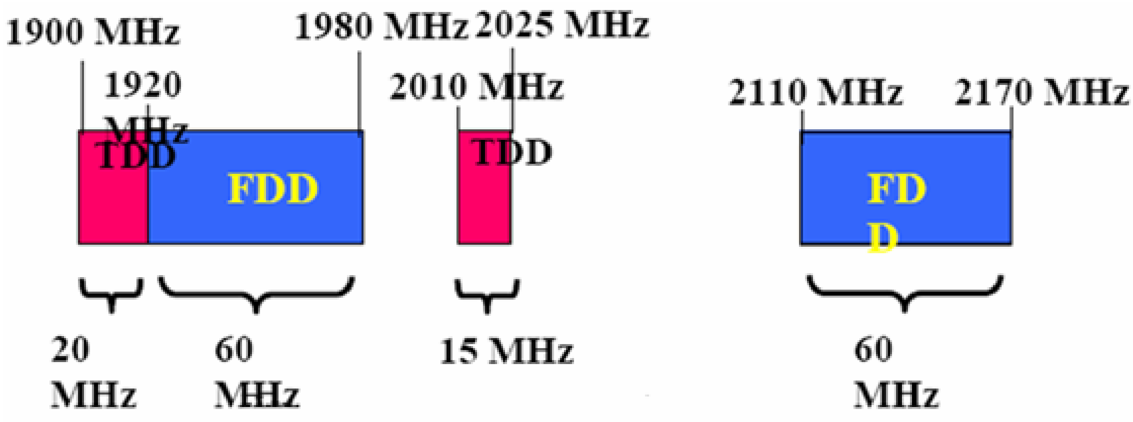


Fig.7.4 The allocation done for both modes

The physical layer L1 is divided in two sub-layers: the one of transport and the physics. First one is in charge of all the processing (macro-diversity, execution of the soft-handover, detection of errors in the transport channels and indication to the superior layers, coding/decoding and interleaving/desinterleaving of channels of transport, multiplexing/demultiplexing of channels composed of transport and mapping of transport channels in physical channels) to provide different services with different qualities of services QOS. Second one is in charge of the mapping of the bits coming from the transport sub-layer to electrical signals that can be transmitted on the air interface (multiplexed of data and control, modulation NRZ, series-parallel conversion, synchronization in frequency and time, measures and indication to higher layers FER, SIR, interference, etc., power control).

The L1 layer offers transport services of data to the higher layers by means of the transport channels. These services are offered through radio links, formed by one or several channels of transport and a physical channel that that is established by means of signaling links. The functions of the physical layer are made by the mobile and by the Node B (except the macro-diversity that is made by the RNC).

7.1.2 Physical Layer Services

7.1.2.1 Physical Sublevel Services

Related to the physical channels it is defined:

Radio frame: It lasts 10 ms (38400 Chips) and it is divided in 15 time intervals (slots). The duration of frame corresponds to a period of power control.

Slots or Intervals of time: Unit that takes fields of bits and that lasts 2/3 of ms that corresponds to 2560 Chips. Depending of the bit rate of the physical channel it varies the number of bits by slot.

Diverse types of physical channels exist, whose more important characteristics summary in the next figures.

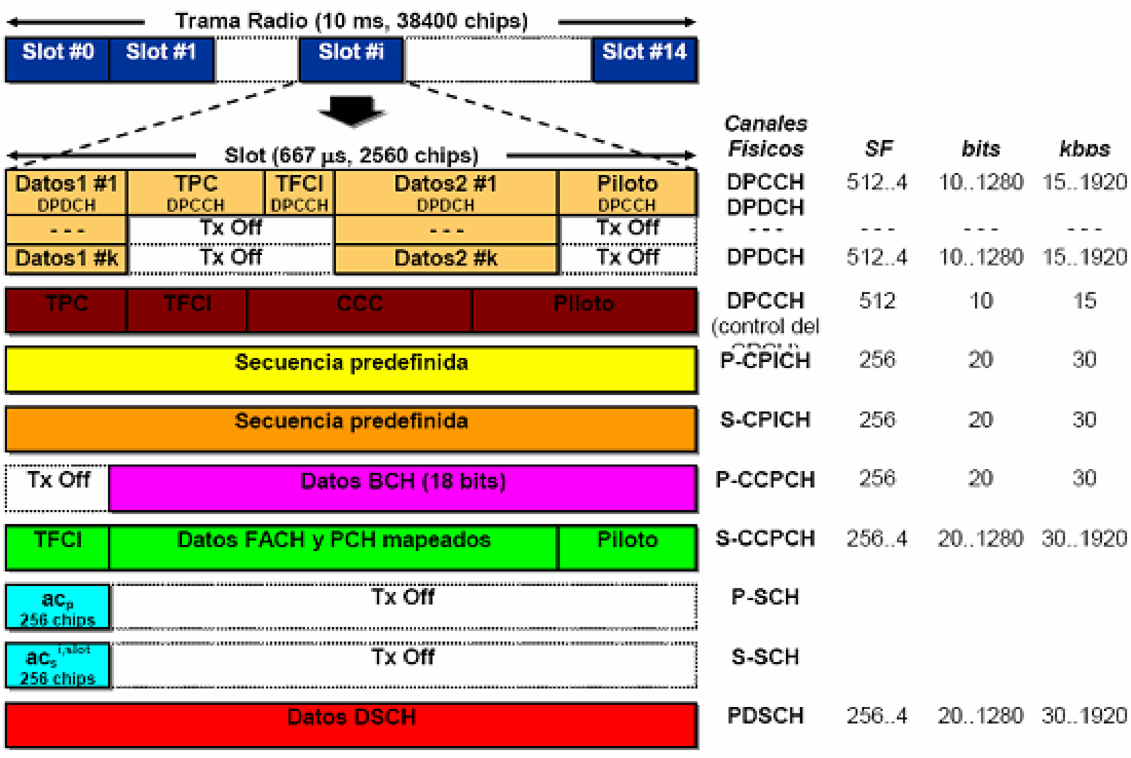


Fig.7.5 Frame structure of the Physical Channels in downlink.

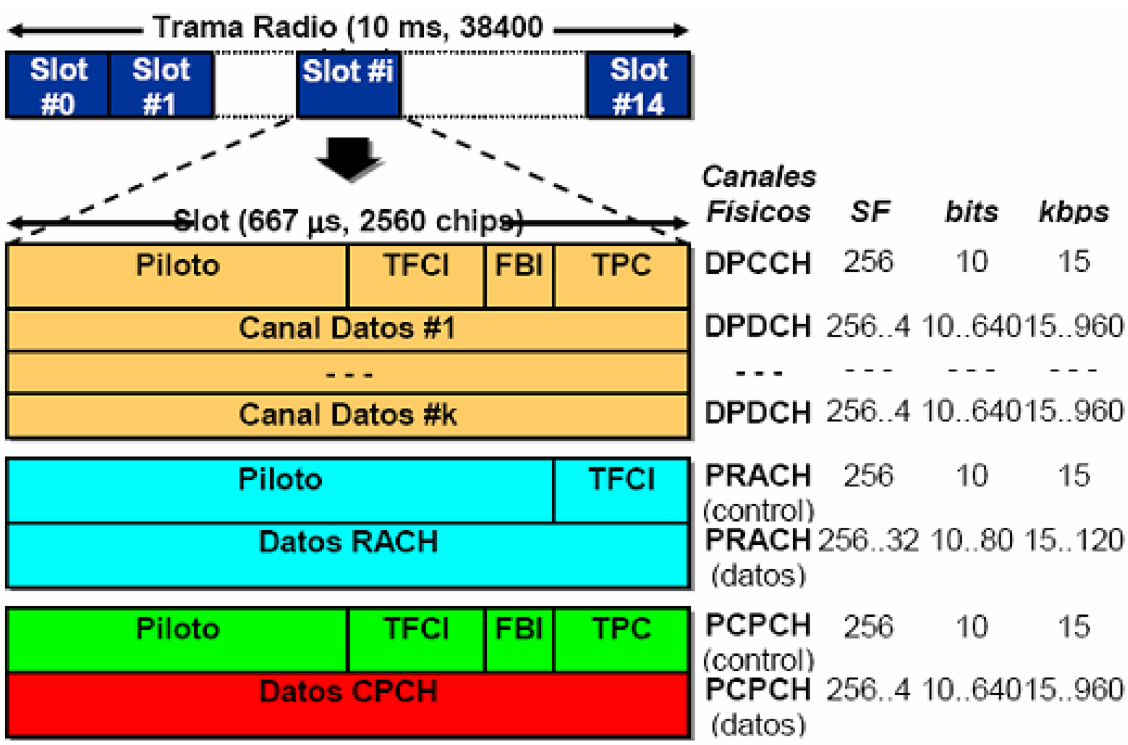


Fig.7.6 Frame structure of the Physical Channels in uplink.

The physical sublevel adds control bits to the data given by the transport sublevel (head of level 1) that are:

Bits of pilot: predefined sequence that serves to consider the channel and that allows confirming the frame synchronization. They are sent by the transmitter and the receiving one already knows them. With them it is possible to consider some characteristics of the channel.

Information of Feedback FBI: it is used in uplink and only in dedicated channels, and serves so that the UE indicates to Node B the quality of the link when the technique that uses this one requires feedback of the UE.

TPC Transmit Power Control: they are used by the emitter in the algorithm of power control and serves to indicate its increase or decrement.

The TFCI bits are added in the transport sublevel and they are explained in the following section.

7.1.3.Transport Sublevel Services

7.1.3.1. Definition of the services

The Physical layer offers transport services of data to the higher layers. The access to these services is made through the transport channels by means of sub-layer MAC. The unit of data that interchanges between the L1 layer and the MAC is denominates transport block. Typically a transport block corresponds to a PDU (protocol data unit) of MAC layer.

A UE can establish several channels of transport simultaneously, each one having their own characteristics of transport (different capacities from correction of errors). Each channel of transport can be used to transmit information of a radio carrier or information of signalling of layer 2 or higher layers.

All the channels of transport are unidirectional (uplink or downlink). This implies that a UE can have simultaneously one or several channels of transport in downlink, and one or more channels of transport in uplink.

The next definitions are necessary to understand the channels of transport.

- **Transport block:** unit of data that is interchanged between the layer MAC and the L1 layer for the processing of this one (adds the CRC to each block). Typically is corresponding with a PDU of the RLC layer. In fact it is equal to a PDU of the MAC layer.

- **Transport Block Set**: set of transport blocks that are interchanged during the same time interval of transmission (Time Interval Transmission TTI) using the same transport channel. When it is used segmentation in layer RLC corresponds to the different PDUs from a

SDU of layer RLC. The transport blocks are transmitted in the same order in which were received from layer RLC (if they come from the same logical channel). The blocks of transport of a same TBS have all the same size. The size of the TBS is denominates Transport Block Set Size and it is defined as the number of bits that there are in a TBS.

- **Time Interval Transmission (TTI)**: it corresponds to the time that passes between two consecutive transmissions of two sets of transport blocks. It is the period of interleaving for the TBS being a multiple of the minimum period of interleaving. It can be 10, 20, 40 or 80 ms (multiples of the duration of a frame radio) depending on the service (20 ms for the voice). Layer MAC gives a set of transport blocks to the physical layer each TTI.

- **Transport Format (TF):** it is defined as the format offered by the L1 layer to the MAC (and vice versa) for the transmission of a TBS during the TTI for a transport channel. The transport format is constituted on the one dynamic part and other static. The attributes of the dynamic part are:

    - Transport Block Size.
    - Transport Block Set Size.
    - Transmission Time Interval (optional attribute for TDD).

  The attributes of the semi-static part are:

  - Transmission Time Interval (mandatory for FDD, optional for the dynamic part of TDD).
  - Scheme of protection against errors:
    - Turbo code, convolutional code or no channel coding
    - Coding rate
    - Static rate matching parameter
  - CRC size.

- **Transport Format Set:** It is the set of formats that are defined for a transport channel allowing the possibility of changing the bit rate. The semi-static part of all the formats of transport of a same set is the same one. Both attributes of the dynamic part form the instantaneous bit rate of the transport channel. A variable rate in the transport channel, depending on the service that is mapped in the transport channel, can be obtained varying:
    - Transport Block Set Size only
    - Or both Transport Block Size and the Transport Block Set Size

- **Combination of Transport Formats:** Layer 1 multiplexes one or several channels of transport and for each channel of transport exists a list of set of formats of transport channels that are applicable. At a certain moment of time all the combinations in the physical layer cannot be used, only a subgroup denominated transport formats combination. It is defined as an authorized combination of valid transport formats that they can be sent simultaneously to the physical layer for the transmission of a codified channel transport of a UE, it containing a format of transport for each channel.

7.1.3.2. Types of Transport Channels

Two types of transport channels exist: common and dedicated. The difference among them is that the first are characterized for be a distributed resource between a user group in a cell (they use explicit addressing) whereas the dedicated ones are dedicated resources, identified by a code and a certain frequency (inherent addressing to the UE).

Dedicated Transport Channel

A dedicated transport channel denominated DCH (Dedicated Channel) for the Release99 only exists. It is used to transport all the information related with the higher layers (data and signalling of the higher layers) in circuit switch (for packet switching several can be used). It is characterized by:

- Bidirectional Channel (UL and DL)
- Can be transmitted over all or part of a cell using adaptive antennas
- It admits fast Power Control in closed loop (1500 Hz of maximum frequency of Power Control, resultant to send a command by interval)
- Soft-Handover supports
- Possibility of using synchronization in the uplink
- Possibility of changing the bit rate of fast form of one frame to other (each 10 ms)

Commons Transport Channels

There are currently six different common transport channel types defined for UTRA: BCH, FACH, PCH, RACH, CPCH and DSCH. They do not have soft-handover, although some of them can have fast power control.

Broadcast Channel (BCH)

It is a downlink transport channel that is used to spread information of the UTRA system and the concrete cell. The information more typical than is transmitted by this channel are the codes and slots of access in the cell, the types of methods of diversity of transmission used by the channels in the cell, etc... As the terminals cannot be registered in the network if they cannot decode this channel must be transmitted with an elevated power in the entire cell to reach all the zone of cover. The bit rate of this channel is limited by the capacity of terminals of low speed of decode, it what is in a channel of low and fixes rate. It has a simple transport format.

Forward Access Channel (FACH)

It is a downlink transport channel that is used to transport information of control to the terminals located in a determinate cell (it transmits small amounts of data and it is used to respond for example to a random access, to give relative information and traffic information to a service). It is transmitted in the entire cell, or in part of its using adaptive antennas. Its bit rate is low so that it can be decoded by all the terminals in the cell. A slow power control in this channel can be used although it is not possible to use the fast. Its rate from a frame to another one can change, and can have more of a channel FACH in the cell (in this case successive channels FACH can have a greater bit rate). The transmitted messages in this channel must use identification to allow their correct reception.

Paging Channel (PCH)

It is a downlink transport channel that is used to transmit all the information related with the procedure of paging (when the network wishes to contact with the terminal). The terminals must receive the information of paging in the entire cell. The design of the paging channel affects to the consumption of power of the terminal in the standby mode (if the terminal listens this channel little, its battery will last much).

Random Access Channel (RACH)

It is an uplink transport channel that is used to transport control information from the terminal (to ask the establishment of a connection). It can be used to send small amounts of data packages from the terminal to the network. This channel must be listened by the base station from any point of the cover area, reason why the data rate must be low. The field data is limited and it is characterized to support power control in open loop and to be submitted to collisions.

Common Packet Channel (CPCH)

It is an uplink transport channel that is used to transport traffic bursts. This channel is associated to a dedicated channel in downlink that provides the power control and the commands of control for this channel. It is characterized by an initial collision and it can be transmitted with the fast power control in the message. In the preamble and its increase the power control in open loop can be used. It is transmitted in the entire cell or in part of it using adaptive antennas. It offers the possibility of changing the bit rate from a frame to another one.

Downlink Shared Channel (DSCH)

It is a downlink transport channel that is used is used to transport dedicated data of user and information of control that can be shared by several users. This channel is associated to one or several DCHs in the FDD mode (in TDD is possible to associate it to the FACH). It supports fast and slow power control when is associate to a dedicated channel. It is possible to be transmitted on the entire cell or part of it using adaptive antennas. It offers the possibility of varying its bit rate from a frame to another one.

The channels RACH, FACH, BCH and PCH are mandatory for the operation of the network, whereas the DSCH and the CPCH are optional.

7.1.4 Physical Layer Functions

7.1.4.1 Physical Sublevel Functions

1. - *Processing of the physical channels*

Each channel has a different processing. This it consists in the following steps that are made at time slot level:

1. Multiplexed in time of the data and bits of control. The data bits come from the transport sub-layer, whereas the bits control are signalling of the physical layer (forward and feedback control bits). This step is made in downlink, because in uplink they are sent in parallel.
2. NRZ modulation. It consists in associating a signal in baseband to the information in bits that comes from the previous step.
3. Serial-parallel conversion. It is used in the downlink in all the channels (except in the SCH) in order to associate each pair of consecutive symbols in the “I” or “Q”.

4. Spreading signal. It is consists in the channelisation and scrambling processes.

5. Multiplexed of physical channels. It is the sum of the contributions of each one of the channels. In uplink it is only used for channels DPDCHs and DPCCH.

6. Analogical modulation. It is consists in to transfer the signal to a frequency around the 2 Ghz for its transmission to the air.

2. – *Measures*

It is in charge to make measures and to give instructions of the same ones to the higher layers. Among these measures it is possible to emphasize the blocks error rate BLER of the transport channel, the power received in a code CPICH RSCP (received signal code power) and the SIR (signal interference ratio).

3. - *Open Loop Power Control*

In the figure it is observed that the users who are located to different distances from the station base, having therefore different losses of propagation. If all emit with the same power, the signals of the nearest emitters would arrive at the station bases with more power than those of the distant ones, being these last ones masked, therefore it would make worse its reception although they would not be eliminated. This effect is known it with the name of Near-Far Effect.

Fig.7.7 Near-Far Effect

In order to solve this problem it is precise to use technical of power control, so that all the signals arrive at the station bases with the same level of power. This is obtains causing that each user emits with a different power based on his distance, conditions of propagation and occupation of the system. When using power control, is reduced the interference and therefore the total capacity of the system is maximized and in addition the consumption of the mobile terminals that are more near the station bases is reduced. The power control must have three characteristics: exactitude (of the order of 1 dB), rapidity to compensate the fading, and a great dynamic range to control near and remote mobiles. The different methods of power control will be seen in next chapters.

4. - *Synchronization of frame and frequency*

The synchronization is obtained "adding" to the synchronism bits that emit the system through of SCH channel. In addition the system can remain synchronous thanks to the feedback, which is made not to lose the synchronism. In the downlink is possible to send a signal so that the mobile receivers are synchronous in reception.

7.1.4.2 Transport sublevel Functions

The data arrive once at the transport sublevel in form of blocks of transport by each interval of transmission. This one depends of the channel of specific transport and can take values from 10, 20, 40 or 80 ms. In the figure is the processing of the channels of transport in UL as in DL.

Addition of the CRC: CRC (Cyclic Redundancy Check) is formed by a set of bits that are added to the block of transport with object to detect possible errors. The size of the CRC can be of 24, 16, 12, 8 bits, and their size are indicated by the higher layers to the physical layer for each transport channel.

Concatenation of the transport blocks and Segmentation of the bocks: concatenation is used when more of a transport block is sent by the higher layer in the same channel of transport during a TTI. The concatenation function places together all the bits corresponding to the same one.

Channel coding: The intention of the channel coding is to protect the information against the disturbances of the channel (noise, interferences, multipropagation, etc...) to improve the quality of the transmission. It consists of adding redundancy bits (the number of bits is multiplied by 2 or 3) to the bits of the source. Depending of the required QoS in terms of BER and delay, different schemes of coding are used. The encoding schemes that are used are: convolutional, turbo coding and not to use codification. The convolutional codification is simpler that the turbo coding and presents smaller processes delay although it offers worse protection than the turbo coding. The use of each scheme and rate of encoding for the different transport channels is in the following table.

Table.7.2 Channel Coding

Channel Transport	Coding	Encoding Rate
BCH	Convolutional	1/2
PCH		
RACH		
CPCH, DCH, DSCH, FACH		1/3, 1/2
	Turbo Coding	1/3
	Without Encoding	

Equalization of the radio frame: The equalization of the radio frame consists in filling up the sequence of entrance bits to assure that the exit can be segmented in an integral number of segments of data of the same size in the segmentation block of the frame radio. It is made only in the uplink, since in downlink the block of adaptation of speed is in this point of the chain and it already provides to its exit an integral multiple of segments of data.

First interleaving: It consists in to spread the bits of all the radio frames that correspond to a TTI to improve the quality of the transmission. If happens an error in the transmission the losses are distributed between all the frames and the correction is better. This interlace is made only in the bits that correspond to the same channel of transport.

Segmentation of the radio frame: when the transmission interval is superior to 10 ms (the frame size), the sequence of entrance bits is segmented and associated to consecutive radio frames.

Rate matching adaptation: it serves to adapt the original binary speed of the transport channels at the binary speed of the physical channels. Thus, the bits of the transport channels are repeated (repetition) or they are eliminated of selective form (puncturing). The adaptation of speed is semi static and if is necessary to make it or no, it comes indicated by higher levels. The idea is that all the physical channels (except the CCPCH) offer the possibility of supporting different binary rates changing the spreading factor SF. Then will be to choose the SF that allows obtaining the binary rate of data that is almost equal as the requirements of the transport channel and diminishes the interference. In general it will be the greater SF possible that it will allow the smaller binary rate.

Multiplexed of the transport channels: the encoding transport channels are multiplexed in series, or that it is the same, in the time, over a radio frame. Thus, each 10 ms a radio frame coming from each one of the transport channels, it will enter the block of multiplexed.

Insertion of the indication bits of discontinuous transmission (DTX): the bits of indication of discontinuous transmission are not transmitted, they only indicate when the transmission must be interrupt, and only in the downlink. The higher levels decide if the bits of indication DTX are inserted in fixed or flexible positions. In the first insertion of the indication bits DTX, these they are inserted in fixed positions, so that in each radio frame a fixed number of bits for each transport channel are reserved.

Segmentation of the physical channels: when is used more of one physical channel, is in this block where are divided the bits between the different physical channels.
Mapping to physical channels: the bits are associated to the physical channels so that for each physical channel the bits are transmitted in ascending order. The mapping between the different types of physical channels and transport channels are showed in the following figure.

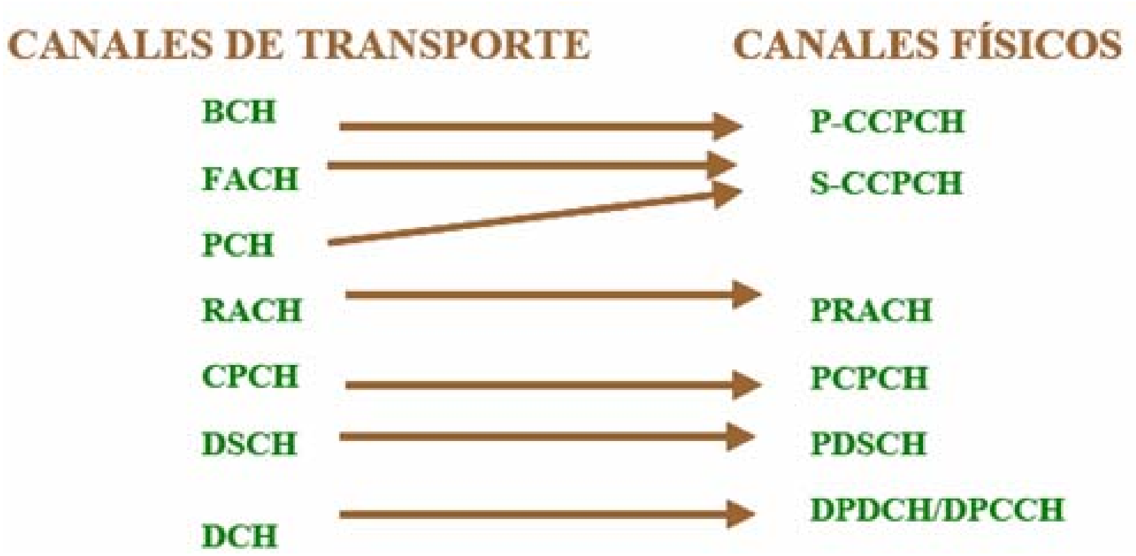


Fig.7.8 Mapping of the transport channels to physical channels

7.2 MAC Layer

In the Medium Access Control (MAC) layer the logical channels are mapped to the transport channels. The MAC layer is also responsible for selecting an appropriate transport format (TF) for each transport channel depending on the instantaneous source rate(s) of the logical channels. The transport format is selected with respect to the transport format combination set (TFCS) which is defined by the admission control for each connection.

The MAC layer is described from entities MAC. The logical entities are the following ones:

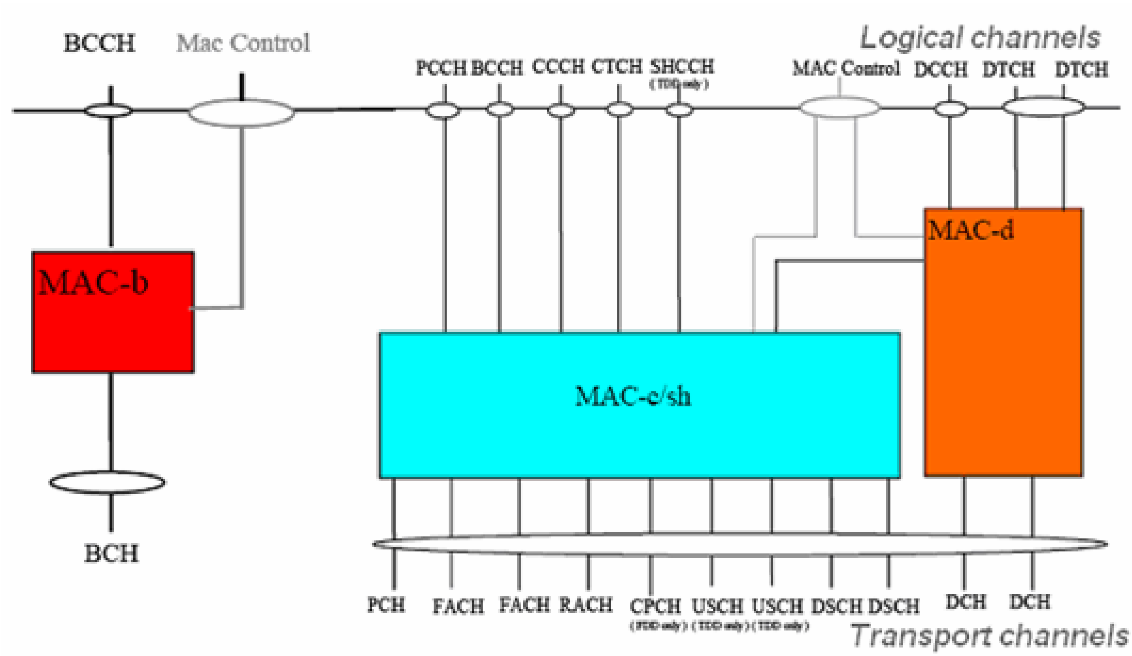


Fig.7.9 MAC layer architecture

MAC-b: Entity that handles the broadcast channel (BCH). There is an entity in UE and one by each UTRAN cell (is located in Node B). The access point to the control service of the MAC layer is used to transfer information of control to the MAC-b.

MSC-c/sh: Entity that handles the following commons transport channels PCH, FACH, RACH, and the shared CPCH (only FDD), DSCH and USCH (only TDD). There is a unique MAC-c/sh entity in each mobile and one unique MAC-c/sh entity in each UTRAN cell.

MAC-d: Entity that handles the transport channels DCH. There is a unique MAC-d entity in each mobile and a unique MAC-d entity in the UTRAN for each UE that has one or more dedicated logical channels towards or from the UTRAN.

Each one of these three entities is acceded from RLC layer using the logical channels and interchanges the data with the physical layer by means of the transport channels. This sub-layer is connected to RRC layer by means of the SAPS of control. These access points to the service are used by RRC layer to configure the MAC for the procedures of data transfer and measures.

7.2.1 Functions of the MAC layer

The functions of the MAC layer include:

- **Mapping between logical channels and transport channels.**

Table.7.3 The mapping between the logical channels and of transport:

Channel	Connected to
BCCH	BCH, it can to FACH
PCCH	PCH
CCCH	RACH and FACH
SHCCH	RACH, USCH/FACH and DSCH
DTCH	RACH and FACH, CPCH and FACH, RACH and DSCH, DCH and DSCH, or DCH and DCH
CTCH	FACH
DCCH	RACH and FACH, CPCH and FACH, RACH and DSCH, DCH and DSCH, or DCH and DCH

- **Selection of appropriate Transport Format (from the Transport Format Combination Set) for each Transport Channel, depending on the instantaneous source rate.**

- **Priority handling between data flows of one UE**. The priorities come given by the attributes of the services of the radio carriers, and by the state of the buffer of the RLC. It is obtained selecting transport formats in which data of high priority are mapped in the physical layer in a format of high speed, whereas for data of low priority, formats of low speed are used.

- **Priority handling between UEs by means of dynamic scheduling.** A dynamic scheduling function may be applied for common and shared downlink transport channels FACH and DSCH.

- **Identification of UEs on common transport channels.** When a common transport channel (FACH, RACH or CPCH) carries data from dedicated logical channels (DCCH, DTCH) it is necessary to identify to the UEs which obtains by means of the Cell Radio Network Temporary Identity (C-RNTI) or UTRAN Radio Network Temporary Identity (U-RNTI) in the head of the MAC-PDUs (fields UE-id and UE-type).

- **Multiplexing/demultiplexing of higher layer PDUs into/from transport blocks delivered to/from the physical layer on common transport channels.** Layer MAC handles the multiplexing of services for common channels RACH/FACH/CPCH. This is necessary, since the physical layer cannot carry out this multiplexing. It is obtained by means of field C/T and TCTF of the head.

- **Multiplexing/demultiplexing of higher layer PDUs into/from transport block sets delivered to/from the physical layer on dedicated transport channels.** Layer MAC allows services multiplexing with the same QoS parameters for the dedicated channels. It is obtained by means of field C/T and TCTF of the head.

- **Traffic volume monitoring**. MAC receives RLC PDUs together with status information on the amount of data in the RLC transmission buffer. MAC compares the amount of data corresponding to a transport channel with the thresholds set by RRC. If the amount of data is too high or too low, MAC sends a measurement report on traffic volume status to RRC.

- **Dynamic Transport Channel type switching**. Execution of the switching between common and dedicated transport channels is based on a switching decision derived by RRC.

- **Ciphering**. If a radio bearer is using transparent RLC mode, ciphering is performed in the MAC sub-layer (MAC-d entity). Ciphering is a XOR operation where data is XORed with a ciphering mask produced by a ciphering algorithm. The ciphering algorithm and the keys are generated for the RRC layer.

- **Acces Service Class (ASC) selection for RACH transmission**. The PRACH resources may be divided between different Access Service Classes in order to provide different priorities of RACH usage. Maximum number of ASCs is 8. MAC indicates the ASC associated with a PDU to the physical layer.

7.2.2 Logical Channels

The data transfer services of the MAC layer are provided on logical channels. A set of logical channels types is defined for the different kinds of data transfer service offered by MAC. A general classification of logical channels is into two groups: Control Channels and Traffic Channels. Control Channels are used to transfer control plane information, and Traffic Channels for user plane information:

The Control Channels are:

Broadcast Control Channel (BCCH)

It is a downlink channel that spreads all the messages of information of the system. In the messages of information of the system all the parameters of the same one like the identity of the network and the cell, the Maxim power to accede to the system, information of the frequency are transmitted, etc...

Paging Control Channel (PCCH)

It is a downlink channel that transfers information of paging. This channel is used by the network to reach one or several UEs when it does not know its location or finds in the states Cell_FACH and UTRA_PCH of the connected mode.

Common Control Channel (CCCH)

It is a bidirectional channel for the transmission of control information between the network and the UEs. It is used to send request messages of RRC connections and update of UTRA and cell. The moving body uses it whenever it is not known by the network or the cell.

Dedicated Control Channel (DCCH)

It is a bidirectional channel that transmits information of dedicated signalling of control between a UE and the network. This channel is used after establishing a RRC connection (the mobile has received a temporary identification). It is used in procedures of handovers Inter-frequency, dedicated paging, update of the activate-set and control and report of measures.

Shared Channel Control Channel (SHCCH)

It is a bidirectional channel that transmits information of control for the shared channels in UL and DL between the network and the UEs. This channel is only for TDD mode.

The Traffic Channels are:

Dedicated Traffic Channel (DTCH)

It is a dedicated point-to-point channel UL/DL for the transfer of user information (voice, data by circuits or packages switching) between a UE and the network.

Common Traffic Channel (CTCH)

It is a point-to-multipoint unidirectional channel for the transference of information for all or a group of specific UE. It is used to transmit messages BMC (services offered by the operator like the information of the weather, traffic, location, etc...).

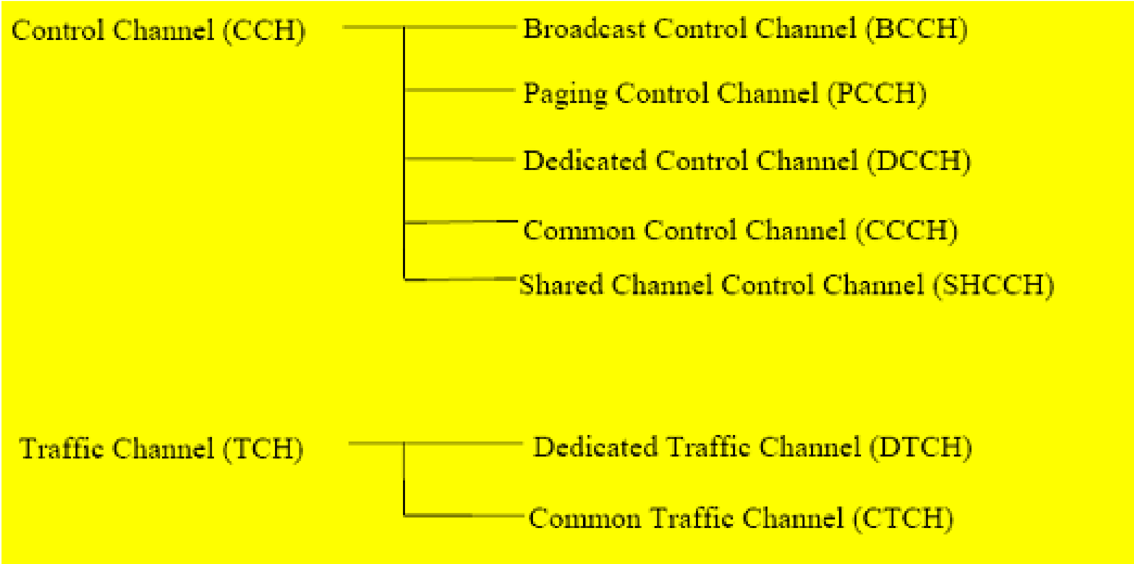


Fig.7.10 Logical Channels

7.3 RLC Layer

7.3.1. RLC Layer Architecture

Radio Link Protocol provides segmentation and retransmission, concatenation, padding, error detection and correction, transfer of user data, duplicate detection, flow control, ciphering, sequence number check and suspend/resume services for the control and user data. Each RLC instance is configured by Radio resource controller (RRC).
The RLC layer architecture is formed by three entities: Transparent Mode entity TM, Unacknowledged Mode entity UM and Acknowledged Mode entity AM. This layer is formed by two parts: a transmitter and another receiving one that is in the control and user planes. In the modes TM and UM there is a transmitting entity and another receiving one whereas in the AM there is a single entity that is transmitting and receiving. In this last case the protocol data unit PDU with information of control and data in separated logical channels can be sent. The services that layer RLC offers to the higher ones are know with the name of radio carrier (signalling or data). Layer RLC notifies the non-recoverable errors, for which in all the modes the physical layer calculates the CRC and notifies to the RLC the result of the verification.

7.3.1.1 Services and functions of the Transparent Mode TM of the RLC layer

In this mode a data transfer service is provided in which are transmitted the PDUs of the higher layers without adding no head to them. To this service is acceded through the access point to the transparent service Tr-SAP. Optionally the functions of segmentation and reassembling are provided that must be negotiated in the establishment of the radio carrier. The segmentation function divides a RLC SDU in several which are fit in the size of TMD PDU (unit of data of RLC protocol in Transparent Mode). All the TMD PDUs pertaining to a RLC

SDU are sent in the same TTI and no segment of another SDU RLC is sent. If segmentation is not used then several RLC SDUs in a TTI can be sent placing them each one in a TMD PDU. All the TMD PDUs must be of the same size. The concatenation consists in reassembling all the received TMD PDUs in a same TTI. The RLC PDUs are sent to the MAC layer through channels BCCH, CCCH (only UL), DCCH, PCCH and SCCH in the control plane and by the DTCH in the user plane. This operation mode usually is used with services of type streaming like the voice.

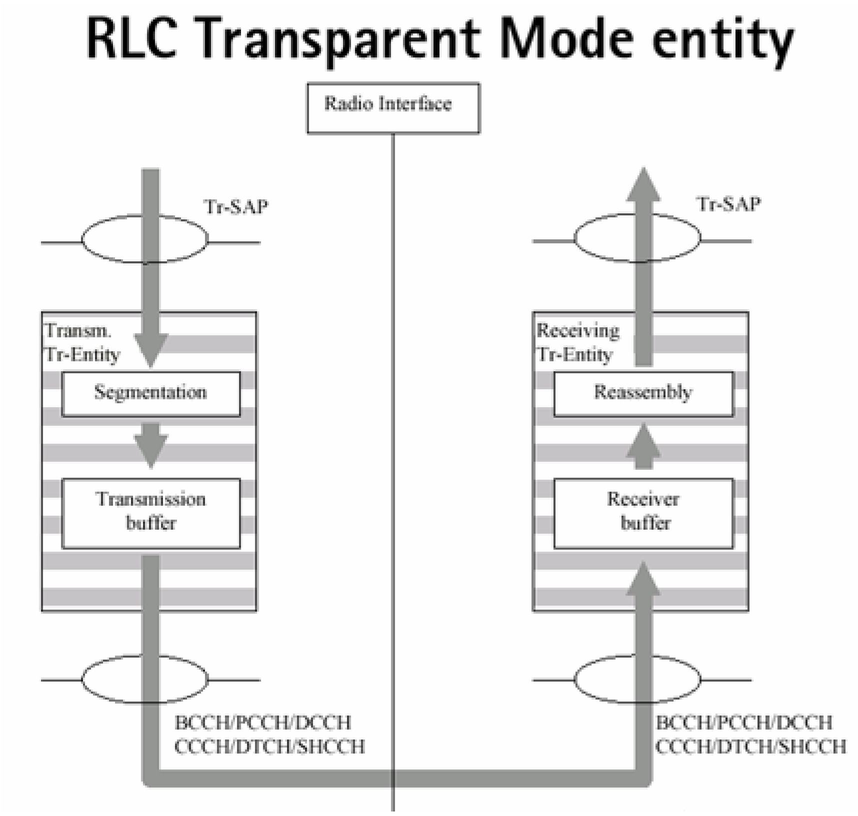


Fig.7.11 RLC Transparent Mode Entity

7.3.1.2. Services and functions of the Unacknowledged Mode entity UM of the RLC layer

To this service is acceded through the access point to the transparent service UM-SAP. This service is similar to the previous one since it is not has any protocol of retransmission with which the delivery of the data is not guaranteed. The segmentation function goes accompanied of other functions that are the concatenation and padding. If the size of RLC SDU does not adjust to a integral number of UMD PDUs (unit of data of protocol RLC in mode without confirmation) the last segment of a PDU RLC with the first segment of the following one can be concatenated. If it cannot be applied to the concatenation and the size of RLC SDU not it fits to the PDU then can insert filling bits. In order to provide this functionality a field in the head UMD PDU named indicating of length is used. Another function that is applied in this mode is the detection of errors by means of the verification of another field that are included in the head denominated number of sequence. If a PDU is erroneous they are discard all those SDUs that are included in the same. A function of ciphered and deciphered of the data (the head takes off) is also provided. The RLC PDUs are sent to MAC layer through channels CCCH (only DL), DCCH and SCCH in the plane of control and by DTCH and CTCH in the user plane. This operation mode usually is used with services of type diffusion in cells and Voice/IP. In figure are the functions to provide this service.

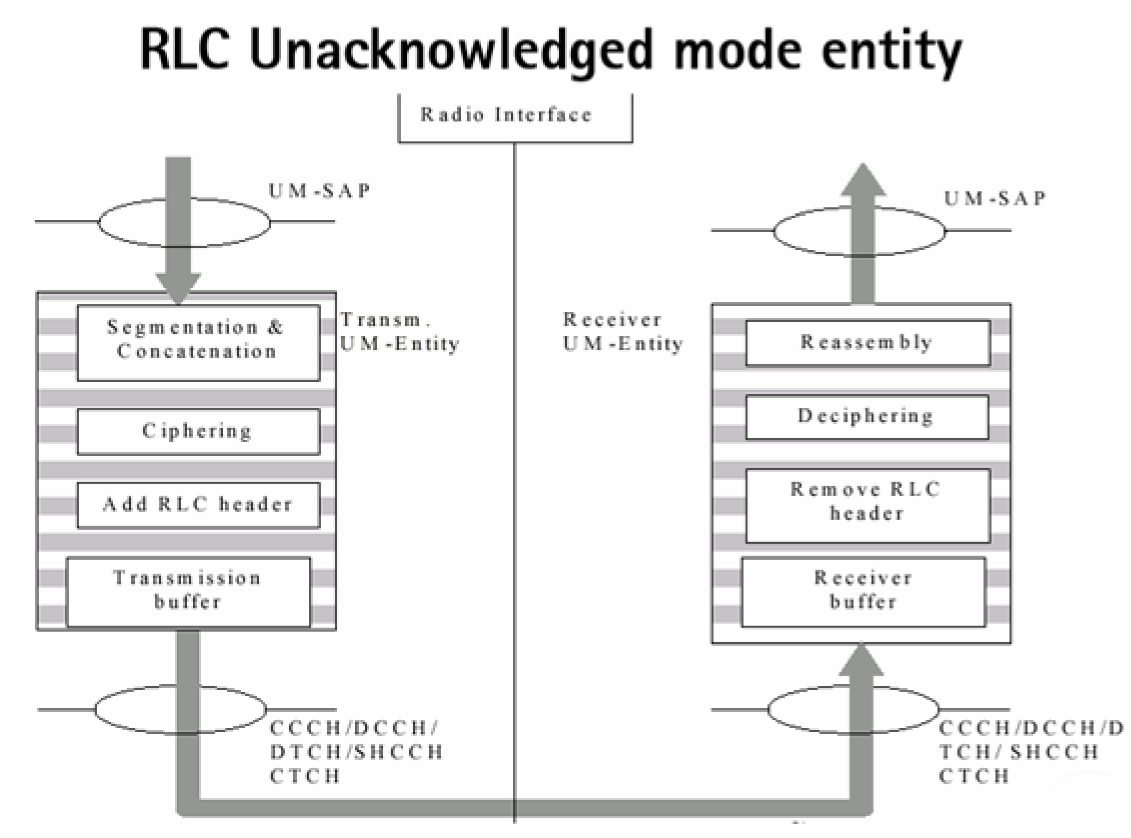


Fig.7.12 RLC Unacknowledged Mode Entity

7.3.1.3. Services and functions of the Acknowledged Mode entity AM of the RLC layer

To this service is acceded through the access point to the transparent service AM-SAP. It uses a request mechanism of automatic retransmission ARQ providing the functionality of errors correction. Just as in the previous mode the segmentation function it goes accompanied of other functions that are the concatenation and padding. RLC SDU is concatenated or it is segmented in payload units PU of fixed size that they are fixed when a radio carrier is established by part of the RRC. In order to provide this functionality a field in the head of denominated UMD PDU indicating of length is used. This it can also indicate in this case the inclusion in the data of the STATUS PDU, allowing the function of piggybacking. In this mode the RLC can be configured to provide the function of delivery in order by means which it preserves the order of the PDUs or the delivery outside order that gives to the PDUs as soon as these are received. Also are allowed the functions of flow control and duplicates detection.

The PDUs is stored in a buffer and passes to the MUX where depending on the STATUS PDU is determines when they are given to MAC layer. Also there are functions of encipherment/decipherment. This operation mode usually is used with services of type package like email or Internet. In figure are the functions to provide this service.

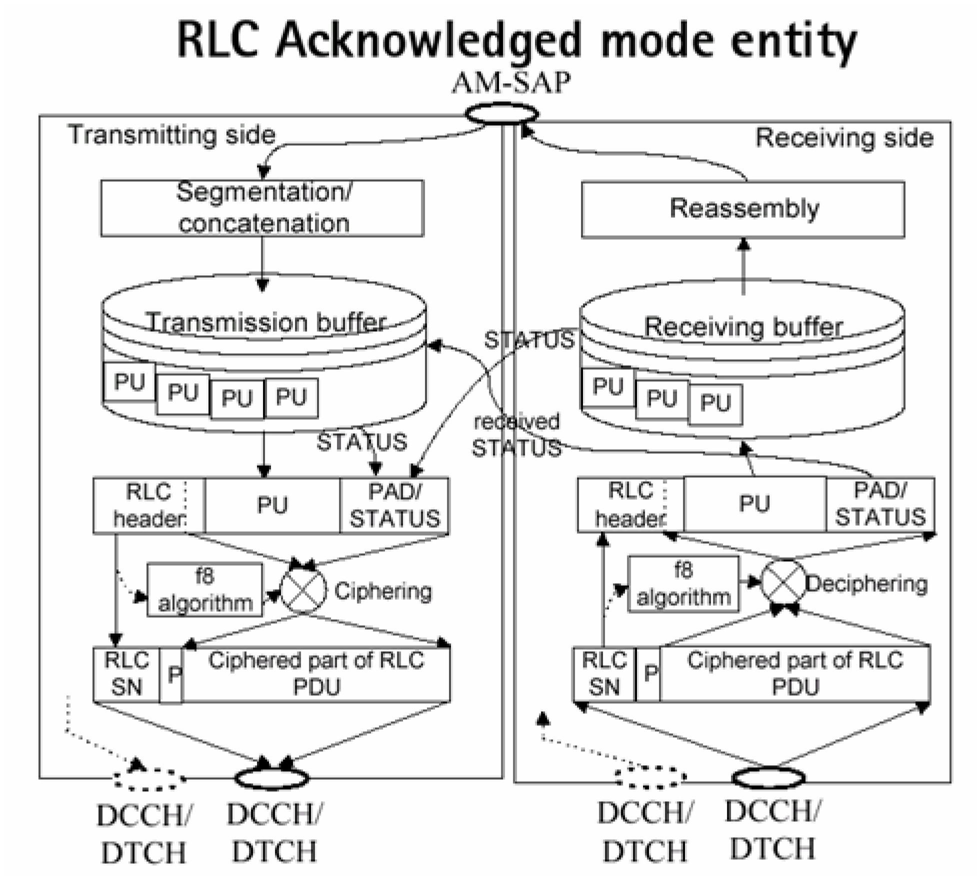


Fig.7.13 RLC Acknowledged Mode Entity

7.4 BMC Layer

7.4.1 BMC Layer Architecture

In the figure is showed the architecture of the Broadcast/Multicast Control Protocol (BMC) layer. The BMC Protocol exists only in the user plane. It is located on RLC layer but is considered part of level 2. It uses the UM service of the RLC for the transference of the broadcast messages of cell CB. The RLC transfers these messages using the combination CTCH/FACH. There is a BMC entity in the UE and one in the RNC by each cell which allows the programming of the messages of separated form in each one of them. The Layer BMC provides a service of data broadcast/multicast transmission common in the user plane of the Radio Interface in a mode without acknowledge.

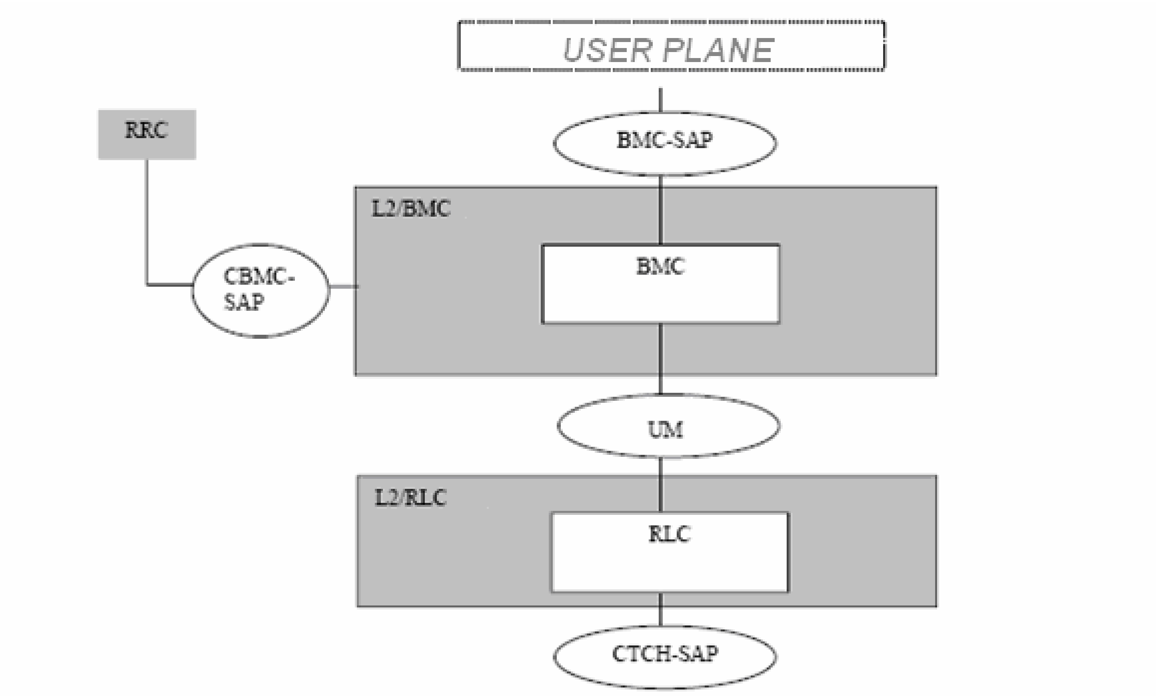


Fig.7.14 The BMC layer architecture

7.4.2. BMC layer Functions

The main functions of the BMC protocol are:

Storage of Cell Broadcast messages. The BMC in RNC stores the Cell Broadcast messages received over the CBC-RNC interface for scheduled transmission.

Traffic volume monitoring and radio resource request for CBS. On the UTRAN side, the BMC calculates the required transmission rate for the Cell Broadcast Service based on the messages received over the CBC-RNC interface, and requests appropriate CTCH/FACH resources from RRC.

Scheduling of BMC messages. The BMC receives scheduling information together with each Cell Broadcast message over the CBC-RNC interface. Based on this scheduling information, on the UTRAN side the BMC generates schedule messages and schedules BMC messages sequences accordingly.

Transmission of BMC messages to UE. This function transmits the BMC messages (Scheduling and Cell Broadcast messages) according to the schedule.

Delivery of Cell Broadcast messages to the upper layer. This UE function delivers the received non-corrupted cell Broadcast messages to the upper layer.

7.5. PDPC LAYER

7.5.1. PDPC Layer Architecture

The Packet Data Convergence Protocol PDCP exists only in the user plane and only for services from the PS domain. The PDCP contains compression methods, wich are needed to get better spectral efficiency for services requiring IP packets to be transmitted over the radio. For 3GPP Release-99 standards, a header compression method is defined, for which several header compression algorithms can be used. As an example of why header compression is valuable, the size of the combined RTP/UDP/IP headers is at least 40 bytes for IPv4 and at last 60 bytes for IPv6, while the payload, for example for IP voice service, can be about 20 bytes or less.

The PDPC has access to the services in the three modes of the RLC: TM, UM and AM. For the released-99 there is a correspondence one to one between PDPC-SAPs and the RLC-SAPs.

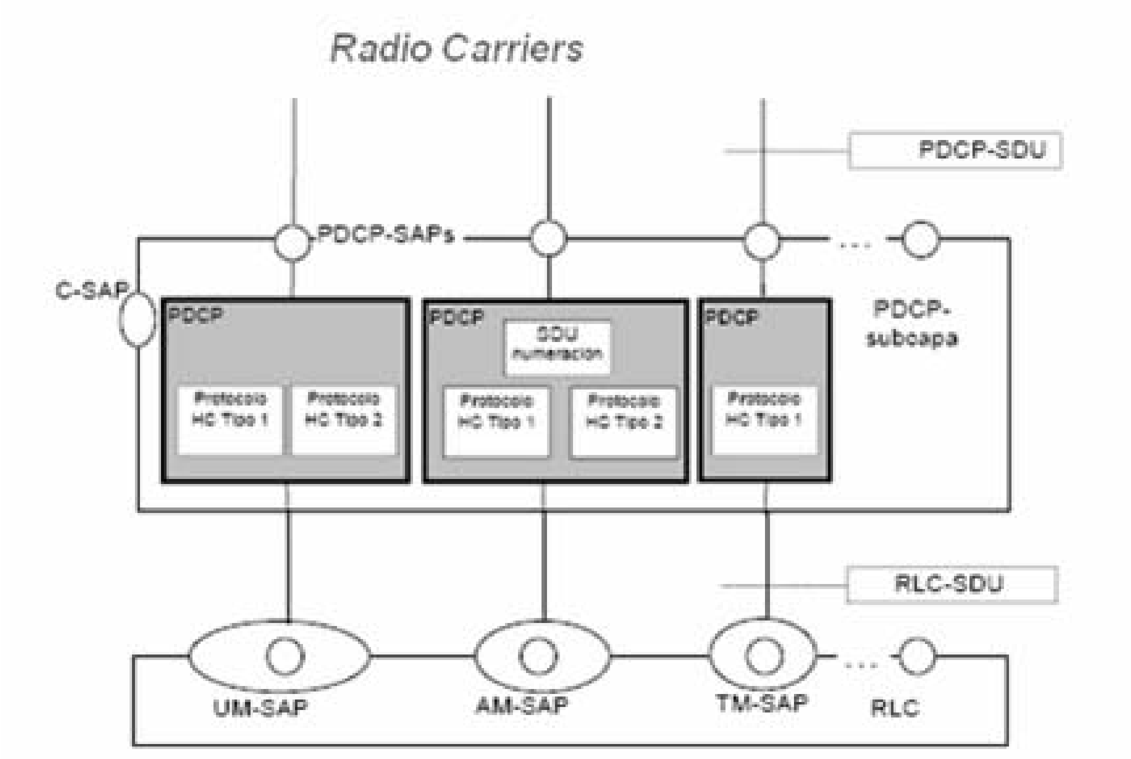


Fig.7.15 The PDPC Layer architecture

7.5.2. PDPC Layer Services

It provides a service of data transfer using compression of heads to improve the efficiency in the radio channel.

7.5.3. PDPC Layer Functions

- Compression of redundant protocol control information (e.g. TCP/IP and RTP/UDP/IP headers) at the transmitting entity, and decompression at the receiving entity.

- Transfer of user data.

- Hold of the numbers of sequence PDPC for the radio carriers that are configured to support losses in a change of SRNS.

7.6. RRC Layer

7.6.1. RRC Layer Architecture

The RRC transports all the signalling of the higher layers, mobility control MM, calls control CC and sessions control SM, thus as the mobility of the UE in connected mode (handovers, measures, etc...). In the figure is the RRC layer architecture.

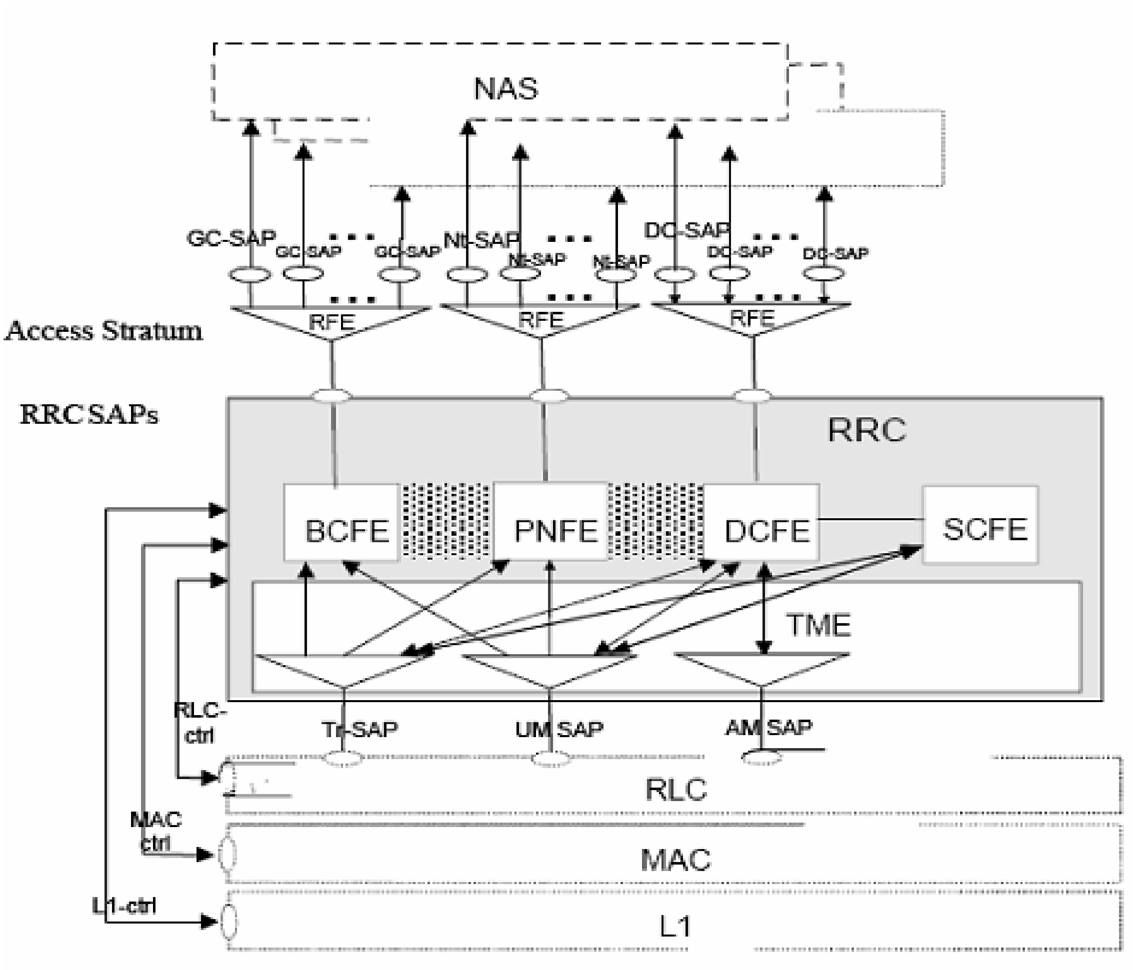


Fig.7.16 RRC Layer Architecture

The entities that form part of the RRC layer architecture are:

Routing Functional Entity (RFE). it assures the correct routing of the information from or towards the NAS. Of this form the messages of different entities of the higher layer or different dominions of core network are routing correctly.

Broadcast Control Functional Entity (BCFE). It handles the diffusion of the information of the system. There is at least one BCFE by each cell in the RNC. It uses logical channels BCCH and FACH through the transparent SAPs.

Paging and Notification Functional Entity (PNFE). It handles the paging and the notifications when the UEs are locate in idle mode (without having a RRC connection with the network). In the UTRAN there is a PNFE by each cell in the RNC. It uses the logical channel PCCH through a transparent SAP of the RLC layer.

Dedicated Control Functional Entity (DCFE). It handles to all the functions and specific signaling of a UE when it is in connected mode. In the SRNC there is one DCFE entity for each UE having an RRC connection with this RNC. DCFE uses mostly acknowledge mode RLC (AM-SAP), but some messages are sent using unacknowledged mode SAP (e.g. RRC Connection Release) or transparent SAP (e.g. Cell Update).

7.6.2. RRC Service States

In the figure are showed the states and the possible transitions in which a multimode terminal can be found.

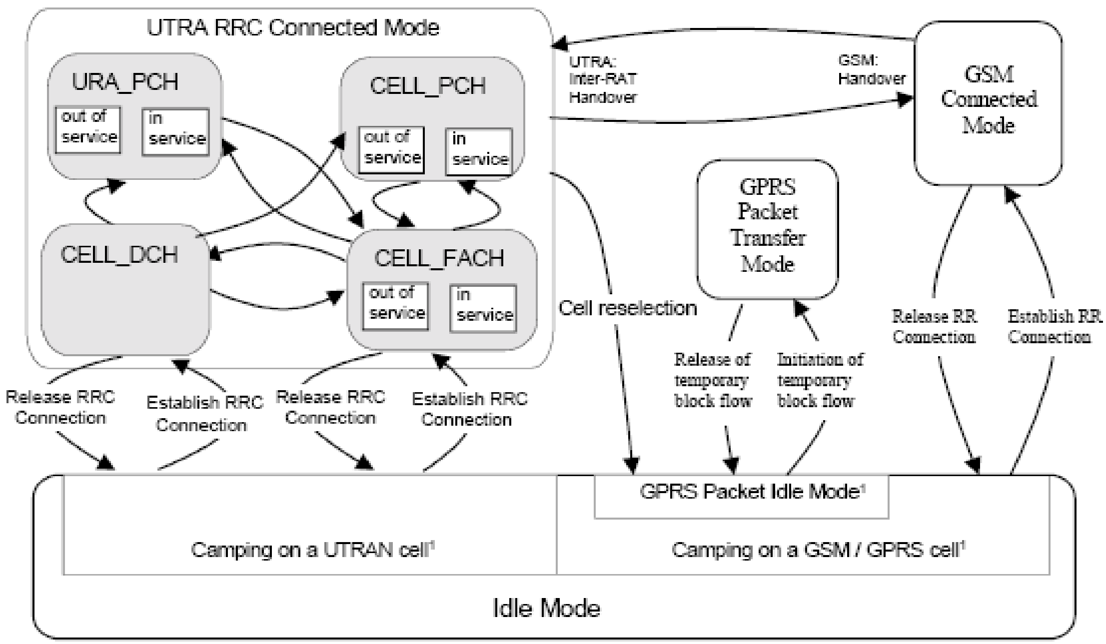


Fig.7.17 RRC Services States

In the systems of second generation two levels of connection only exist: connected mode and idle mode. In UMTS depending on the activity of the UE other modes are defined. In principle when a UE is connected makes a selection of cell and occupy in the same one being in idle mode. When it establishes a RRC connection pass to the connected mode. Several states are defined depending on the level of connection and the transport channels that can be used:

Cell_DCH state. In this state the UE has assigned a physical channel in uplink and another one in downlink. At this state it is possible to be arrived after establishing a connection or when a physical channel is assigned to a UE in Cell_FACH. When the physical channels are released the UE returns to the Cell_FACH state.

Cell_FACH state. The UE does not have a dedicated resource assigned. The UE listens to the FACH in DL and reads the logical channel BCCH to acquire the information of the system. Procedures as the Location_update are made in this state. The UE uses the C-RTNI to be identified and in uplink it uses the RACH. When the UE makes a URA_update moves to state URA_PCH.

Cell_PCH state. The UE monitors the PCH through an assigned PICH. The UE does not have a assigned dedicated resource and it does not have activity in uplink. The mobile reads the logical channel BCCH to acquire the information of the system. When the UE receives paging or wants to initiate a transmission in uplink moves to the Cell_FACH state.

URA_PCH state. This is similar to the previous one although the mobile is known only URA level.

7.6.3. RRC Functions and Signalling Procedures

Since the RRC layer handles the main part of control signalling between the UEs and UTRAN, it has a long list of functions to perform. The main RRC functions are:

- ✓ Broadcast of system information, related to access stratum and non-access stratum.
- ✓ Paging
- ✓ Initial cell selection and reselection in idle mode
- ✓ Establishment, maintenance and release of an RRC connection between the UE and UTRAN
- ✓ Control of Radio Bearers, transport channels and physical channels
- ✓ Control of security functions (ciphering and integrity protection)

- ✓ Integrity protection of signalling messages
- ✓ UE measurement reporting and control of the reporting
- ✓ RRC connection mobility functions
- ✓ Support of SRNS relocation
- ✓ Support for downlink outer loop power control in UE
- ✓ Open loop power control
- ✓ Cell broadcast service related functions
- ✓ Support for UE Positioning functions

Chapter 8. Power Control

Tight and fast power control is perhaps the most important aspect in WCDMA, in particular on the uplink. Without it, a single overpowered mobile could block a whole cell.

The problems of CDMA system come, like some advantages, to share the same portion of the spectrum during all the time to accede to the station base. It is logical to think that if all the users transmit at the same time with the same frequency, each one of them becomes interference for the rest and vice versa.

Mobile stations UE1 and UE2 operate within the same frequency, separable at the base station only by their respective spreading codes. It may happen that UE2 at the cell edge suffers a path loss, say 70 dB above that of UE1 which is near the base station BS. If there were no mechanism for UE1 and UE2 to be power-controlled to the same level at the base station, UE1 could easily to mask UE2 and thus block a large part of the cell, giving rise to the so-called near-far problem of CDMA. The optimum strategy in the sense of maximizing capacity is to equalize the received power per bit of all mobile station at all times.

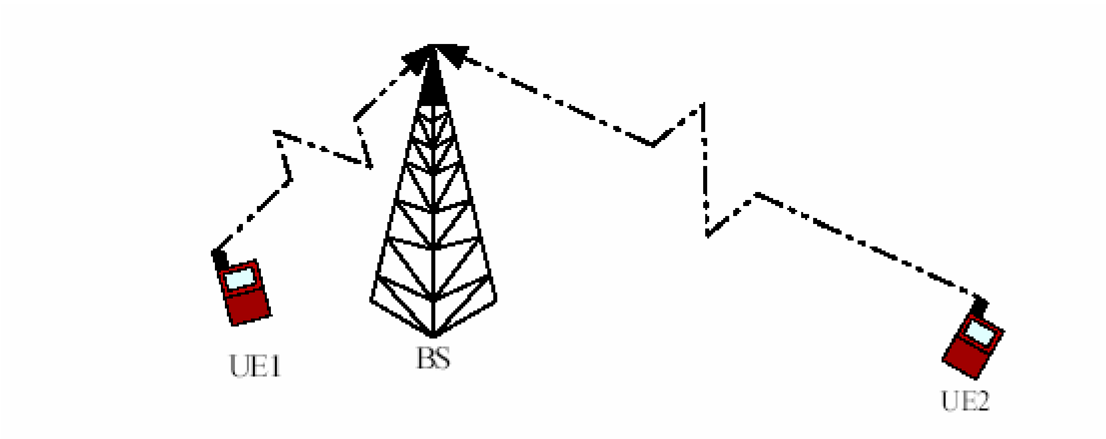


Fig.8.1 Near-Far problem

There are two types of algorithms of power control in UMTS. Open-loop power control is used in WCDMA, but only to provide a coarse initial power setting of the mobile station at the beginning of a connection. The solution to power control in WCDMA is fast closed-loop power control.

8.1. Open Loop Power Control

This happens when a user decides to accede to the system. Initially, this new user will not be controlled in power, with which he will accede to the system with a level of initial power that will be a random variable. If this initial power is not sufficient to be taken care of, it will increase at constant intervals it in dB, until it receives confirmation of the base station of that its signal has been received. If from a first moment the power had been excessive, it would directly have entered to execute the algorithms of power control.

8.2. Closed Loop Power Control

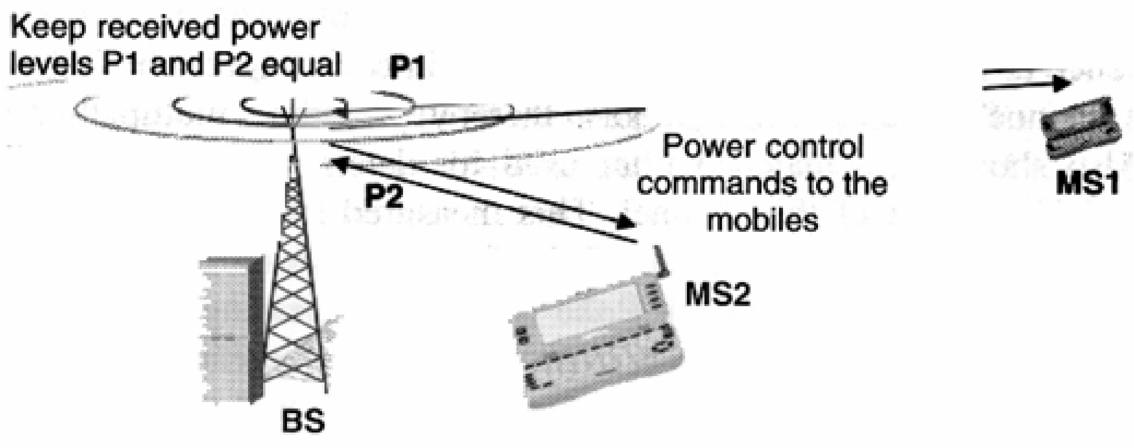


Fig.8.2 Close-loop power control in CDMA

It is made in both links. In uplink the RNC establishes the BER for the asked service and then from that number, it calculates the SIR target sending it to the Node B. Node B considers the SIR in the UL and it compares it with the received one determining if the power of the mobile must be increased or decremented (this is done with the TPS bits). This operation is made 1500 times by second and receives the name of Inner Loop. On the other hand each 10 ms the RNC calculates the SIR and fits the target SIR. This process it is known with the name of Outer Loop and is controlled by RRC layer. In downlink the users receive different interference from the other cells based on their position, and therefore it is necessary to vary the powers to have a relation signal interference (S/I or SIR) fixes (this situation occurs for example in the cellular edge). In this case the UE sends the TPC bits to the Node B based on the considered SIR and of which it has like target.

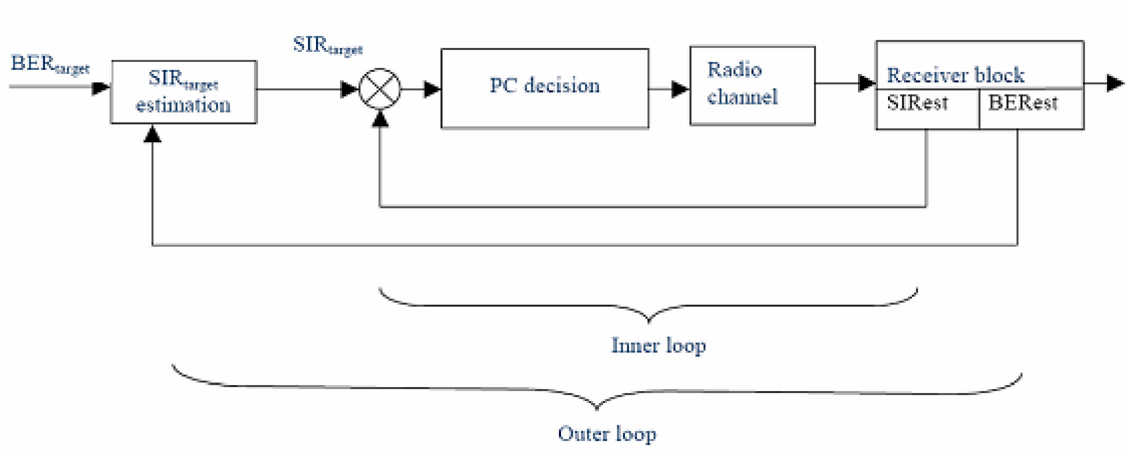


Fig.8.3 Power control in WCDMA system. In the receiver block, the received SIR and BER are estimated and used respectively for the inner-loop and the outer-loop.

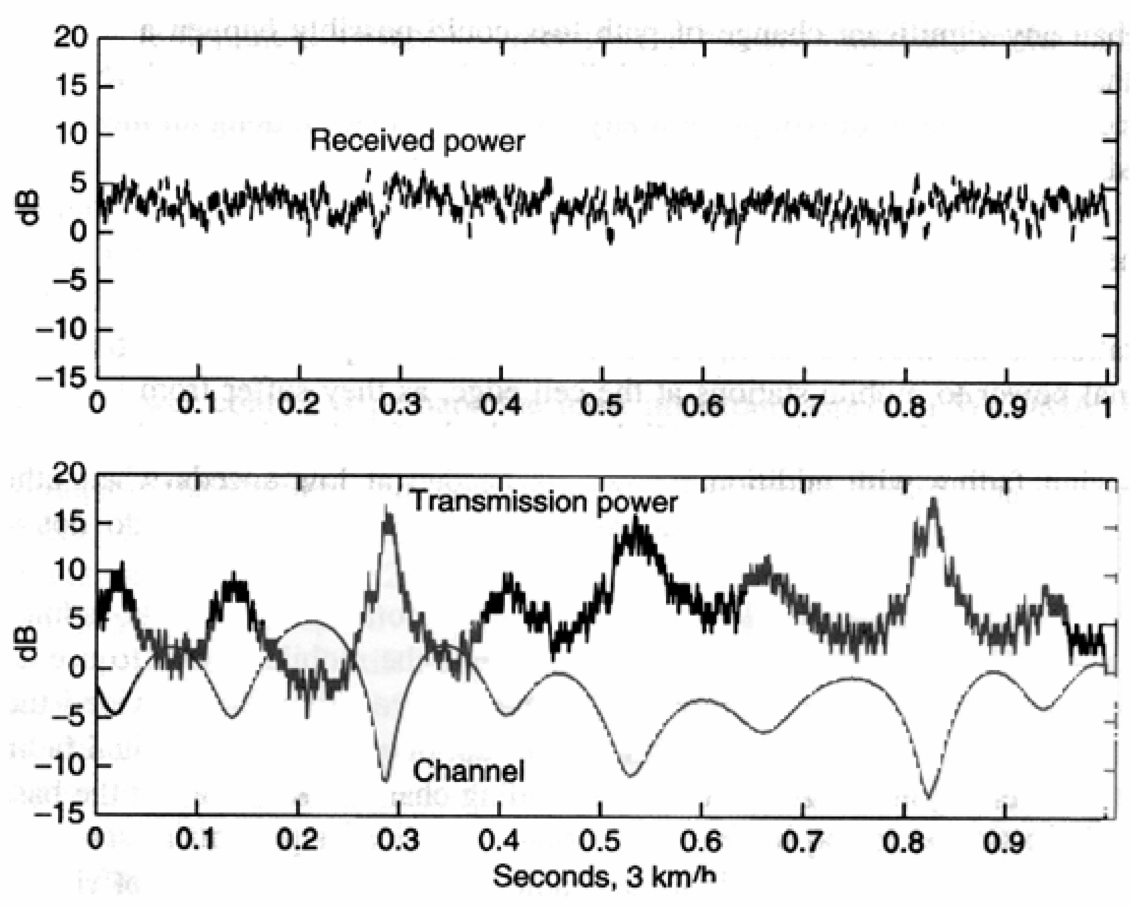


Fig.8.4 Closed-loop power control compensates a fading channel

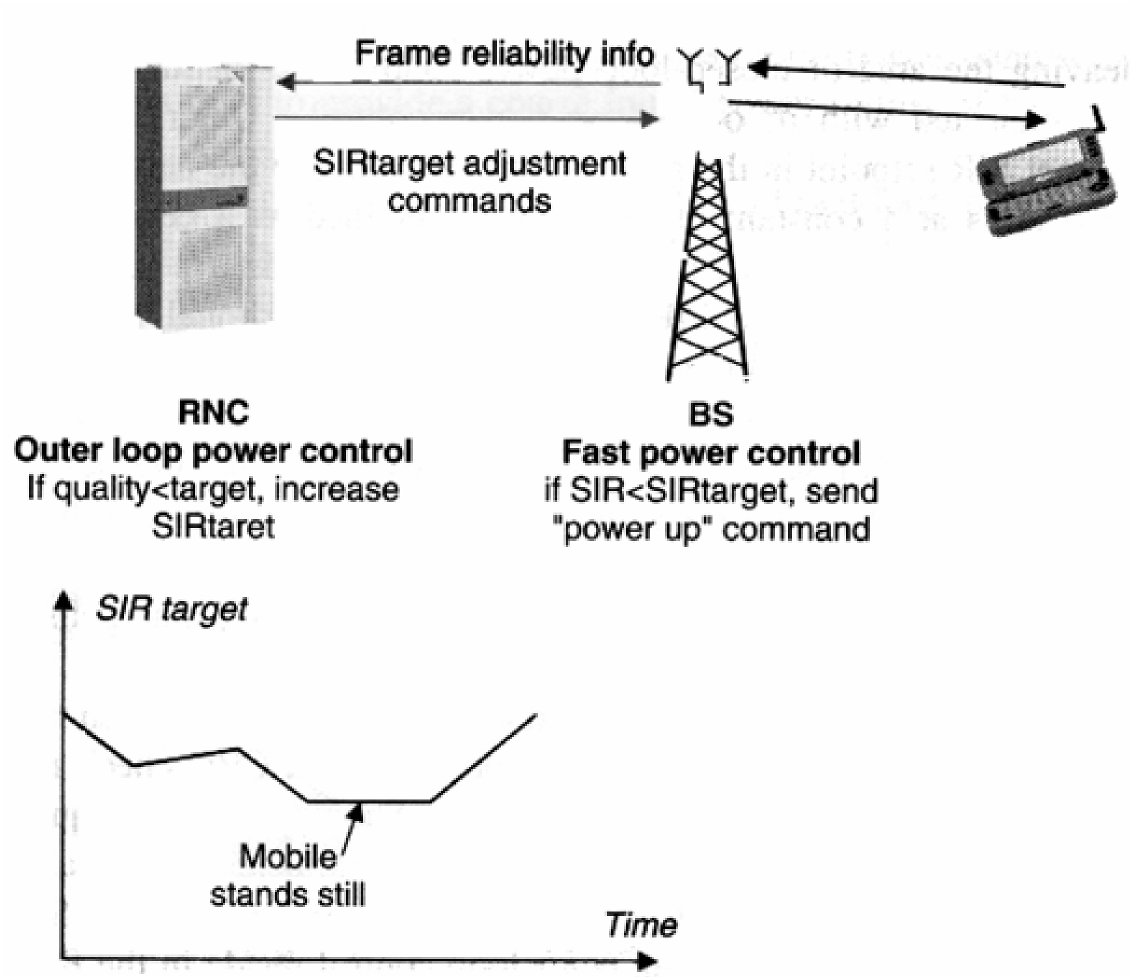


Fig.8.5 Outer loop power control

8.3. Cell breathing

In addition to diminish the interference level, with the power control appears the called phenomenon “cell breathing”. Cell Breathing means that depending on the number of users the size of the cell it can vary, whereas with many users the size of the cell will be smaller, while fewer users are in the system the coverage will be much greater. This phenomenon is shown in the following figure.

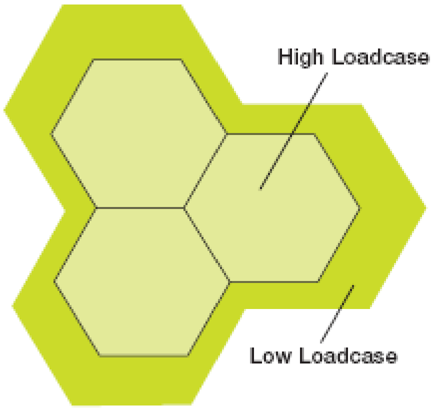


Fig.8.6 Cell's size depending of the load.

8.4. Cell selection: CPICH coverage

The Common Pilot Channel is one of the broadcast signals of UMTS system, that is to say, it is transmitted for equal to all the users within of a cell and therefore, a percentage of the power available in the base station always will be reserved for it. The pilot has two basic missions. On the one hand, the terminals use it to make an estimation of the radio channel. On the other hand, it is the used signal as entered in the mechanisms of cell selection and handover.

The cell selection on the part of a terminal is made according to a certain measurement of quality over the CPICH signal. In concrete the value of the Ec/Io[1] (CPICH Ec/Io) for all the cells is evaluated so that when the correlator of the terminal finds the best peak decides to connect itself with that base. This can be made because each cell has a different code of randomization and the number of codes reserved for the cells is finite.

8.5. Softer and Soft Handovers

When a mobile terminal is connected to a base station and enters within of a cell which receives coverage of another base station, it takes place what we know as a handover.

One of the most excellent advantages of technology UMTS is the implementation of the Soft Handover. The Soft Handover is not another thing that the possibility that has the terminal or UE to be connected to more than a base (BS) simultaneously. Thanks to it, the handover from cells to others is made of a natural mode and are solved some of the problems that present the handovers of type hard (like in GSM) where can appear losses of signal and for example the called "corner effect" (a terminal tour in a corner and loses the direct visibility with its base, due to the strong attenuation that introduces the

[1] A notation used to represent a dimensionless ratio of the average power of a channel, typically the pilot channel, to the total signal power.

building is very complicated to maintain the communication to it and it is not possible to manage the handover). On the contrary, in handovers of type soft more resources are consumed (several active connections for an only terminal).

The set of bases with which a certain terminal is connected is the denominated "Active Set" and will be necessary to define a mechanism that serves to determine to which of the BS the UE will be connected. It is at this moment when CPICH signal appears again.

The form in that signals of the different BS are eliminated or incorporated on UMTS scene, is not other than the estimation of the quality (level) with that the terminal listens to the originating pilots of these bases, concretely becomes to use the measurement of Ec/Io. A CPICH signal of low level of power will be rejected of Active Set, whereas a CPICH signal of an acceptable level of power will be added and it could even force the elimination of a previous connection of smaller level of signal.

During softer handover, a mobile station is in the overlapping cell coverage area of two adjacent sectors of a base station. The communications between mobile station and base station take place concurrently via two air interface channels, one for each sector separately. This requires use of two separate codes in the downlink direction, so that the mobile station can distinguish the signals. The two signals are received in the mobile station by means of Rake[1] processing, very similar to multipath reception, except that the fingers need to generate the respective code for each sector for the appropriated dispreading operation. This scenario is showed in the figure. In the uplink a similar process takes place at the base station: the code channel of the mobile station is received in each sector, then routed to the same baseband Rake receiver and the maximal ratio combined there in the usual way. Softer handover typically occurs in about 5-15 % of connections.

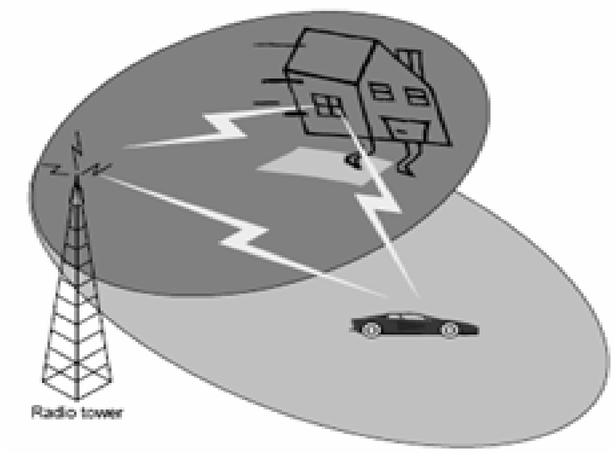


Fig.8.7 Softer Handover

[1] The rake receiver is a technique which uses several baseband correlators to individually process multipath signal components. The outputs from the different correlators are combined to achieve improved reliability and performance.

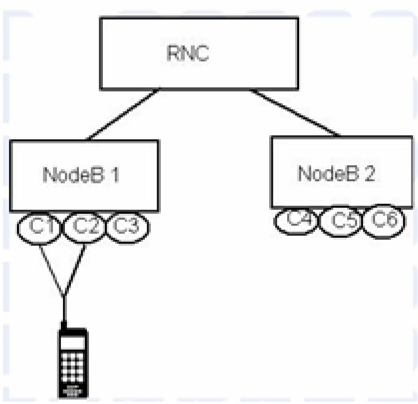


Fig.8.8 Softer Handover

During the soft handover, a mobile station is in the overlapping cell coverage area of two sectors belonging to different base stations. As in softer handover, the communications between mobile station and base station take place concurrently via two air interface channels from each base station separately. As in softer handover, both channels (signals) are received at the mobile station by maximal ratio combining Rake processing. Seen from the mobile station, there are very few differences between softer and soft handover.

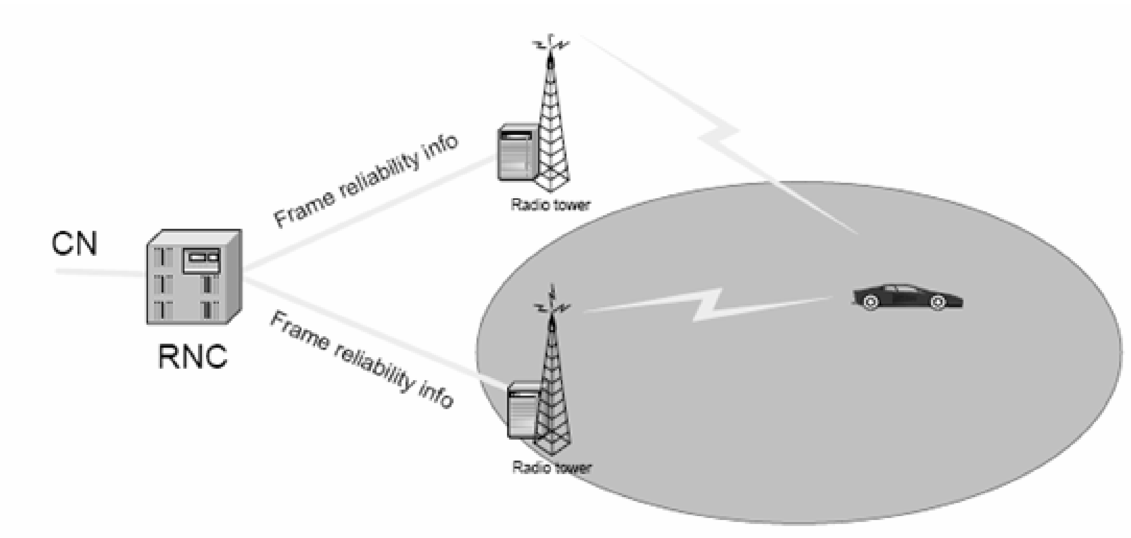


Fig.8.9 Soft Handover

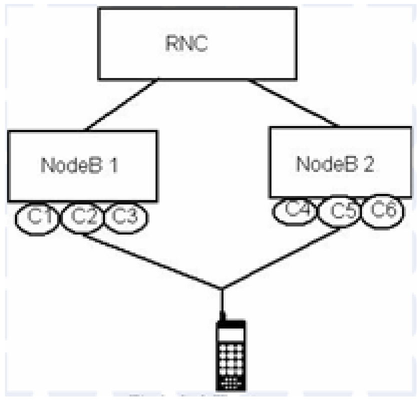


Fig.8.10 Soft Handover

However, in the uplink direction soft handover differs significantly from softer handover: the code channel of the mobile station is received from both base stations, but the received data is then routed to the RNC for combining. This is typically done so that the same frame reliability indicator are provided for outer loop power control is used to select the better frame between the two possible candidates within the RNC.

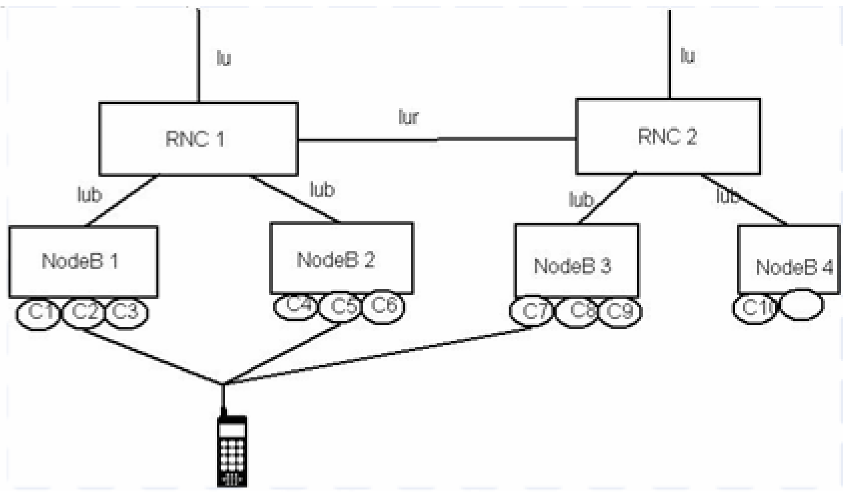


Fig.8.11 Soft Handover with Iur connection

A more complicated soft handover would include a cell that belongs to a Node B in different RNC. In this case an Iur connection is established with the drift RNC (RNC 2) and the data would be transferred to the Serving RNC (RNC 1) via Iur connection.

Note that during soft handover two power control loops per connections are active, one for each base station. Soft handover occurs in about 20-40 % of connections. To cater for soft handover connections, the following additional resources need to be provided by the system and must be considered in the planning phase:

- Additional Rake receiver channels in the base stations
- Additional transmission links between base station and RNC
- Additional Rake fingers in the mobile stations

These handovers are needed for similar reasons as closed-loop control, because without soft/softer handover there would be near-far scenarios of a mobile station penetrating from one cell deeply into an adjacent cell without being power-controlled by the latter. Very fast and frequent hard handovers could largely avoid this problem; however, they can be executed only with certain delays during which the near-far problem could develop.

In addition to soft/softer handover, WCDMA provides other handover types:

Inter-frequency hard handovers that can be used, for example, to hand a mobile over from one WCDMA frequency carrier to another. One application for this is high capacity base stations with several carriers.

Inter-system hard handovers that takes place between the WCDMA FDD system and another system, such as WCDMA TDD or GSM.

8.6. Admission Control

The admission control must ask itself in some moments if with the incorporation of a new user to the system his requirements of QoS (quality of service) are to be able guarantee to the time that is respected the QoS of the users already incorporated. The answer could occur through a previous simulation of the network in the greater number of situations possible to determine the admission region (number of users of each class, with specific parameters of QoS, that is possible to be admitted) and a later dynamic adjustment of the region of admission by means of tools of visualization and measures of the real network, that usually are based on a measurement of the system’s load, which, habitually, is the denominated " loading factor".

Admitting a new call always increases the interference level in the system. Hence a robust method of accepting or blocking potential users, i.e. a Call Admission Control (CAC) technique, is required. The basic strategy under heavy congestion is to protect ongoing calls by denying a new user access to the system because dropping an ongoing call is considered to be far worse than blocking a new call. But Handoff calls are also a very important element of mobile communications networks and a mechanism is needed to maintain connectivity during the call as the user migrates between cells. From the user perspective, a connection terminated in the middle of a call because of a handoff failure is equivalent to a dropped call.

8.7. Load Control (Congestion Control)

The congestion control must act when the admitted users cannot satisfy the requirements of quality during certain period of time due to an overload in the radio network. The control mechanisms of congestion include the following parts:

- **Congestion Detection**: Some criterion is due to establish to decide if the network is in congestion or no. A possible criterion is when the load is superior to certain threshold, during certain period of time.

- **Congestion's Resolution**: When congestion in the network is assumed, are due to carry out certain actions to maintain the stability in the network. Multiple possibilities exist to do it, but in general, three steps can be differentiated:

    a. Priority: They are ordered in a table to the different users based on its priority (for example based on the quality of service requirements (QoS).

    b. Load Reduction: During the congestion new connections are not admitted and the peak rate of transmission of users already admitted set is reduced.

    c. Load Control: After carrying out point b), it is due to return to verify the condition that activates or deactivates the congestion control. If it persists, it will return to the previous section (load reduction), limiting the following user group of the priority table. Thus, even to be below the threshold of the load factor.

- **Congestion Recovery:** An algorithm of congestion recovery is necessary to recover the transmission parameters that had the users before the congestion. This part is important for not return to fall in congestion. A possible mechanism would be to increase the rate of a user and when this user has completed the transmission in course, the rate of the following user is increased.

8.8. Power Control and Diversity

At low UE speed the fast power control can compensate for the fading of the channel and keep the received power level fairly constant. The main sources of errors in the received powers arise from inaccurate SIR estimation, signaling errors and delays in the power control loop. The compensation of the fading causes peaks in the transmission power. The received power and the transmitted power are shown as a function of time in figures 8.12 and 8.13 with a UE speed of 3 Km/h. These simulation results include realistic SIR estimation and power control signaling. A power control step size of 1 dB is used. In Figure 8.12 very little diversity is assumed, while in the figure 8.13 more diversity is assumed in the simulation. Variations in the transmitted power are higher in

Figure 8.12 than in Figure 8.13. This is due to the difference in the amount of diversity. The diversity can be obtained with, for example, multipath diversity, receive antenna diversity, transmit antenna diversity or macro diversity.

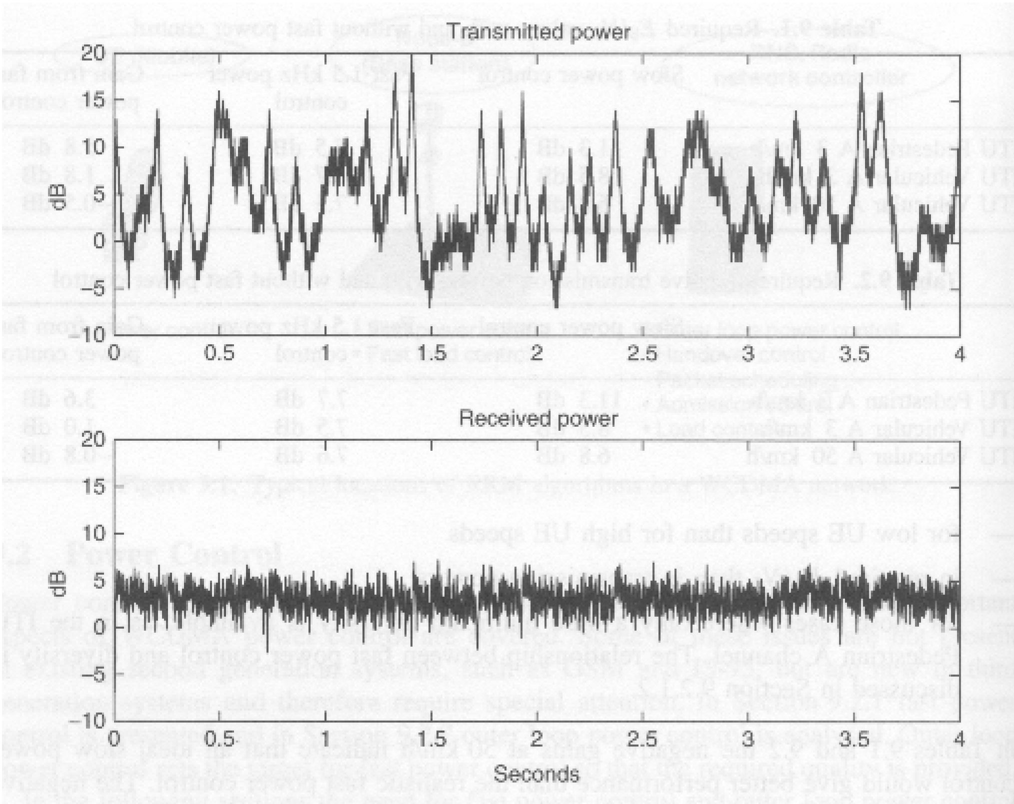


Fig.8.12 Transmitted and received powers in two-path (average tap powers 0 dB, -10 dB) Rayleigh fading channel at 3 Km/h

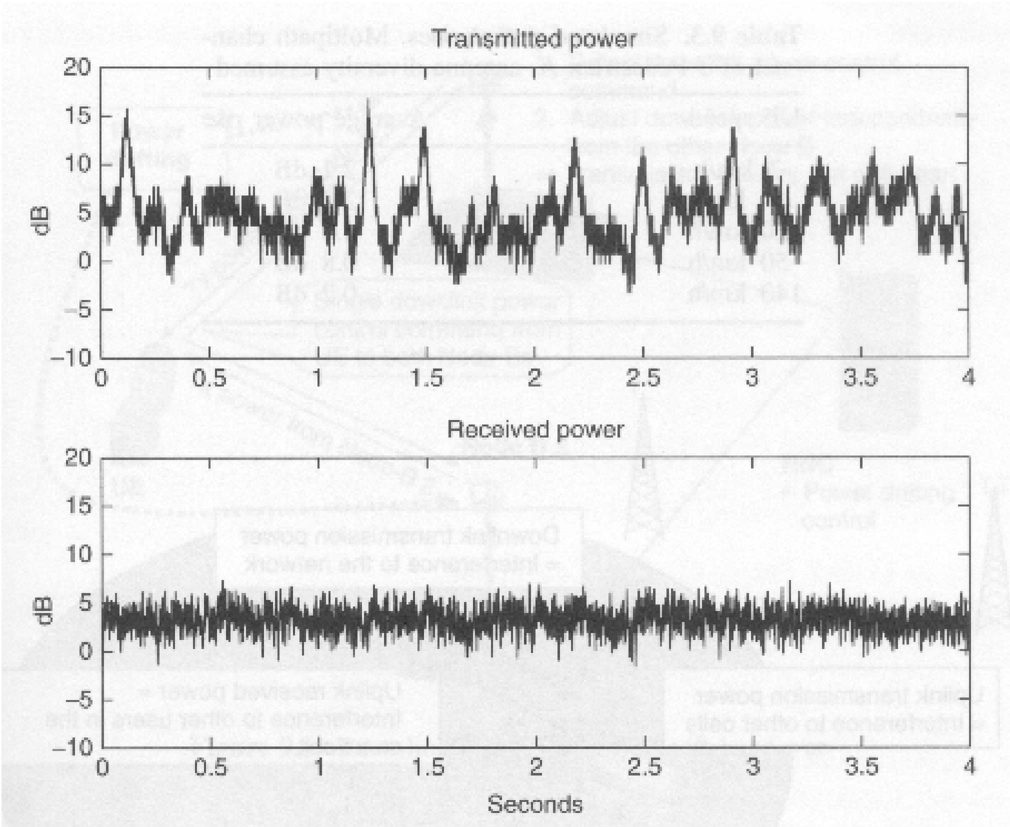


Fig.8.13 Transmitted and received powers in three-path (equal tap powers) Rayleigh fading channel at 3 Km/h

Why is the power rise important for WCDMA system performance? In the downlink, the air interference capacity is directly determinate by the required transmission power, since that determines the transmitted interference. Thus, to maximize the downlink capacity the transmission power needed by one link should be minimized. In the downlink, the received power level in the UE does not affect the capacity.

In the uplink, the transmission powers determine the amount of interference to the adjacent cells, and the received powers determine the amount of interference to other UEs in the same cell. If, for example, there were only one WCDMA cell in one area, the uplink capacity of this cell would be maximized by minimizing the required received powers, and the power rise would not affect the uplink capacity. We are, however, interested in cellular networks where the design of the uplink diversity schemes has to take into account both the transmitted and received powers. The effect of received and transmission powers on network interference levels is illustrated in figure 8.14

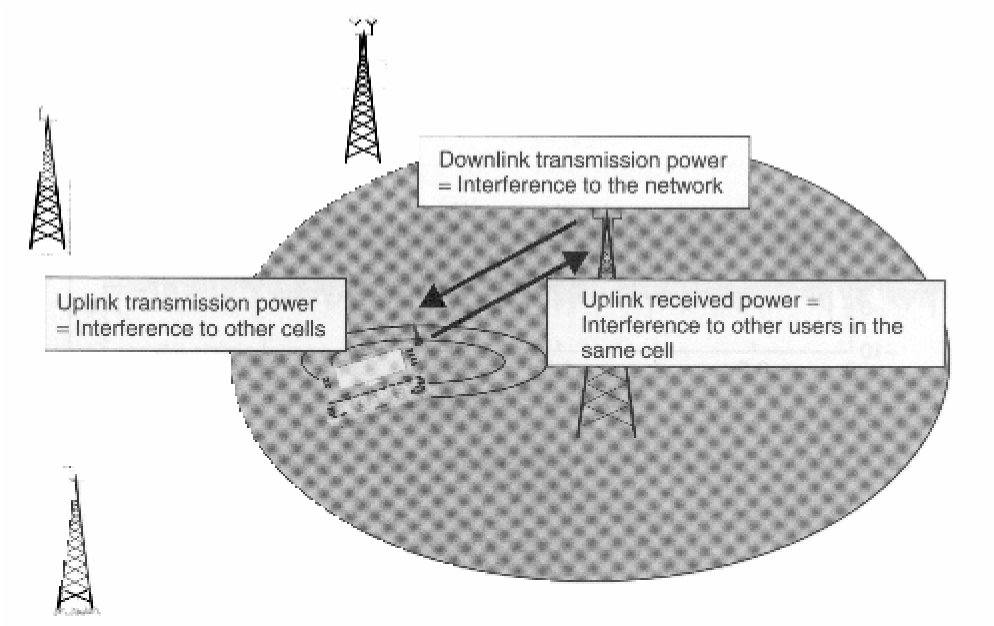


Fig.8.14 Effect of received and transmission powers on interface levels

Chapter 9. Future Lines

4G is short for fourth-generation the successor of 3G and is a wireless access technology. 4G technology stands to be the future standard of wireless devices. A leading wireless company NTT DoCoMo is testing 4G communications at 100 Mbps while moving, and 1 Gbps while still. NTT DoCoMo plans on releasing the first commercial network in 2010.

9.1. OFDM Technology

Ideally, this would provide users with on demand high quality video and audio. The application of 4G is not clear, but video is one of the big differences between 4G and 3G. 4G may use OFDM (Orthogonal Frequency Division Multiplexing), and also OFDMA (Orthogonal Frequency Multiple Access) to better allocate network resources to multiple users.

Unlike the 3G networks which are a hodgepodge of circuit switched and packet switched networks, 4G will be based on packet switching only. This will allow low-latency data transmission.

An OFDM baseband signal is the sum of a number of orthogonal sub-carriers, with data on each sub-carrier being independently modulated commonly using some type of quadrature amplitude modulation (QAM) or phase-shift keying (PSK). This composite baseband signal is typically used to modulate a main RF carrier.

The benefits of using OFDM are many, including high spectrum efficiency, resistance against multipath interference (particularly in wireless communications), and ease of filtering out noise (if a particular range of frequencies suffers from interference, the carriers within that range can be disable or made to run slower). Also, the upstream and downstream speeds can be varied by allocating either more or fewer carriers for each purpose. Some forms of Rate Adaptive DSL use this feature in real time, so that bandwidth is allocated to whichever stream needs it most.

9.2. The New Network

The main characteristic of the proposals of 4G mobile networks is the use of technologies IP in the core and the access networks, to support all the services. While in 3G networks will coexist a IP core for the data network with another core based on circuits switching for voice services, in the 4G networks will only exist a IP core on which all the traffic will be transported.

One of the desirable characteristics in the 4G networks would be that the core was IPv6, with which would be resolute problems like the space of directions, vital to the unfolding of a new network where the use of public directions would be desirable.

Different access technologies will appear in a scene 4G. They are not complementary technologies; so that all will be able to coexist, and based on the necessities of the client it will be able to choose some of the following ones:

WCDMA (UMTS): It would be the more expensive access means (infrastructure and terminal's consumption) but with greater capacity of mobility. At first it would offer bandwidth a little reduced comparing it with the rest of technologies, but it provides a practically limitless coverage and mobility.

Wireless LAN 802.11: The coverage would come limited by the situation from the access points. So that it good to cover certain zones (airports, meeting rooms), of cheap form and with a considerable bandwidth.

Ethernet: with this technology we lose all mobility, but we can reach greater the bandwidth. It is good for access zones identified well (meeting zones, work laboratories) with great requirements from bandwidth. In figure 9.1 is shown the functional elements of which a 4G network is made up.

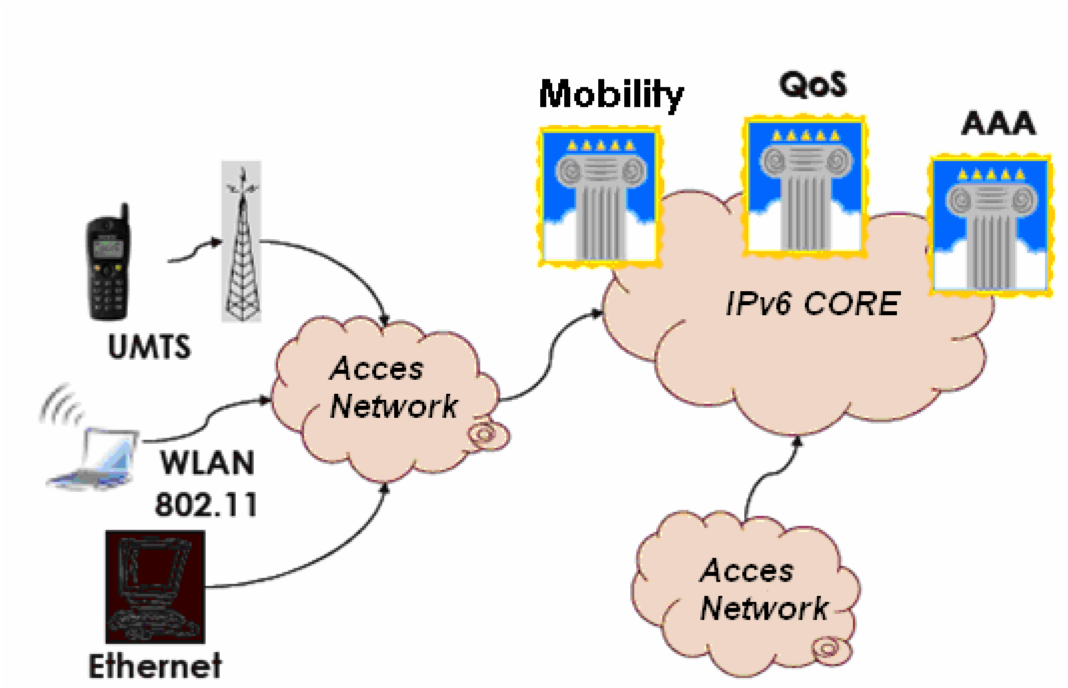


Fig.9.1 4G Network Architecture

Chapter 10. Mobile phone radiation and the environment

Mobile phone radiation and health concerns have been raised following the enormous increase in the use of wireless mobile telephony throughout the world. This is because mobile phones use electromagnetic waves in the microwave range. These concerns have induced a large body of research (experimental in animals as well as in human). Concerns about effects on health have also been raised regarding other digital wireless systems, such as data communications networks.

The results, so far, have been controversial; the majority of experimental studies have not found any clear indication of short and medium term health dangers. Some experimental studies have described effects on several biological parameters, such as the growth of certain tumors, cell death, increased permeability of the blood-brain barrier and others, but they represents less than 5% of all published works, which are in its majority negative. On the other hand there is extensive literature on so-called non-thermal effects of weak microwave radiation on biological tissue in animal models or in-vitro, which may suggest the possibility of adverse health effects in humans.

Possible health dangers of microwave EMF (electromagnetic field) used in cellular telephony could be classified into:

- Health dangers of handset for habitual users
- Health dangers of radio base stations for the exposed population
- Occupational health dangers (for workers in the telecommunications industry)
- Other indirect health dangers (such as driving while using handsets, radio interference with medical equipment and handset malfunction)

Fig.10.1A tower used in base stations for mobile telephony

10.1. Health hazards of mobiles

Part of the radio waves emitted by a mobile telephone handset are absorbed by the human head; the radio waves emitted by a GSM handset, for example, can have a power of up to 2 watts, and an analog phone in the USA (probably very few in use today) can have 3.6 watts, as in the old large mobile phone units installed in cars.

On the other hand, the digital mobile technologies, like CDMA and TDMA, have today lower rates, below 1 watt. The average radiation rate of cellphones in some countries is regulated and it is mandatory to inform the consumers about it (usually printed in the battery compartment). In some systems the cellphone and the tower (radio base station) check reception quality and signal strength and the power level is increased or decreased automatically, within the above limits, such as inside buildings or vehicles, etc.

The rate at which radiation is absorbed by the human body is measured by the Specific Absorption Rate (SAR), and its maximum levels for modern handsets have been set by governmental regulating agencies in many countries. In the USE, the FCC (Federal Communications Commission) has set a SAR limit of 1.6 W / Kg for most parts of the body.

10.2. Health hazards of base stations

Another area of worry about effects on the population's health have been the radiation emitted by base stations (the antennas located inside geographical areas named cells which are part of the cellular network), because, in contrast to mobile handset, it is emitted continuously. Due to the attenuation of power with square of distance, however, field intensities are extremely low, even a few meters away from the base of the antenna. Any significant biological effects are thus improbable. All evidence shown by methodologically correct studies have shown no discernible effects.

As technology progresses and data demands have increased on the mobile network, the number of towers has increased sharply in many cities, and competing telecommunications companies usually do not make an effort toward sharing towers.

Experts in molecular engineering, doctors in chemistry and environmental consultants, remembered that, in prevention measurement, the antennas have to be placed far from the considered sensible areas like schools, hospitals or residential areas. This preventive measure has to be fulfilled until that the scientific data prove that really the antennas do not damage to anybody. To this affirmation, some telecommunications companies reacted saying that this preventive measure is not possible, because to provide an effective communications and to avoid the interferences, the antennas must be located in the proximities of the urban cores where mobiles is a high number of consumers of mobiles telephones.

10.3. Effects on animal population

Another issue raised relates to the studies on radiation hazards to other living species. The current safety standards relate mostly to human species and there are very few studies on non-human species. Although reports of dwindling insect species (such as flies, butterflies, fireflies, grasshoppers and moths) around base stations have been made, it is extremely difficult to prove that this decrease is actually due to microwave radiation. In fact, it is most probably caused by other factors, such as the use of insecticides or urban alternations in the vegetation environment which maintain these species.

10.4. Scientific assessment

The World Health Organization (WHO) has a special study program on the effects of electromagnetic fields on human health which periodically examines the scientific evidence on these aspects. So far (the next report is scheduled for 2006-2007) it has concluded that there are no demonstrable effects of EMF used in mobile phones and wireless telecommunications systems on human health.

10.5. Conclusion

Mobile phones and its corresponding base stations seem to be remarkably safe devices, as far as the majority of well accepted and reproducible experimental and observational studies could determinate. They are in use for more than 30 years, so long range effects have also been taken into account.

A number common sense and science-based facts would sum up to the conclusion that significant ill effects are improbable.

Even with a very low risk ratio, an increase in the number of several diseases which have been attributed to low-level microwave radiation would be easily detected, and this has not been the case.

The penetration power of microwaves into the human body is very low. Most of the radiation is converted to heat within a few millimeters of external anatomic structures and clothing.

The levels of radiation emitted by base stations are too low to be biologically significant, and represent an increase of a few tenths of microwatts per cm over the already-existent microwave background radiation of a typical modern city.

Emission power absorbed by the human body is higher for handsets, but they are typically used only a few minutes per day close to the head.

Exposure limits defined by international standards, are typically 50 or more times lower than the biological safety limit. If they are respected, biological effects are extremely improbable.

In conclusion, more than a cellular heating we are living a social heating produced fundamentally to the fact that the electromagnetic fields are, in general, strangers and imperceptible by the human and this fact it causes certain distrust, that, in some cases, it is translated in a rejection of a part of the population towards the mobile telephony antennas.

Chapter 11. Conclusions

The WCDMA air interface is seen to develop far beyond its initial capabilities to satisfy future service and application needs.

With more than 75 WCDMA networks now launched commercially and a choice of terminal devices that already exceeds 180 models, it's no surprise that 3G/UMTS customer numbers are growing faster than ever. A compelling blend of handsets, tariffs and user-friendly services are convincing more consumers and business users to experience the benefits of 3G/UMTS for themselves. Supported by a fast-growing choice of terminal options, it's already clear that net customer additions will increase rapidly.

The evolving capabilities of 3G/UMTS will offer business customers and consumers even higher data rates and new service capabilities. With the first deployments of HSDPA, the true value of 3G/UMTS as an enabler for high speed mobile broadband will be fully realised.

In order to the future, 4G needs to be something that 3G evolution cannot do. Looking at the complexity of application contents and development of such contents, going toward even higher data rates and availability of high data rates everywhere is a trend. Thus, one distinguishing factor between 3G and 4G will be the data rates. We assume that 4G should support at least 100 Mb/s peak rates in full-mobility wide area coverage and 1 Gb/s in low-mobility local area coverage. There will be other characteristics for 4G, but at this point in time the requirements for 4G need further studies (including market studies).

UMTS can be summarized as a revolution of the air interface accompanied by an evolution of the core network. Handover and backward compatibility with GSM ensure that both technologies will coexist for many years. The UMTS Forum predicts that the number of mobile phone users will increase to 1800 million world-wide by 2010. UMTS will be the technology that fuels this growth and delivers a whole range of exciting multimedia services to many new users.

Chapter 12. Personal Conclusions

At the beginning of the project many were the barriers for the accomplishment of an suitable project, the little familiarisation, not only with the language, but also with the subject and characteristics of the project, since throughout the professional career, my tastes and preferences have taken me more by the computer’s world and the communication through them, that not through the mobile telephones.

All uniting presented before me a great challenge. In spite of this, throughout the project I have been verifying the made advances day by day with this language, as well as in the same way my knowledge on the mobile technology have increased considerably, since it was a subject with which it was not very familiarized.

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An international and independent body committed through the building of cross-industry consensus to the successful introduction and development of UMTS/IMT-2000.

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The Third Generation Partnership Project is producing the technical specifications for a 3rd generation mobile system based on evolved GSM core networks and UTRA radio access technologies.

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The Third Generation Partnership 2 is a collaborative third generation specifications-setting project. Comprising North American and Asian interests developing global specifications.

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It is the free encyclopedia that anyone can edit. In English version, started in 2001, we are currently working on 815.000 articles.

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Nokia is a world leader in mobile communications, driving the growth and sustainability of the broader mobility industry. Nokia connects people to each other and the information that matters to them with easy-to-use and innovative products

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The ITU, headquartered in Geneva, Switzerland is an international organization within the United Nations Systems where governments and the private sector coordinate global telecom networks and services.

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Chapter 14. Glossary of Figures

Chapter 15. Principal abbreviations used in this project

2G = Second Generation

3G = Third Generation

3GPP = Third Generation Partnership Project

AAL = ATM Adaptation Layer

ACTS = Advanced Communications Technology and Services

ANSI = American National Standards Institute

ATDMA = Advanced TDMA (a RACE project)

ATM = Asynchronous Transfer Mode

BER = Bit Error Ratio

CDMA = Code Division Multiple Access

CEPT = European Conference of Postal and Telecommunications Administrations

CODIT = UMTS Code Division Tested (a RACE Project)

DECT = Digital Enhanced Cordless Telecommunications

DTI = Department of Trade and Industry

EDGE = Enhanced Data rates for GSM Evolution

ERC = European Radiocommunications Committee

ETSI = European Telecommunications Standards Institute

FDD = Frequency Division Duplex

FLPMTS = Future Land Public Mobile Telecommunication System

FMA = FRAMES Multiple Access

FP = Frame Protocol

FRAMES = Future Radio wideband Multiple access Systems (an ACTS project)

G3G = Global Third Generation

GPRS = General Packet Radio Service

GSM = Global System for Mobile communications

HSCSD = High Speed Circuit Switched Data

IMT-2000 = International Mobile Telecommunications for the year 2000

IP = Internet Protocol

ISDN = Integrated Services Digital Network

ITU = International Telecommunication Union

MAC = Medium Access Control

MAP = Mobile Application Part

MONET = Mobile Networks (a RACE project)

NBAP = Node B Application Part

OHG = Operator Harmonisation Group

PCS = Personal Communication Services

PDC = Personal Digital Cellular

PHY = PHYsical

PSTN = Public Switched Telecommunications Network

QPSK = Quadrature Phase Shift Keying

RACE = Research into Advanced Communications in Europe

RANAP = Radio Access Network Application Part

RLC = Radio Link Control

RNC = Radio Network Controller

RNS = Radio Network Subsystem

RNSAP = Radio Network Subsystem Application Part

RRC = Radio Resource Control

RTT = Radio Transmission Technology

SMG = Special Mobile Group

TD-CDMA = Time Division – Code Division Multiple Access

TDD = Time Division Duplex

TDMA = Time Division Multiple Access

UE = User Equipment

UMTS = Universal Mobile Telecommunications System

UTRA = UMTS Terrestrial Radio Access

UTRAN = UTRA Network

WAP = Wireless Application Protocol

WARC = World Administrative Radio Conference

WCDMA = Wideband CDMA