Capítol 4. Xarxes d'accés

1

4.1 Parell de coure

Sources: 1. DSL White Paper: Allied Telesyn 2. ITU-T G992.1

2

Parell de coure és igual a fil de telèfon. El fil s'aprofita en tot l'ampla de banda possible (fins 15 Mhz), no com en el cas del servei telefònic que només es fa servir el canal 300-3400 hz.

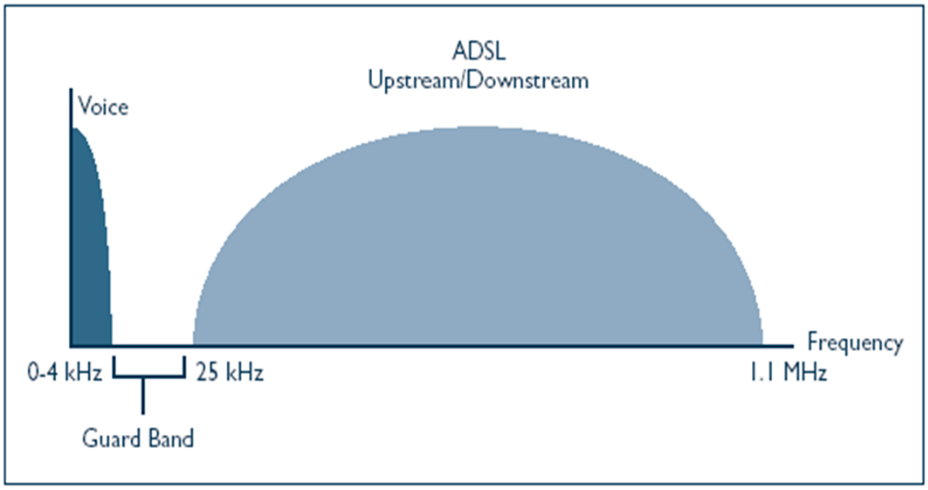
xDSL technologies

A whole family of technologies for data transmission over the copper pair is referred to as xDSL, where "x" is replaced starting in each case by the letters that distinguish each mode. In general xDSL is a set of technologies that provide high bandwidth over local loop copper wire without signal amplifiers or repeaters along the route of the wiring connection between the client and the telephone exchange to which is connected.

DSL White Paper Allied Telesyn | White Paper

http://www.hit.bme.hu/~jakab/edu/litr/Access/DSL/dsl2++_wp.pdf

Splitting the frequencies

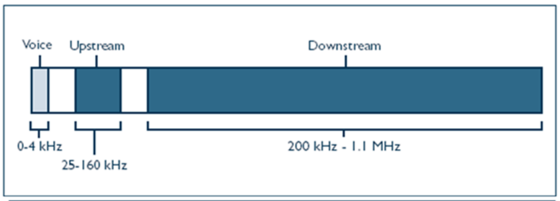


The telephone analogue frequency uses only a small proportion of the bandwidth on a line (under 4kHz).The maximum amount of data that conventional dial-up modems can transmit through a POTS system is about 56Kbps. Using this method to send data, the transmission through the telephone company is a bandwidth bottleneck.

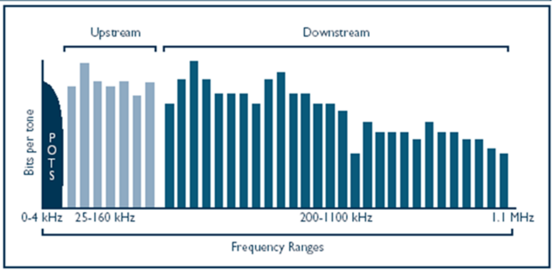
Typical telephone cabling is capable of supporting a greater range of frequencies (around 1MHz). With DSL modems, the digital signal is not limited to 4kHz of voice frequencies, as it does not need to travel through the telephone switching system. DSL modems enable up to 1MHz of bandwidth to be used for transmitting digital (data) alongside analogue (voice) signals on the same wire by separating the signals, thereby preventing the signals from interfering with each other. Figure 2 shows how the analogue and digital frequencies are split.

Modulation.

CAP



DMT



The basic idea of DMT is to split the available bandwidth into a large number of subchannels. DMT is able to allocate data so that the throughput of every single subchannel is maximized. If some subchannel can not carry any data, it can be turned off and the use of available bandwidth is optimized.

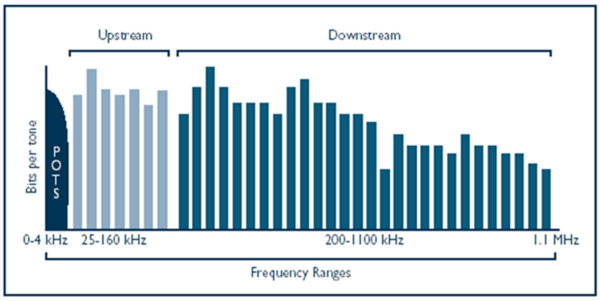
Carrierless Amplitude Phase (CAP) is an encoding method that divides the signals into two distinct bands: • The upstream data channel (to the service provider), which is carried in the band between 25 and 160kHz.

• The downstream data channel (to the user), which is carried in the band that starts at 200kHz and continues to a variable end point, depending on a number of factors, such as line length and line noise, but the maximum is about 1.1MHz. These channels are widely separated in order to minimise the possibility of interference between the channels. Discrete Multi-Tone (DMT), the most widely used modulation method, separates the DSL signal so that the usable frequency range is separated into 256 channels of 4.3125kHz each. DMT has 224 downstream frequency bins (or carriers) and 32 upstream frequency bins. Up to 15 bits per signal can be encoded on each frequency bin on a good quality line. Each of the 256 channels is monitored separately to ensure the data travelling along it is not impaired. DMT constantly shifts signals between different channels to ensure that the best

channels are used for transmission and reception. DMT can take advantage of all usable tones in the spectrum and works around areas where interference is present. Some of the lower channels can be used as bi-directional channels for both upstream and downstream information. The basic idea of DMT is to split the available bandwidth into a large number of subchannels. DMT is able to allocate data so that the throughput of every single subchannel is maximized. If some subchannel can not carry any data, it can be turned off and the use of available bandwidth is optimized. Discrete multitone (DMT) uses multiple carrier signals at different frequencies, sending some of the bits on each channel. The available transmission band (upstream or downstream) is divided into a number of 4-kHz subchannels. On initialization, the DMT modem sends out test signals on each subchannel to determine the signal-to-noise ratio (SNR). The modem then assigns more bits to channels with better signal transmission qualities and less bits to channels with poorer signal transmission qualities.

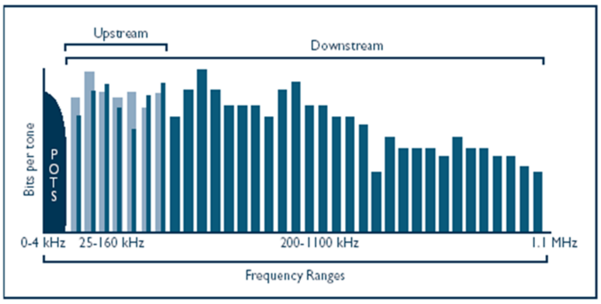
FDM and Echo cancellation

FDM



UP: 25 carriers
DW: 224 sub carriers

EC



UP: 25 carriers
DW: 250 sub carriers

The DMT frequency bands can be used in two different ways, which are referred to as Frequency Division Multiplexing (FDM) and Echo Cancellation. Frequency Division Multiplexing (FDM) With FDM, the low-speed upstream channel is quite separate from the high-speed downstream channel. In order to prevent interference between the frequency bands, a space, known as the guardband, is required between the upstream and downstream

frequencies. Most ADSL modems today use FDM. With Echo Cancellation the downstream channel overlaps the upstream channel, so simultaneous upstream and downstream signals are sent on the lower frequencies. An echo on the upstream signal can cause corruption on the downstream signal. Echo cancellation is used to obtain a clear signal in the event that both streams send data simultaneously.

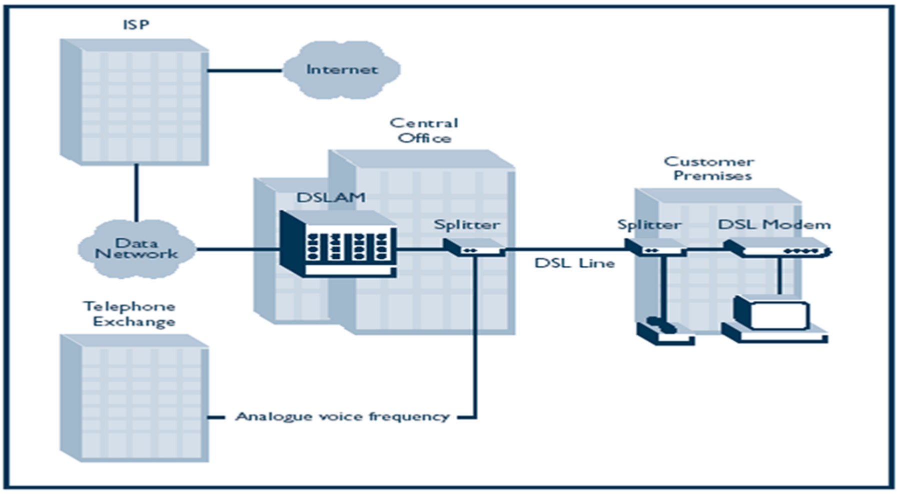
ADSL concept

Asymmetric Digital Subscriber Line (ADSL), an important variant of the DSL family, has become very popular. With ADSL, most of the data bandwidth is devoted to sending data downstream towards the user and a smaller proportion of the bandwidth is available for sending data upstream towards the service provider. This scenario suits Internet browsing applications, which typically involve much more downstream than upstream dataflow.

Standards

• ANSI (American National Standards Institute) in sucomité T1.143 issue 1 (1995) and T1.413 issue 2 (1998) defines the standard for the physical layer.
• ETSI (European Telecomunication Standards Institute) has contributed to including an annex with European requirements.
• ITU (International Telecommunications Union) has developed recommendations G.992.1, G.994.1, G.995.1, G.996.1 and G.997.1.
•ADSL Forum proposed protocols, interfaces and architectures necessary for the development of ADSL.
•The ATM Forum and DAVIC (Digital Audio-Visual Council) have been recognized as a transmission protocol ADSL physical layer for unshielded pairs.

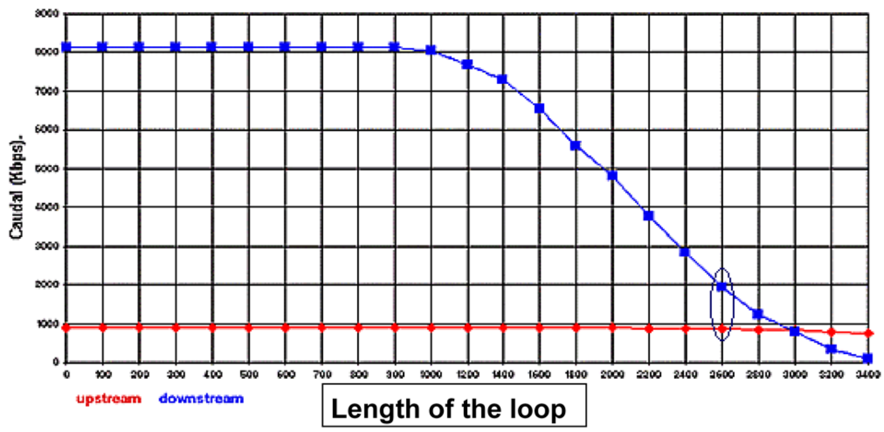
ADSL network setup



When digital data is sent from a customer's premises, it travels from their computer through a DSL modem and a splitter.When analogue voice signals are sent from a customer's telephone they are also sent through the splitter, which combines the analogue voice and digital data signals, enabling them to be sent over the same line. At the other end of the line, the local loop goes into a splitter at the local phone company's COs, which splits the digital data frequencies from the analogue voice frequencies.The voice frequencies are sent to the local telephone exchange and the digital data is sent to a Digital Subscriber Line Access Multiplexor (DSLAM) before being sent on to the Internet Service Provider (ISP).The digital data never enters the standard telephone switching system. Voice and data frequencies going in the opposite direction—to the customer's premises—follow the reverse route from the ISP through a DSLAM, then a splitter at the CO, and are then sent over the copper wires to the customer's site before being split again. The DSLAM is the equipment that really allows DSL to happen.The DSLAM handles the highspeed digital data stream coming from numerous customers and aggregates it onto a single high-capacity connection (ATM or Gigabit Ethernet line) to the Internet Service Provider and

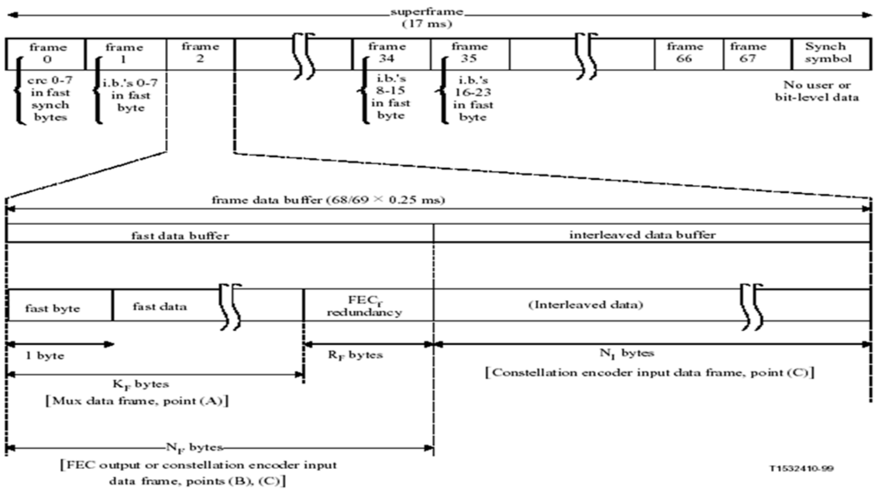
vice versa. DSLAMs are generally flexible and can support a number of different DSL connections as well as different protocol and modulation technologies in the same type of DSL. Figure 4 shows how an ADSL network is setup.

Performance of ADSL. Throughput

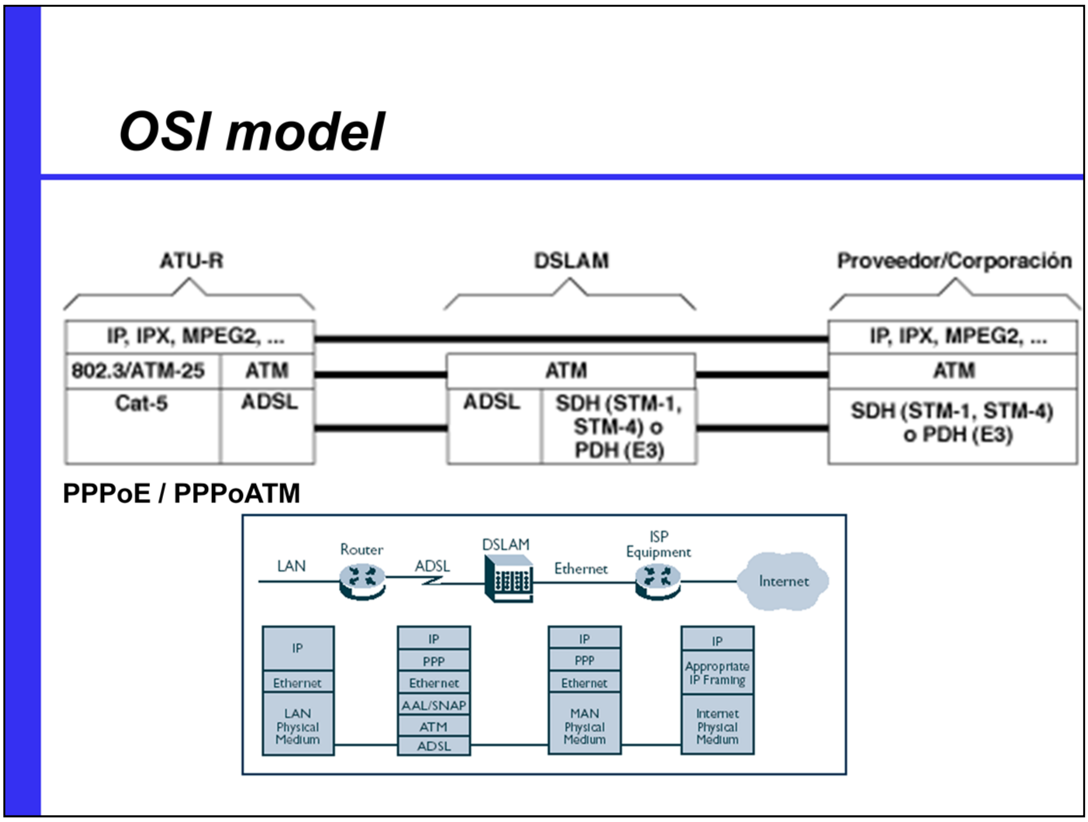


A més distància menys troughput debut a la pèrdua de freq. per causa de l'atenuació que no és igual per a totes les freq.

Super frame ADSL



Hay 68 tramas pero el canal adicional de sincronismo está introducido por el modulador y repartido por todas las tramas por lo que el tamaño del buffer de cada trama es 68/69x0,25ms aunque cada trama es de 250 microsegundos. El fast data buffer permet millor resposta a la latència però pitjor al troughput,debut a les capçaleres. El interleaved buffer és al revés. La raó és que el interleaved consumeix recursos de computació elevats i no té capçaleres.



There has been no universal agreement reached over the sort of packet on which to perform RFC 1483 encapsulation, so there are now a number of different choices of protocol stack to have above the RFC 1483 Layer.

The most common protocol stack is Point-to-Point Protocol over Ethernet and ATM (PPPoEoA). Figure 9 demonstrates how PPPoEoA enables IP packets to travel over both an Ethernet and an ATM connection. When travelling from the LAN to an ADSL connection, IP packets encapsulated in Ethernet frames pass through an ADSL router, which attaches a PPP header to the frames.The frames then undergo AAL5 encapsulation to create smaller ATM cells, which are sent over the ADSL connection to a DSLAM at the local phone company office. The DSLAM in this instance is connected to an Ethernet network, so the ATM cells go through the reverse process described above to reveal the Ethernet frames, which are sent on to the ISP. At the ISP, the Ethernet frames are removed to reveal the IP data, which is then framed according to the network it will continue to travel on. Other protocol stacks include: IPoA, which was designed to make IP subnets map directly onto ATM networks in the same way that IP subnets map onto VLANs. So, an ATM address resolution protocol was introduced to enable the IP stack to obtain an "ATM address" for another IP host connected to its local ATM subnet (RFC 2225).The structure required for this kind of network is quite complex, mostly because trying to make a channel oriented transportation method like ATM appear like a broadcast domain is not a very natural fit. RFC 1483 Bridged, which is where the whole Ethernet packet that arrives at the ADSL router is encapsulated into AAL5, using the 'bridged-data' format defined in RFC 1483, and sent on the ADSL line.The packets are forwarded based on their MAC address, so they are bridged. RFC 1483 Routed, which uses the same 'bridged-data' format as RFC 1483 Bridged to

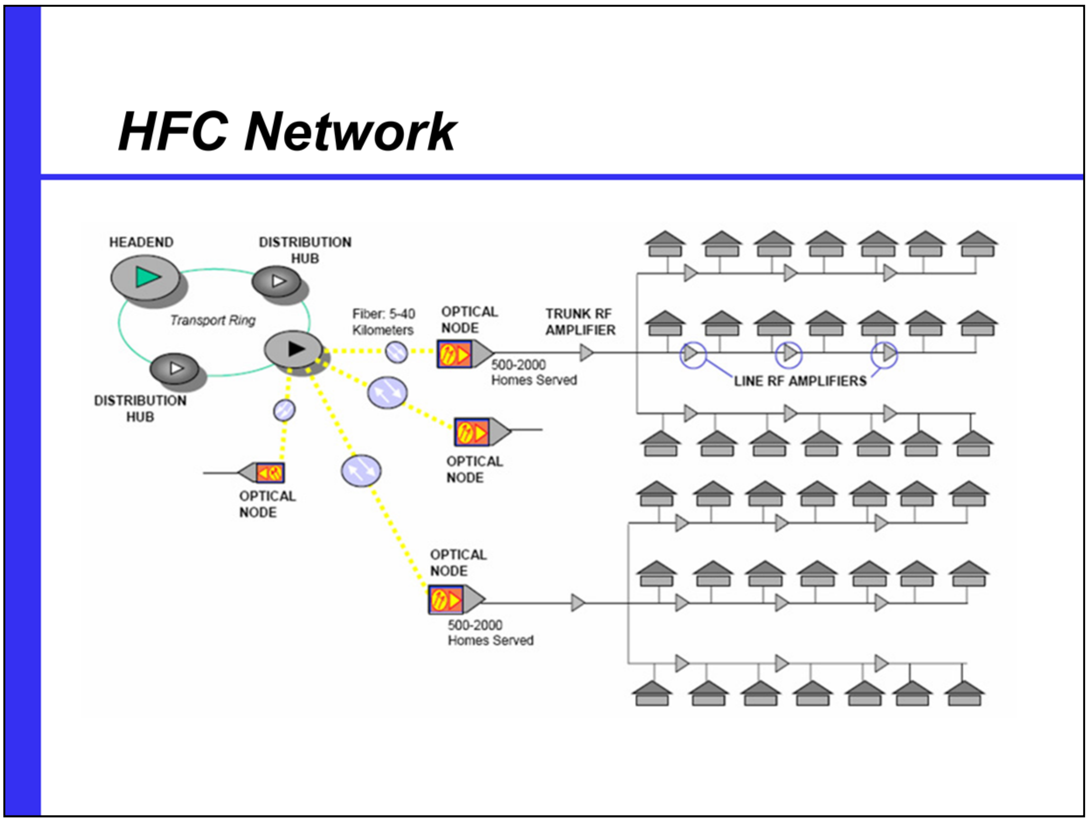
encapsulate Ethernet packets into AAL5. However, the packets are forwarded based on their IP address, so they are routed.

Solució anomenada “El cable”.

Referències:

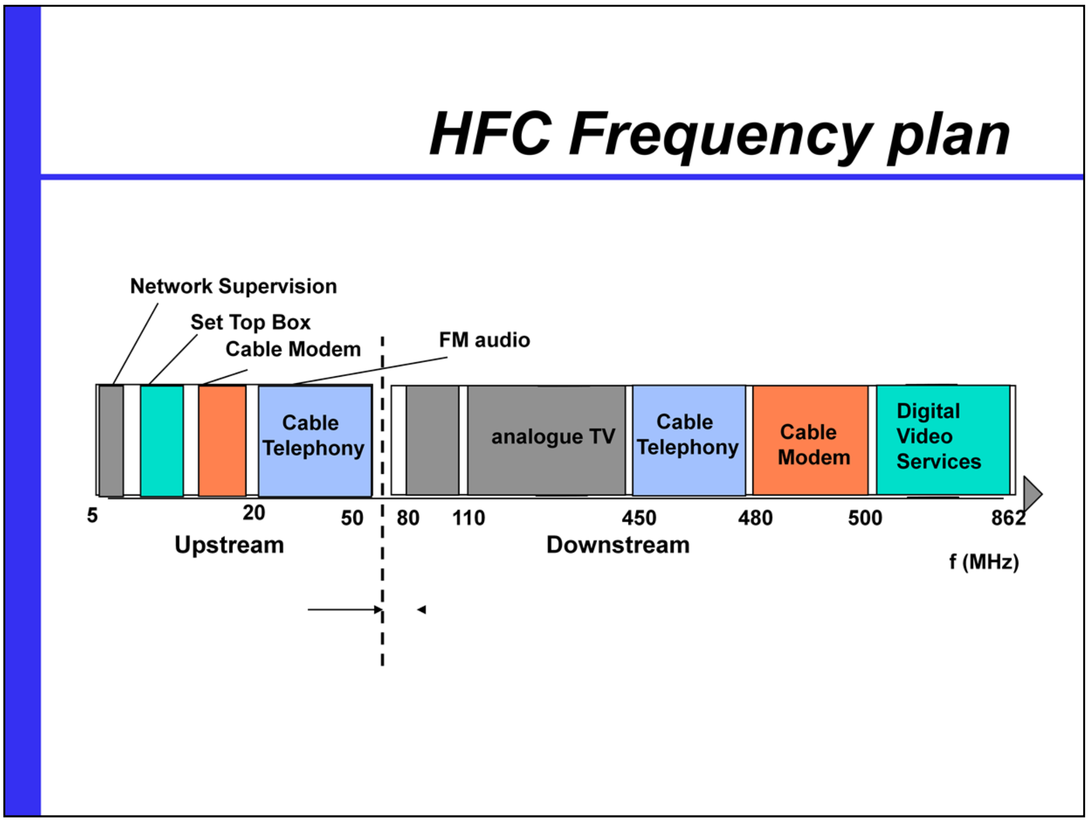
http://www.cable-europe.eu/wp-content/uploads/bsk-pdf-manager/4_CM-SP-CMCIV3-I01-080320.PDF

file:///C:/Users/German/Downloads/CM-SP-MULPIv3.0-C0I-171207.pdf



Les xarxes HFC són híbrides de fibra òptica per a la distribució i coaxial per a l’accés d’usuari.

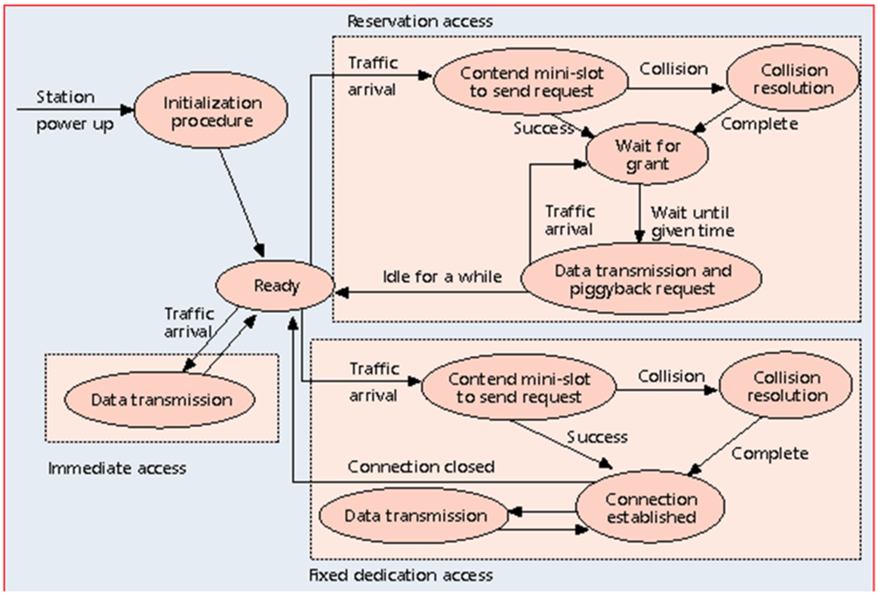
La utilització de fibra òptica és irrellevant en la tecnologia. Només importa la tecnologia analògica sobre cable coaxial que és la que dona les seves prestacions als usuaris finals.



Distribució dels canals de freq. en el cable coaxial.

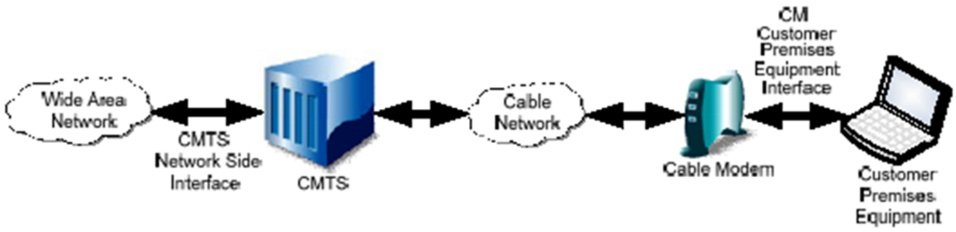
Per accedir a internet ens interessa el canal de cable modem

MAC access mode



Reservation acces és el mètode més just ja que proporciona més equitat entre usuaris i és el més utilitzats per les operadores.

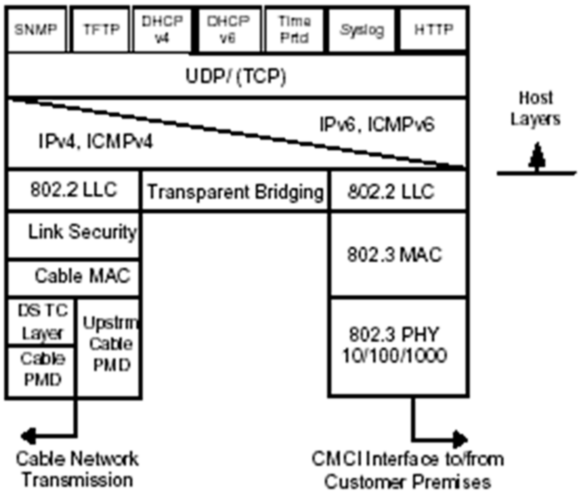
Transparent IP traffic



As cable operators have widely deployed high-speed data services on cable television systems, the demand for bandwidth has increased. Additionally, networks have scaled to such a degree that IPv4 address constraints are

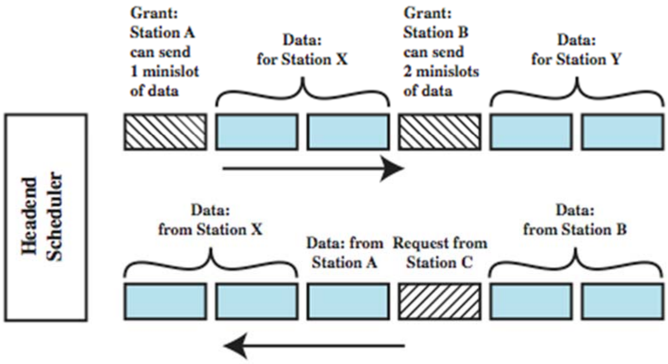
becoming a burden on network operations. To this end, CableLabs' member companies have decided to add new features to the DOCSIS specification for the purpose of increasing channel capacity, enhancing network security, expanding addressability of network elements, and deploying new service offerings. The DOCSIS system allows transparent bi-directional transfer of Internet Protocol (IP) traffic, between the cable system head-end and customer locations, over an all-coaxial or hybrid-fiber/coax (HFC) cable network. This is shown in simplified form in Figure.

Docsis Cable Modem protocols stack



Cal destacar el nivell de seguretat ja que la xarxa és compartida.

Cable Modem Scheme



A form of statistical TDM is typically used with Cable Modems, as illustrated in Figure. This also shows the request and allocation of upstream time slots.

DOCSIS 3.0 keys

• Downstream Channel Bonding with Multiple Receive Channels

• Upstream Channel Bonding with Multiple Transmit Channels

• IPv6

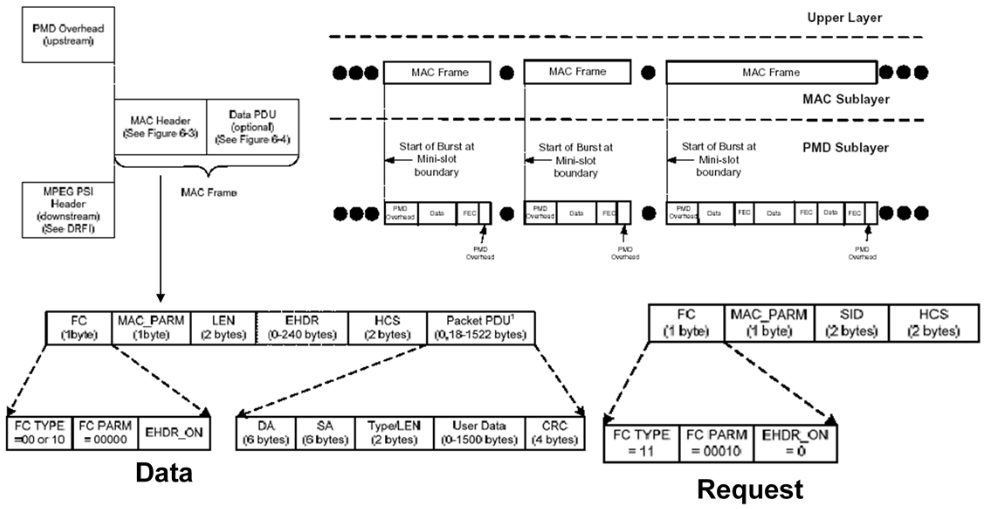
• Source-Specific Multicast

• Multicast QoS

• **Downstream Channel Bonding with Multiple Receive Channels:** DOCSIS 3.0 introduces the concept of a CM that receives simultaneously on multiple receive channels. Downstream Channel Bonding refers to the ability (at the MAC layer) to schedule packets for a single service flow across those multiple channels. Downstream Channel Bonding offers significant increases in the peak downstream data rate that can be provided to a single CM. • **Upstream Channel Bonding with Multiple Transmit Channels:** DOCSIS 3.0 introduces the concept of a CM that transmits simultaneously on multiple transmit channels. Upstream Channel Bonding, refers to the ability to schedule the traffic for a single upstream service flow across those multiple channels. Upstream Channel Bonding offers significant increases in the peak upstream data rate that can be provided to a single

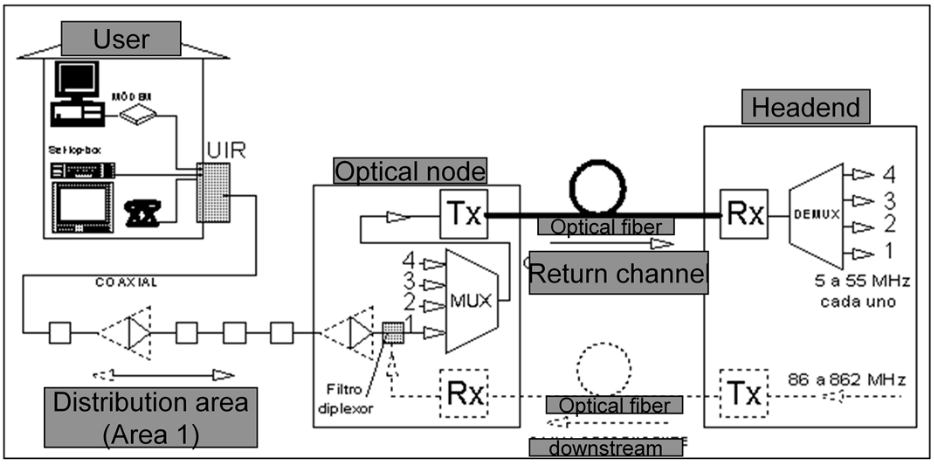
CM. DOCSIS 3.0 also introduces other enhancements in the upstream request-grant process that improve the efficiency of the upstream link. • **IPv6:** DOCSIS 3.0 introduces built-in support for the Internet Protocol version 6. DOCSIS 3.0 CMs can be provisioned with an IPv4 management address, an IPv6 management address, or both. Further, DOCSIS 3.0 CMs can provide transparent IPv6 connectivity to devices behind the cable modem (CPEs), with full support for Quality of Service and filtering. • **Source-Specific Multicast:** DOCSIS 3.0 supports delivery of Source-Specific IP Multicast streams to CPEs. Rather than extend the IP multicast protocol awareness of cable modems to support enhanced multicast control protocols, DOCSIS 3.0 takes a different approach. All awareness of IP multicast is moved to the CMTS, and a new DOCSIS-specific layer 2 multicast control protocol between the CM and CMTS is defined which works in harmony with downstream channel bonding and allows efficient and extensible support for future multicast applications. • **Multicast QoS:** DOCSIS 3.0 defines a standard mechanism for configuring the Quality of Service for IP multicast sessions. It introduces the concept of a "Group Service Flow" for multicast traffic that references a Service Class Name that defines the QoS parameters for the service flow.

DOCSIS MAC format



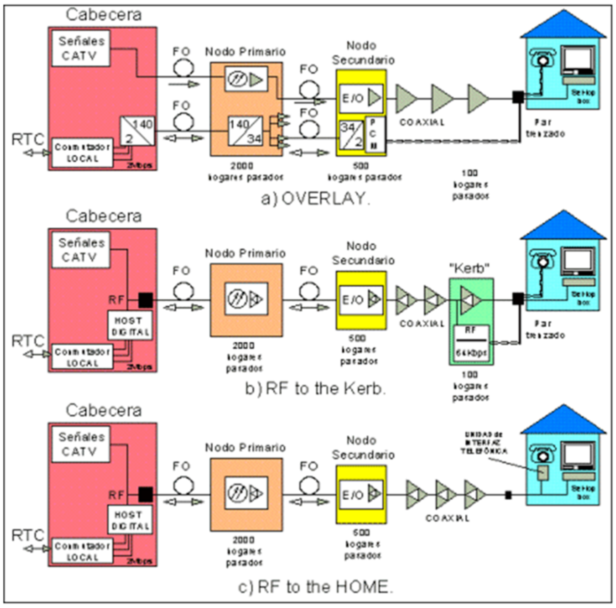
Format de les trames MAC de nivell 2.

HFC real network



Els canals de pujada es multiplexen sobre la xarxa de fibra òptica i es distribueixen, així com els canals de baixada, en analògic sobre el cable coaxial d’accés al usuari.

HFC telephone



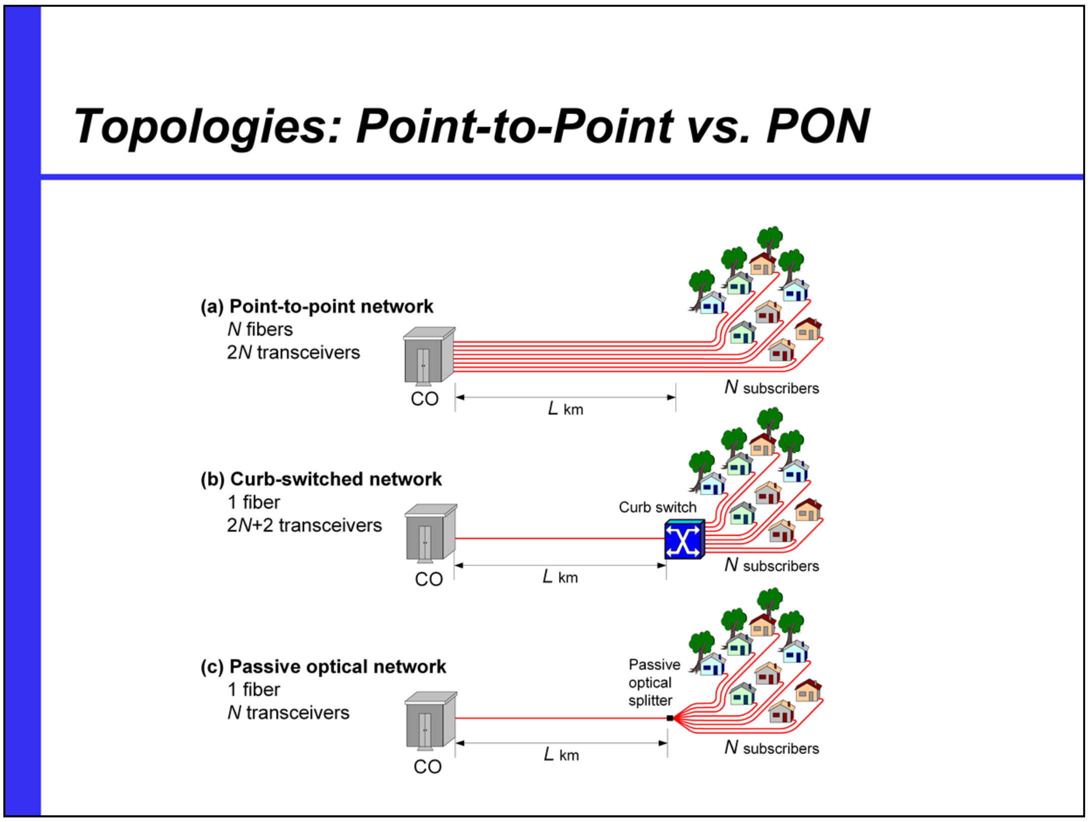
La solució adoptada és la Overlay.

4.3 Fibra òptica

Source: ITU-T G.984.3

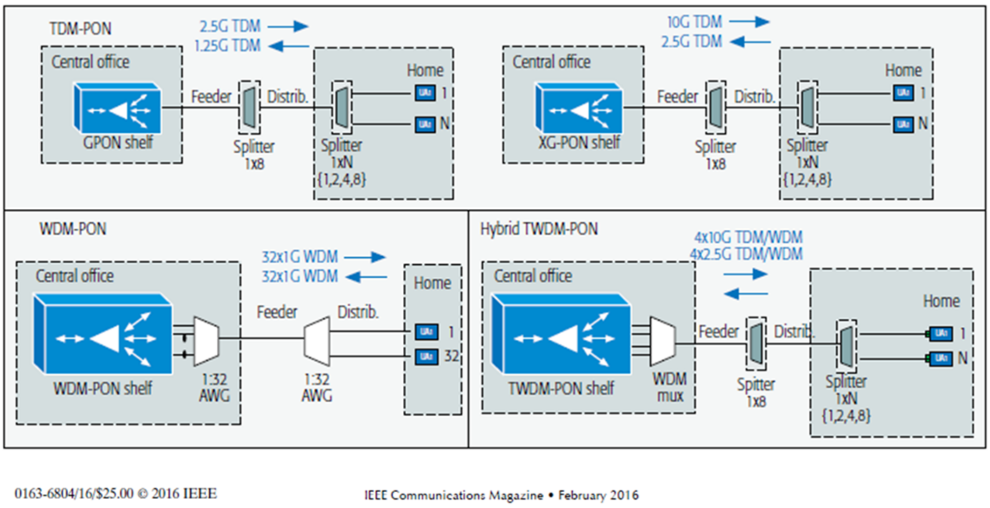
24

Referència: file:///C:/Users/German/Downloads/T-REC-G.984.3-200402-S!!PDF-S.pdf



La solució adptada és la tercera amb splitter pasiu

PON evolution



26

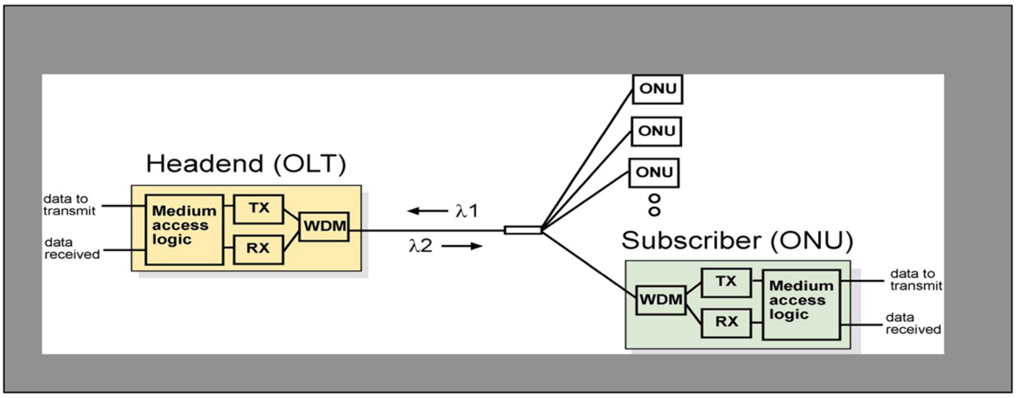
There is passive optical network (PON) technology available to provide 1 Gb/s services to end users, and a number of next-generation PON (NG-PON) standards to be completed very soon.

Gigabit PON (GPON), XGPON, and wavelength-division multiplexing (WDM)-PON standards with the new time-shared WDM (TWDM)-PON approaches concerning the provisioning of 1 Gb/s symmetrical

connectivity to residential customer.

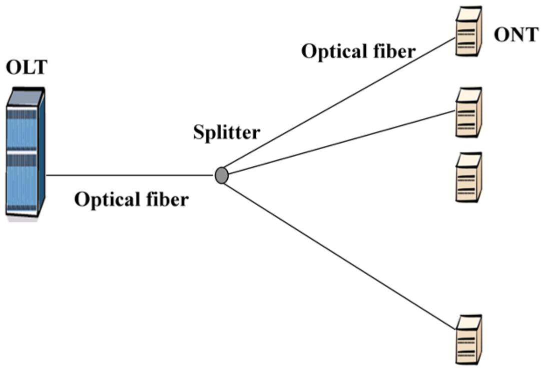
Single-Fiber PON

- Use 2 wavelength, but save fiber (repair and maintenance)
- Use TDM in the upstream to avoid collisions



GPON Technology

GPON: Gigabit Passive Optic Network



- **Optical Fiber**
- **Point to multipoint**
- **Several levels of splitting**
- **2.5 Gps DS and 1.25 Gbps US**
- **Up to 20 Km**
- **TDM DS and TDMA US**

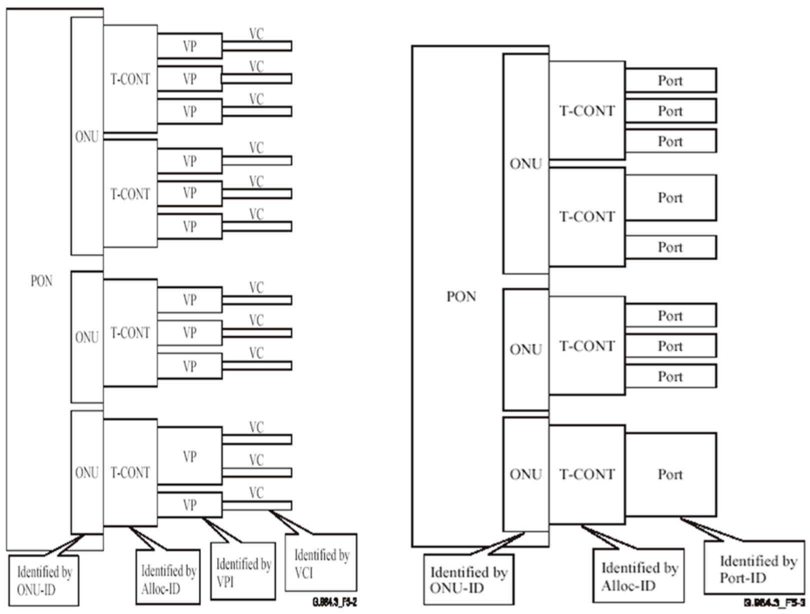
In downstream technology TDM is used. GPON frame is sloted between all users connected. Once the frame arrive to the splitter, this one sends the information that arrives to him by the entrance towards all the exits. This implies that all customers receive the same information, although each one extracts only directed to him.

In sense upstream technology TDMA is used. This means that, each user knows the slot that he has assigned and only he transmits then. Each user knows the moment exact at which he must transmit, of such form that splitter is able to recompose the complete frame with the information of all the users.

A mechanism between OLT and ONT exists (ranging) that among them compute the range and applies the necessary delays, so splitter can reconstruct the complete frame without collisions.

Each frame, as much upstream as downstream, use 125 µseg time range.

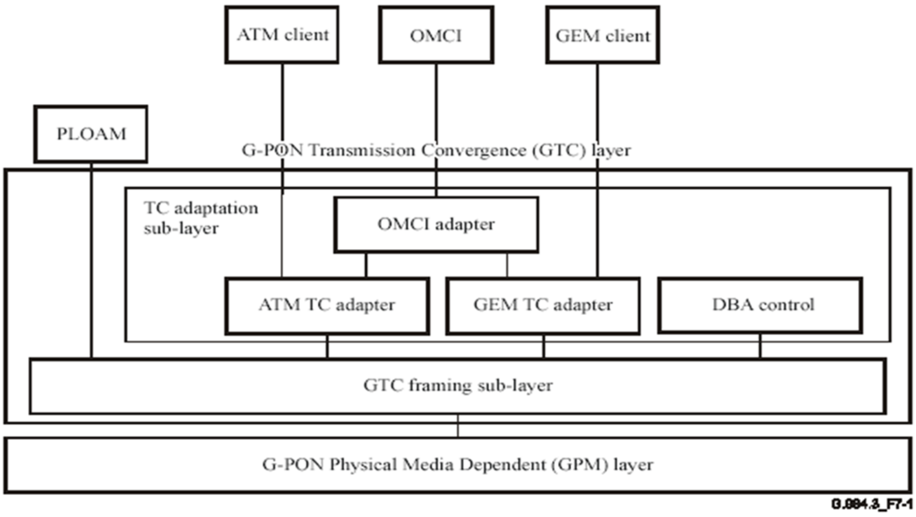
Multiplexed architecture



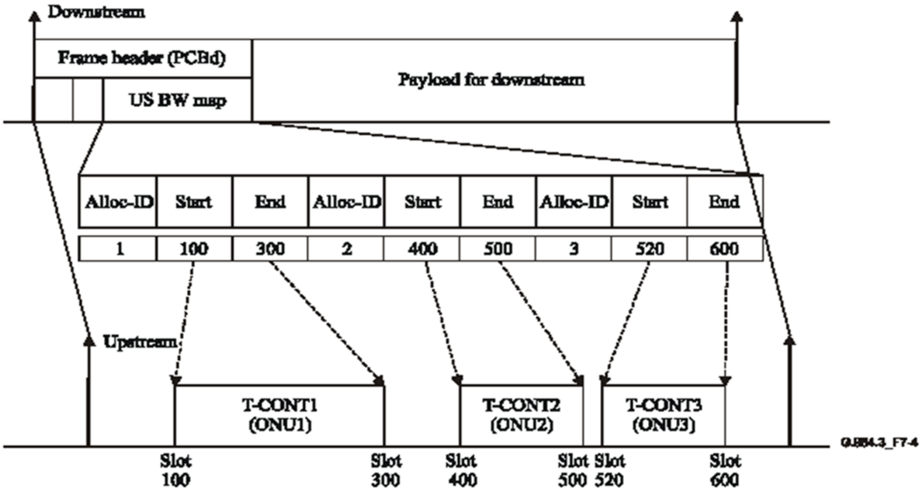
La multiplxeació ATM no es fa servir actualment. Referència: file:///C:/Users/German/Downloads/T-REC-G.984.3-200402-S!!PDF-S.pdf

Aquesta transparència i fins el final del tema estan explicades a la referència indicada des de el capítol 5 fins el 8.

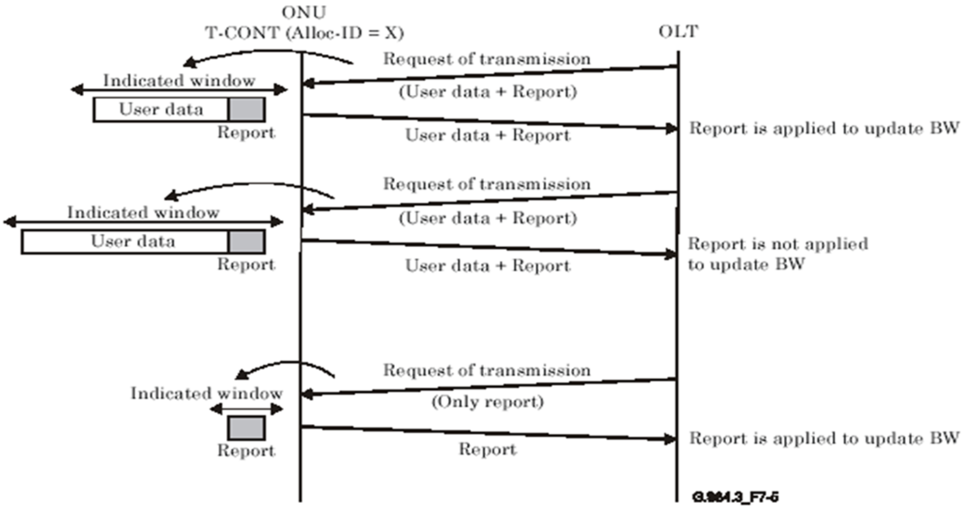
Protocol stack



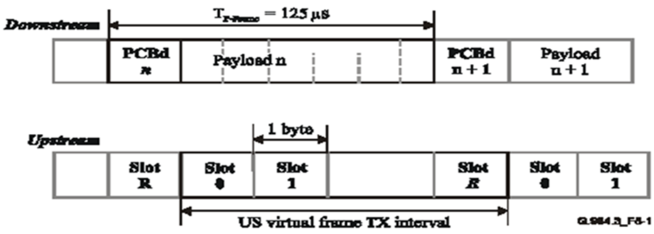
Media access control



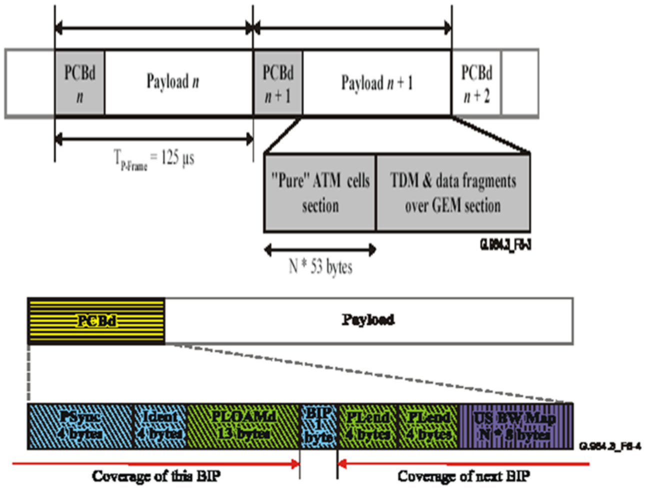
SR-DBA operation



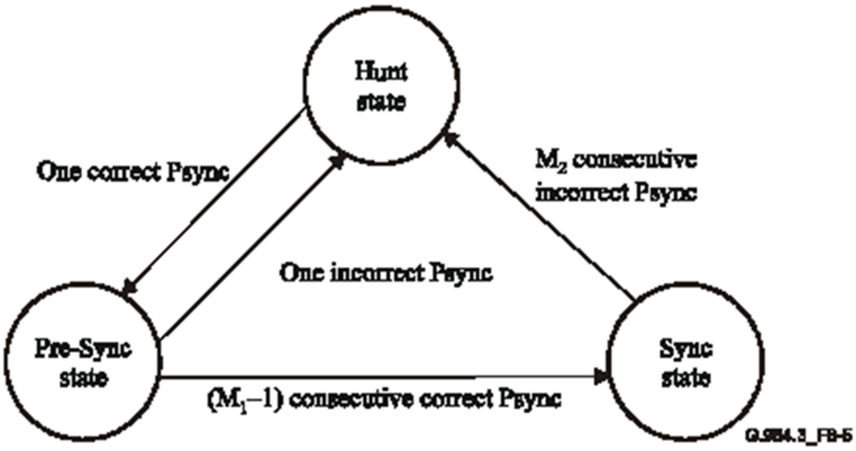
Frame structure



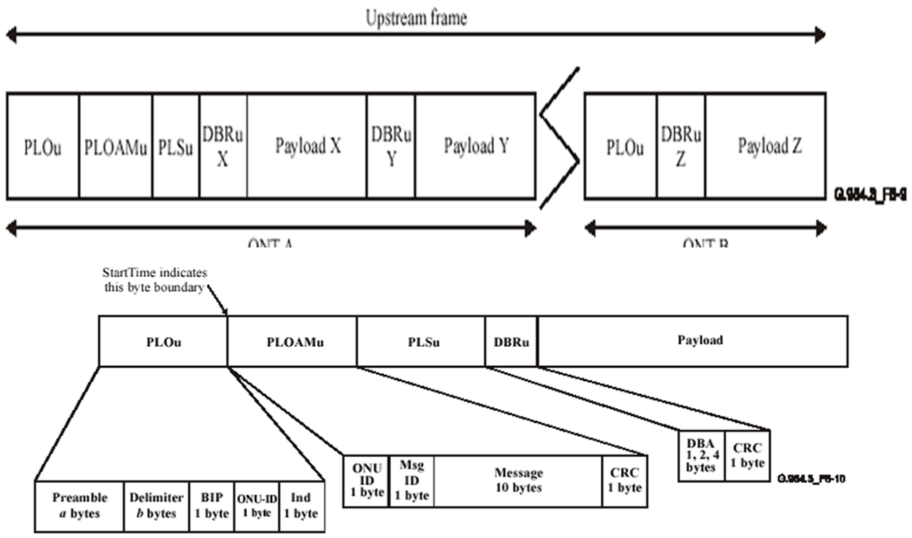
Downstream frame



Downstream synchronization



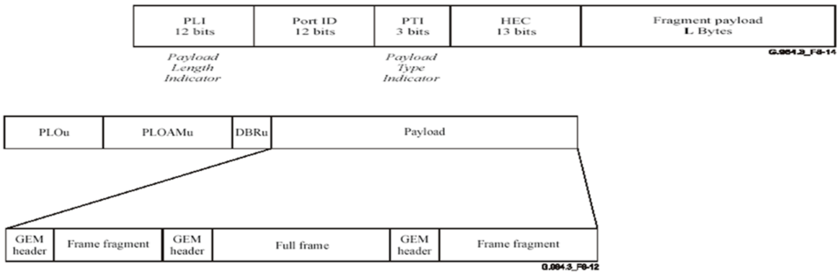
Upstream frame



IND field

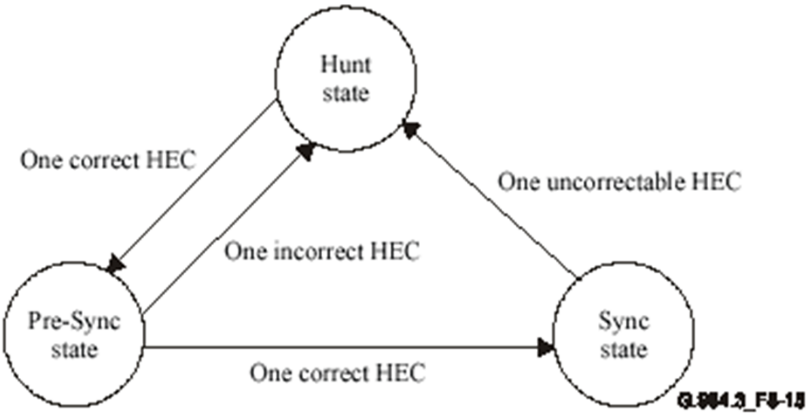
Bit position	Function
7 (MSB)	Urgent PLOAMu waiting (1 = PLOAM waiting, 0 = no PLOAMs waiting)
6	FEC status (1 = FEC ON, 0 = FEC OFF)
5	RDI status (1 = Defect, 0 = OK)
4	Traffic waiting in type 2 T-CONTs
3	Traffic waiting in type 3 T-CONTs
2	Traffic waiting in type 4 T-CONTs
1	Traffic waiting in type 5 T-CONTs
0 (LSB)	Reserved

GEM upstream payload

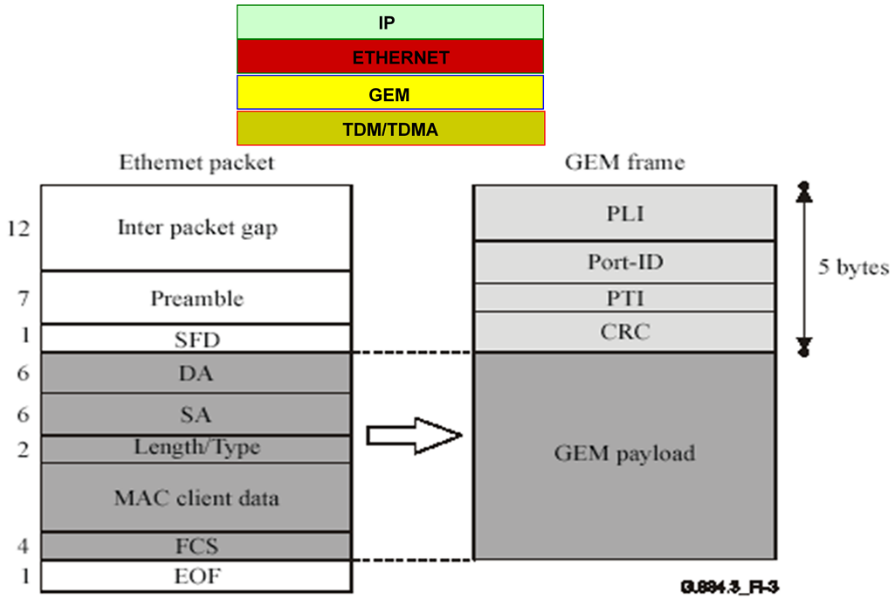


PTI code	Meaning
000	User data fragment, Congestion has Not occurred, Not the end of a frame
001	User data fragment, Congestion has Not occurred, End of a frame
010	User data fragment, Congestion Has occurred, Not the end of a frame
011	User data fragment, Congestion Has occurred, End of a frame
100	GEM OAM
101	Reserved
110	Reserved
111	Reserved

GEM delineation



Ethernet over GEM



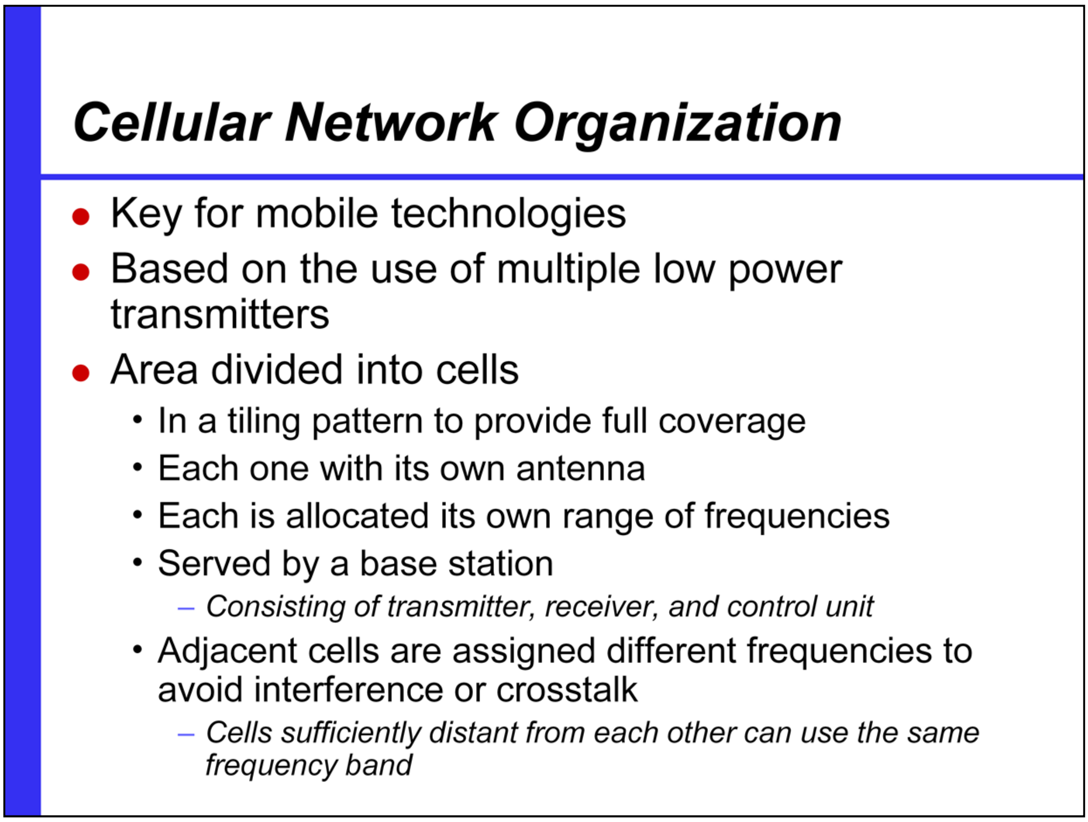
4.4 Mòbils

Book: Data and Computer Communications, Tenth Edition by William Stallings, (c) Pearson Education - Prentice Hall, 2013

Principles of Cellular Networks

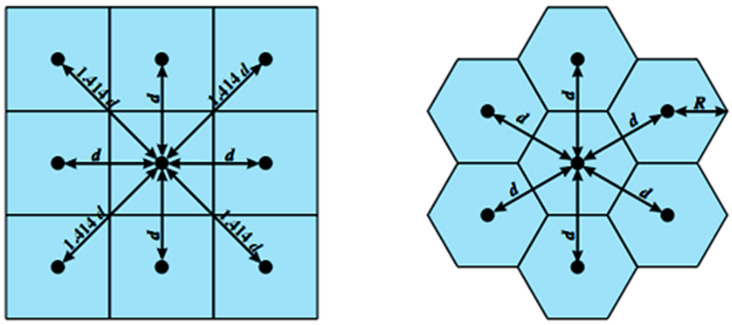
- Developed to increase the capacity available for mobile radio telephone service
- Prior to cellular radio:
  - Mobile service was only provided by a high powered transmitter/receiver
  - Typically supported about 25 channels
  - Had an effective radius of about 80km

Cellular radio is a technique that was developed to increase the capacity available for mobile radio telephone service. Prior to the introduction of cellular radio, mobile radio telephone service was only provided by a high-power transmitter/receiver. A typical system would support about 25 channels with an effective radius of about 80 km. The way to increase the capacity of the system is to use lower-power systems with shorter radius and to use numerous transmitters/receivers.



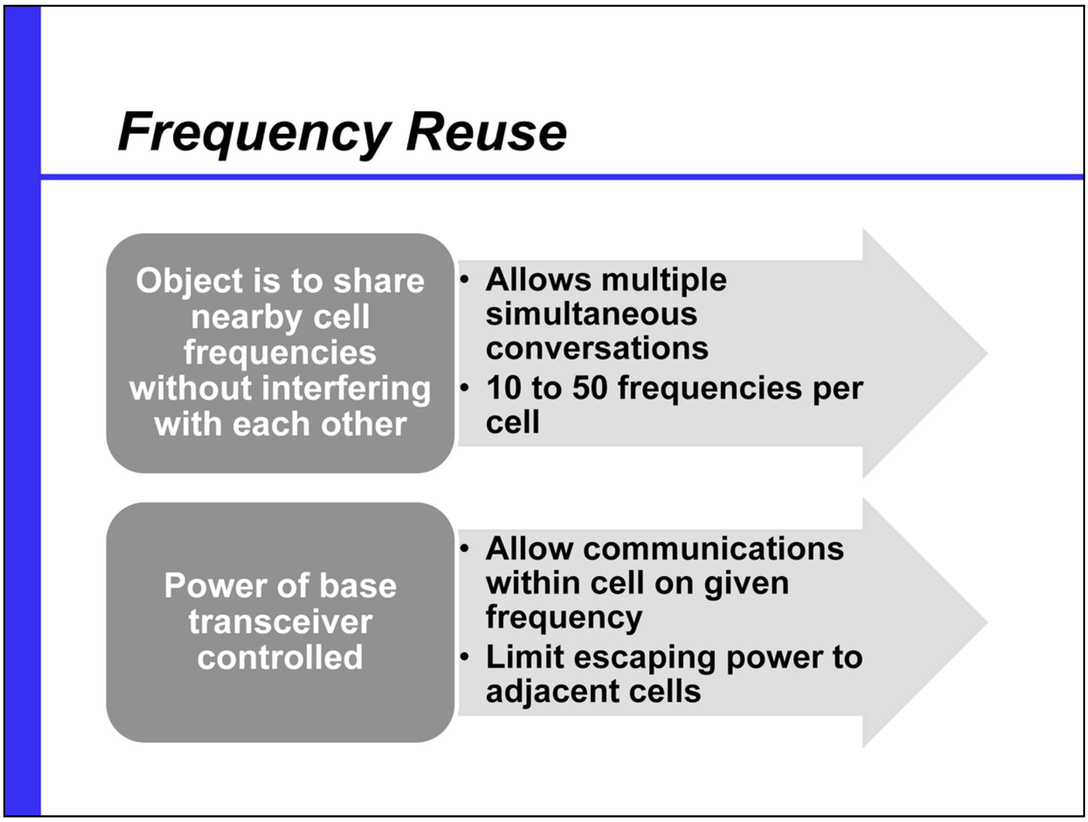
The essence of a cellular network is the use of multiple low-power transmitters, on the order of 100 W or less. Because the range of such a transmitter is small, an area can be divided into cells, each one served by its own antenna. Each cell is allocated a band of frequencies and is served by a **base station**, consisting of transmitter, receiver, and control unit. Adjacent cells are assigned different frequencies to avoid interference or crosstalk. However, cells sufficiently distant from each other can use the same frequency band.

Cellular Geometries



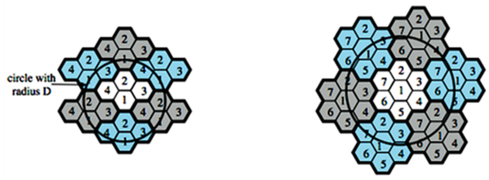
(a) Square pattern (b) Hexagonal pattern

The first design decision to make is the shape of cells to cover an area. A matrix of square cells would be the simplest layout to define (Stallings DCC9e Figure 14.1a). However, this geometry is not ideal. If the width of a square cell is *d*, then a cell has four neighbors at a distance *d* and four neighbors at a distance *d*. As a mobile user within a cell moves toward the cell's boundaries, it is best if all of the adjacent antennas are equidistant. This simplifies the task of determining when to switch the user to an adjacent antenna and which antenna to choose. A hexagonal pattern provides for equidistant antennas (Stallings DCC9e Figure 14.1b). The radius of a hexagon is defined to be the radius of the circle that circumscribes it (equivalently, the distance from the center to each vertex; also equal to the length of a side of a hexagon). For a cell radius *R*, the distance between the cell center and each adjacent cell center is $d = R$. In practice, a precise hexagonal pattern is not used. Variations from the ideal are due to topographical limitations, local signal propagation conditions, and practical limitation on sitting antennas. A wireless cellular system limits the opportunity to use the same frequency for different communications because the signals, not being constrained, can interfere with one another even if geographically separated. Systems supporting a large number of communications simultaneously need mechanisms to conserve spectrum.

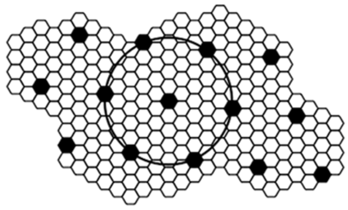


In a cellular system, each cell has a base transceiver. The transmission power is carefully controlled (to the extent that it is possible in the highly variable mobile communication environment) to allow communication within the cell using a given frequency while limiting the power at that frequency that escapes the cell into adjacent ones. The objective is to use the same frequency in other nearby (but not adjacent) cells, thus allowing the frequency to be used for multiple simultaneous conversations. Generally, 10 to 50 frequencies are assigned to each cell, depending on the traffic expected.

Frequency Reuse Patterns



(a) Frequency reuse pattern for $N = 4$ (b) Frequency reuse pattern for $N = 7$



(c) Black cells indicate a frequency reuse for $N = 19$

The essential issue is to determine how many cells must intervene between two cells using the same frequency so that the two cells do not interfere with each other. Various patterns of frequency reuse are possible. Stallings DCC9e Figure 14.2 shows some examples. If the pattern consists of N cells and each cell is assigned the same number of frequencies, each cell can have K/N frequencies, where K is the total number of frequencies allotted to the system. For AMPS (Section 14.2), $K = 395$, and $N = 7$ is the smallest pattern that can provide sufficient isolation between two uses of the same frequency. This implies that there can be at most 57 frequencies per cell on average.

In characterizing frequency reuse, the following parameters are commonly used:

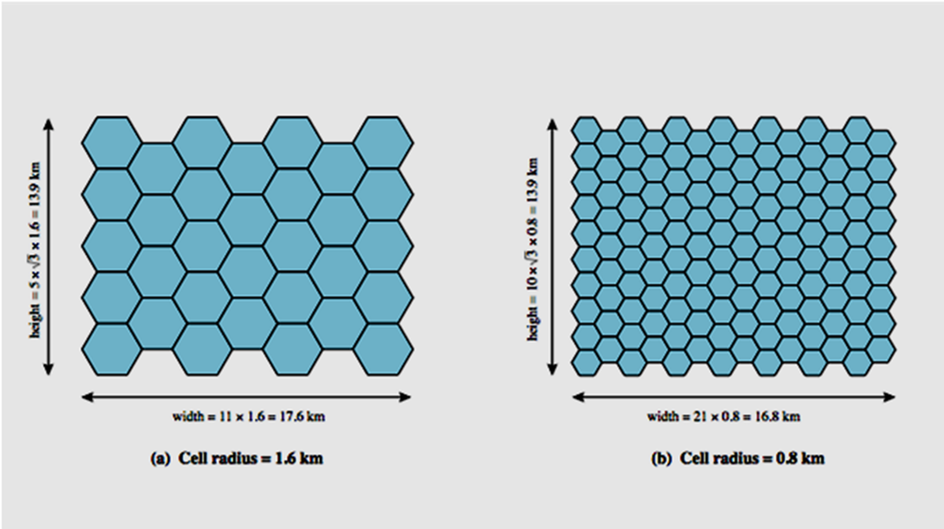
D = minimum distance between centers of cells that use the same band of frequencies (called cochannels)

R = radius of a cell

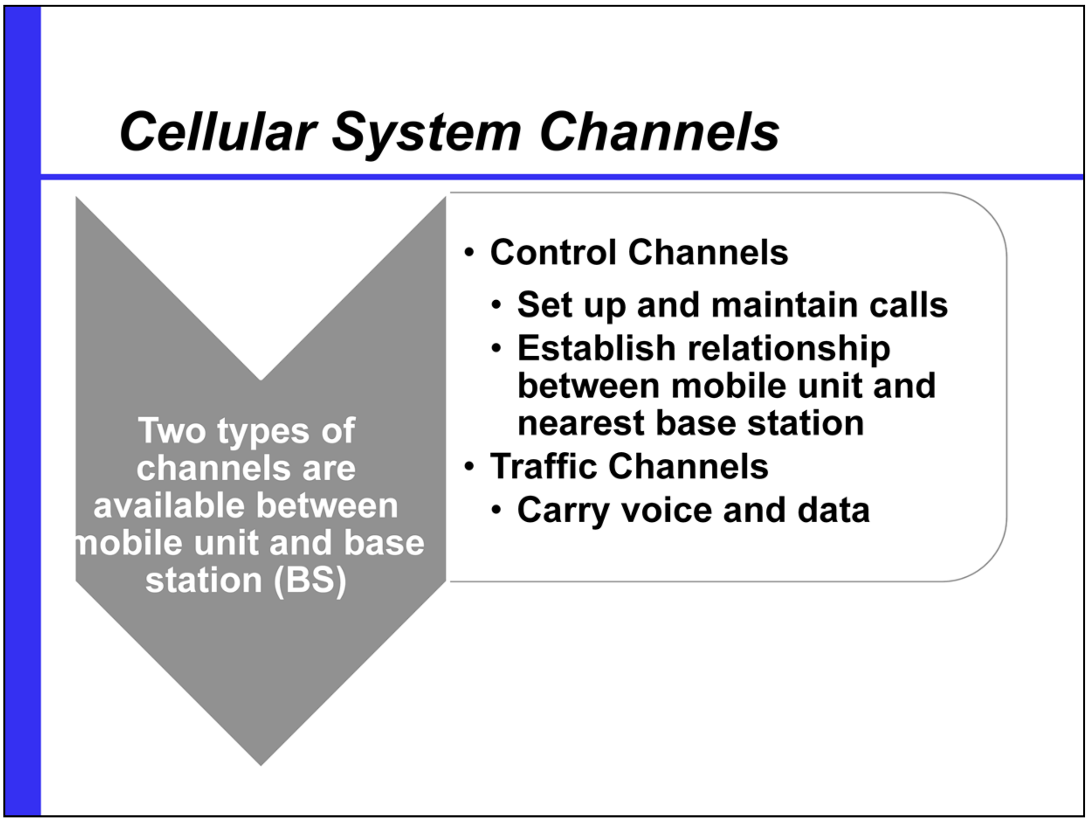
d = distance between centers of adjacent cells ($d = R$)

N = number of cells in a repetitious pattern (each cell in the pattern uses a unique band of frequencies), termed the **reuse factor**

Frequency Reuse Example



Assume a system of 32 cells with a cell radius of 1.6 km, a total of 32 cells, a total frequency bandwidth that supports 336 traffic channels, and a reuse factor of N = 7. If there are 32 total cells, what geographic area is covered, how many channels are there per cell, and what is the total number of concurrent calls that can be handled? Repeat for a cell radius of 0.8 km and 128 cells. Figure shows an approximately square pattern. A hexagon of radius 1.6 km has an area of 6.65 km2, and the total area covered is 6.65 × 32 = 213 km2. For N = 7, the number of channels per cell is 336/7 = 48, for a total channel capacity of 48 × 32 = 1536 channels. For the layout of Figure 14.4b, the area covered is 1.66 × 128 = 213 km2. The number of channels per cell is 336/7 = 48, for a total channel capacity of 48 × 128 = 6144 channels.



The use of a cellular system is fully automated and requires no action on the part of the user other than placing or answering a call. Two types of channels are available between the mobile unit and the base station (BS): control channels and traffic channels. **Control channels** are used to exchange information having to do with setting up and maintaining calls and with establishing a relationship between a mobile unit and the nearest BS. **Traffic channels** carry a voice or data connection between users.

Wireless Network Generations

Technol ogy	1G	2G	2. 5G	3G	4G
Design began	1970	1980	1985	1990	2000
Implementation	1984	1991	1999	2002	2012
Services	Analog voice	Digital voice	Higher capacity packetized data	Higher capacity, broadband	Completely IP based
Data rate	1.9. kbps	14.4 kbps	384 kbps	2 Mbps	200 Mbps
Multiplexing	FDMA	TDMA, CDMA	TDMA, CDMA	CDMA	OFDMA, SC-FDMA
Core network	PSTN	PSTN	PSTN, packet network	Packet network	IP backbone

Since their introduction in the mid-1980s, cellular networks have evolved rapidly. For convenience, industry and standards bodies group the technical advances into "generations." We are now up to the fourth generation (4G) of cellular network technology. Table lists some of the key characteristics of the cellular network generations.

First Generation (1G)

- Original cellular telephone networks
- Analog traffic channels
- Designed to be an extension of the public switched telephone networks
- The most widely deployed system was the Advanced Mobile Phone Service (AMPS)
- Also common in South America, Australia, and China

The original cellular telephone networks provided analog traffic channels; these are now referred to as first-generation systems. Since the early 1980s the most common first-generation system in North America has been the **Advanced Mobile Phone Service (AMPS)** developed by AT&T. This approach is also common in South America, Australia, and China. In North America, two 25-MHz bands were allocated to AMPS, one for transmission

from the base station to the mobile unit (869–894 MHz) and the other for transmission from the mobile to the base station (824–849 MHz). Each of these bands is split in two to encourage competition (i.e., in each market two operators can be accommodated). An operator is allocated only 12.5 MHz in each direction for its system. The channels are spaced 30 kHz apart, which allows a total of 416 channels per operator. Twenty-one channels are allocated for control, leaving 395 to carry calls. The control channels are data channels operating at 10 kbps. The conversation channels carry the conversations in analog using frequency modulation (FM). Simple

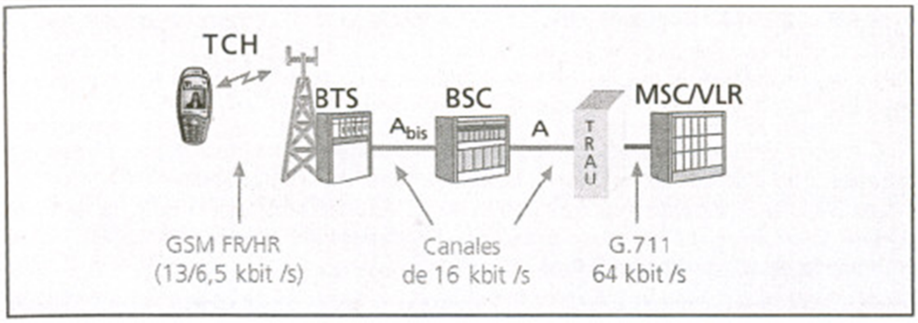
FDMA is used to provide multiple access. Control information is also sent on the conversation channels in bursts as data. This number of channels is inadequate for most major markets, so some way must be found either to use less bandwidth per conversation or to reuse frequencies. Both approaches have been taken in the various approaches to 1G telephony. For AMPS, frequency reuse is exploited.

Second Generation (2G)

- Developed to provide higher quality signals, higher data rates for support of digital services, and greater capacity
- Key differences between 1G and 2G include:
  - Digital traffic channels
  - Encryption
  - Error detection and correction
  - Channel access
    - *Time division multiple access (TDMA)*
    - *Code division multiple access (CDMA)*

First-generation cellular networks, such as AMPS, quickly became highly popular, threatening to swamp available capacity. Second-generation systems have been developed to provide higher quality signals, higher data rates for support of digital services, and greater capacity. [BLAC99b] lists the following as the key differences between the two generations: **Digital traffic channels:** The most notable difference between the two generations is that first-generation systems are almost purely analog, whereas second-generation systems are digital. In particular, the first-generation systems are designed to support voice channels using FM; digital traffic is supported only by the use of a modem that converts the digital data into analog form. Second-generation systems provide digital traffic channels. These readily support digital data; voice traffic is first encoded in digital form before transmitting. **Encryption:** Because all of the user traffic, as well as control traffic, is digitized in second-generation systems, it is a relatively simple matter to encrypt all of the traffic to prevent eavesdropping. All second-generation systems provide this capability, whereas first-generation systems send user traffic in the clear, providing no security. **Error detection and correction:** The digital traffic stream of second-generation systems also lends itself to the use of error detection and correction techniques, such as those discussed in Chapters 6 and 16. The result can be very clear voice reception. **Channel access:** In first-generation systems, each cell supports a number of channels. At any given time a channel is allocated to only one user. Second-generation systems also provide multiple channels per cell, but each channel is dynamically shared by a number of users using time division multiple access (TDMA) or code division multiple access (CDMA).

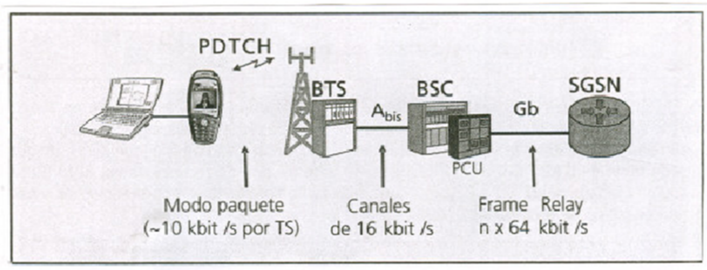
2G GSM



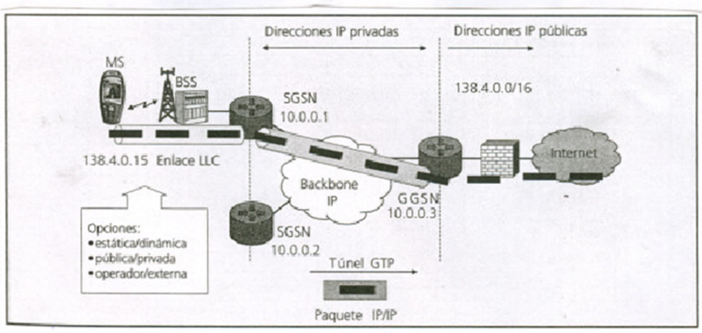
52

Arquitectura de GSM formada per l'antena (BTS), el concentrador d'antenes (BSC) i el commutador de circuits (MSC).

2.5G GPRS



Data transport



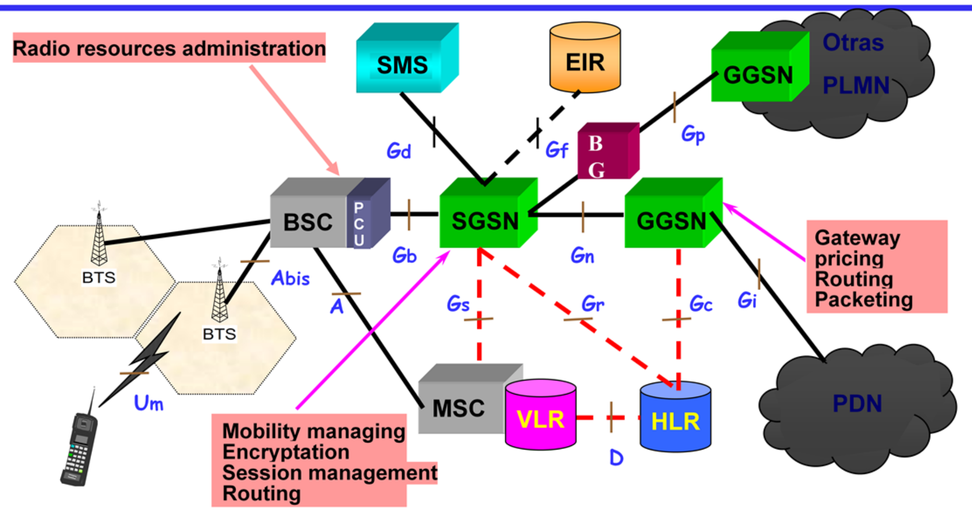
Tunneling

53

GPRS introdueix el commutador de paquets SGSN.

La xarxa IP interna crea túnels amb adreçament privat.

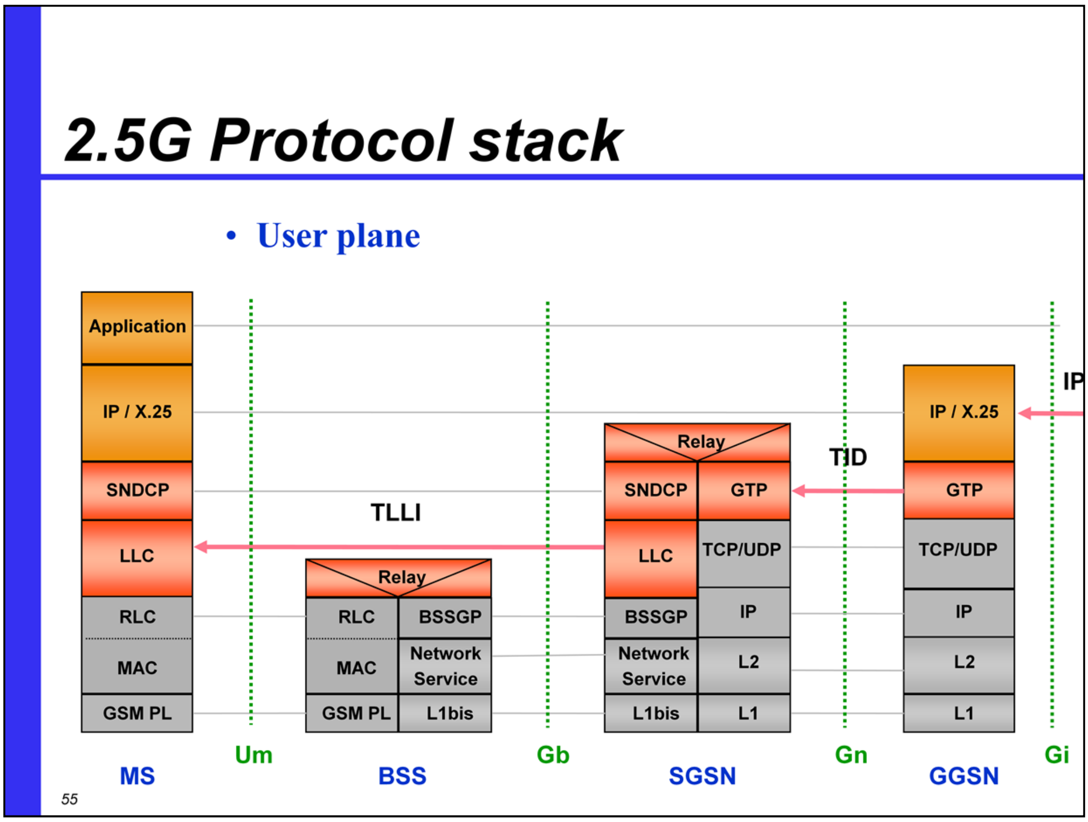
2.5G GPRS system architecture



SGSN Serving GPRS Support Node
GGSN Gateway GPRS Support Node
PDN Packet Data Network
PCU Packet Control Unit

54

SGSN és un commutador de paquets. GGSN és el gateway.



Torres de protocols dels core network.

Referència: https://www.sciencedirect.com/topics/computer-science/protocol-stack

Third Generation (3G)

- Objective is to provide high-speed wireless communications to support multimedia, data, and video in addition to voice

3G capabilities:

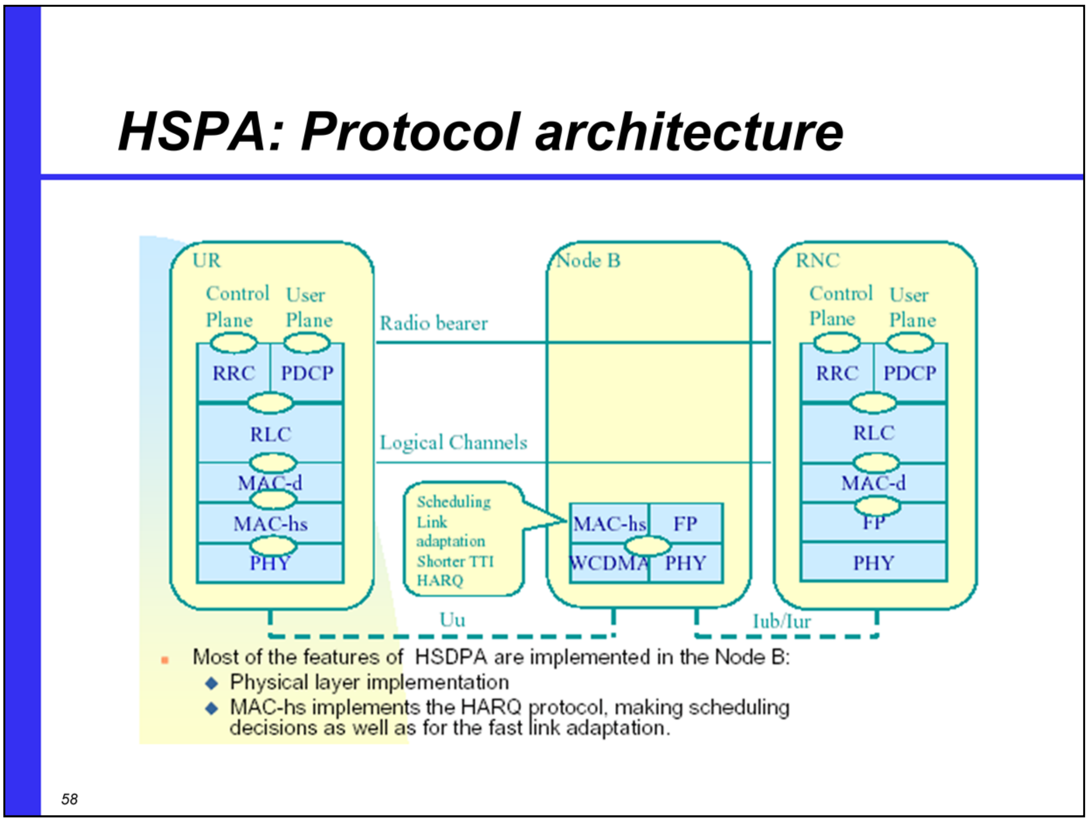
- Voice quality comparable to PSTN
- 144 kbps available to users in high-speed motor vehicles over large areas
- 384 kbps available to pedestrians standing or moving slowly over small areas
- Support for 2.048 Mbps for office use
- Symmetrical and asymmetrical data rates
- Support for both packet-switched and circuit-switched data services
- Adaptive interface to Internet
- More efficient use of available spectrum
- Support for a wide variety of mobile equipment
- Flexibility to allow the introduction of new services and technologies

The objective of the third generation (3G) of wireless communication is to provide fairly high-speed wireless communications to support multimedia, data, and video in addition to voice. The ITU's International Mobile Telecommunications for the year 2000 (IMT-2000) initiative has defined the third-generation capabilities as:Voice quality comparable to the public switched telephone network, 144 kbps data rate available to users in high-speed motor vehicles over large areas, 384 kbps available to pedestrians standing or moving slowly over small areas, Support (to be phased in) for 2.048 Mbps for office use, Symmetrical and asymmetrical data transmission rates, Support for both packet-switched and circuit-switched data services, An adaptive interface to the Internet to reflect efficiently the common asymmetry between inbound and outbound traffic, , More efficient use of the available spectrum in general, Support for a wide variety of mobile equipment, Flexibility to allow the introduction of new services and technologies

3.5G HSPA (High Speed Packet Access)

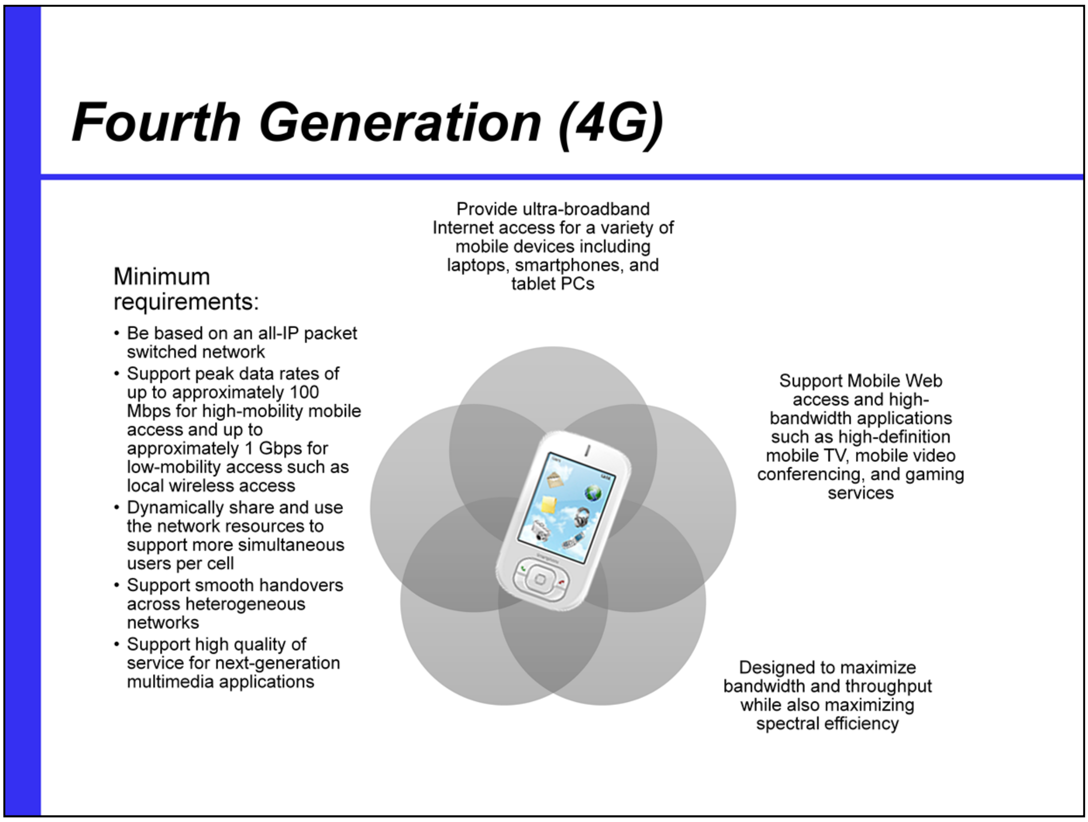
- In order to improve the packet data performance, the UMTS systems have been enhanced with HSPA.
- HSPA consists of two components, HSDPA and HSUPA:
- In the DL a new shared transport channel, the HS-DSCH
  - It allows to assign all available resource to one or more users in an efficient manner.
  - HS-DSCH does no adjust to transmission power for each user, but rather adapts the rate to match the current channel conditions.
- In the UL dedicated channels have been enhanced: E-DCHs
  - Even though the UL channels are dedicated, the UL resources can be shared between users in an efficient manner.

57



El nivell 2 afegeix un nou nivell MAC que permet fer scheduling i triar els terminals amb millor relació senyal/soroll.

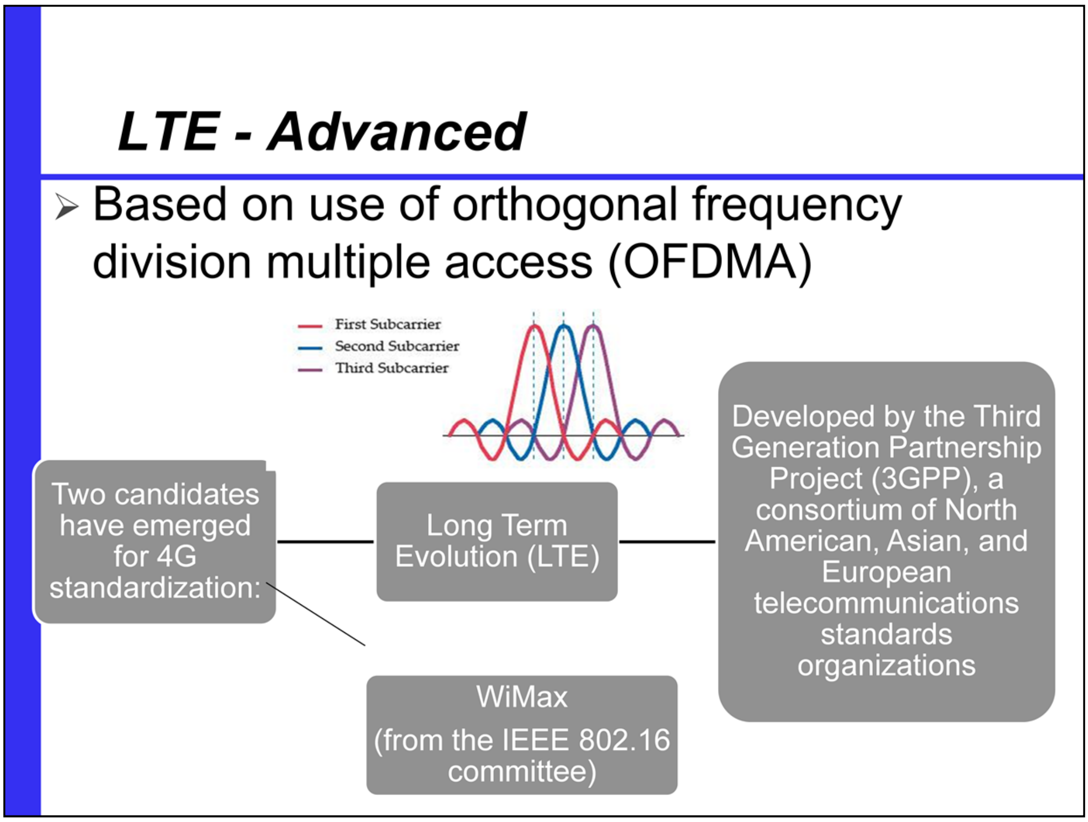
HSDPA és de baixada i HSUPA de pujada.



The evolution of smartphones and cellular networks has ushered in a new generation of capabilities and standards, which is collectively called 4G. 4G systems provide ultra-broadband Internet access for a variety of mobile devices including laptops, smartphones, and tablet PCs. 4G networks support Mobile Web access and high-bandwidth applications such as high-definition mobile TV, mobile video conferencing, and gaming services.

These requirements have led to the development of a fourth generation (4G) of mobile wireless technology that is designed to maximize bandwidth and throughput while also maximizing spectral efficiency. The ITU has issued directives for 4G networks. According to the ITU, an IMT-Advanced (or 4G) cellular system must fulfill a number of minimum requirements, including the following: • Be based on an all-IP packet switched network.

• Support peak data rates of up to approximately 100 Mbps for high-mobility mobile access and up to approximately 1 Gbps for low-mobility access such as local wireless access. • Dynamically share and use the network resources to support more simultaneous users per cell. • Support smooth handovers across heterogeneous networks. • Support high quality of service for next-generation multimedia applications. In contrast to earlier generations, 4G systems do not support traditional circuit-switched telephony service, providing only IP telephony services. And, as may be observed in Table 10.1, the spread spectrum radio technologies that characterized 3G systems are replaced in 4G systems by OFDMA (orthogonal frequency-division multiple access) multicarrier transmission and frequency-domain equalization schemes.

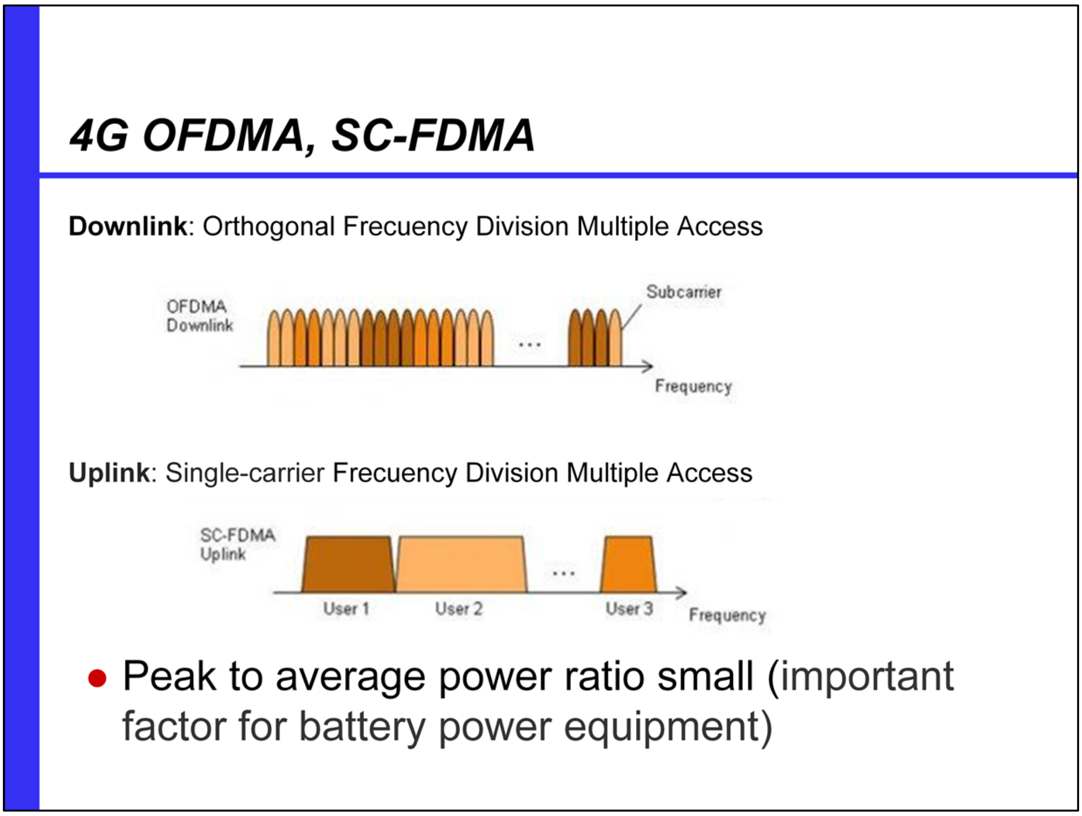


Two candidates emerged for 4G standardization. One is known as Long Term Evolution (LTE) , which has been developed by the Third Generation Partnership Project (3GPP), a consortium of Asian, European, and North American telecommunications standards organizations. The other effort is from the IEEE 802.16 committee, which has developed standards for high-speed fixed wireless operations known as WiMAX (described in Chapter 18). The committee has specified an enhancement of WiMAX to meet 4G needs. The two efforts are similar in terms of both performance and technology. Both are based on the use of orthogonal frequency-division multiple access (OFDMA) to support multiple access to network resources. WiMAX uses a pure OFDMA approach of both uplink (UL) and downlink (DL). LTE uses pure OFDMA on the downlink but a technique that is based on OFDMA offers enhanced power efficiency for the uplink. While WiMAX retains a role as the technology for fixed broadband wireless access, LTE has become the universal standard for 4G wireless. For example, all of the major carriers in the United States, including AT&T and Verizon, have adopted a version of LTE based on frequency-division duplex (FDD), whereas China Mobile, the world's largest telecommunication carrier, has adopted a version of LTE based on time-division duplex (TDD).

Comparison of Performance Requirements for LTE and LTE-Advanced

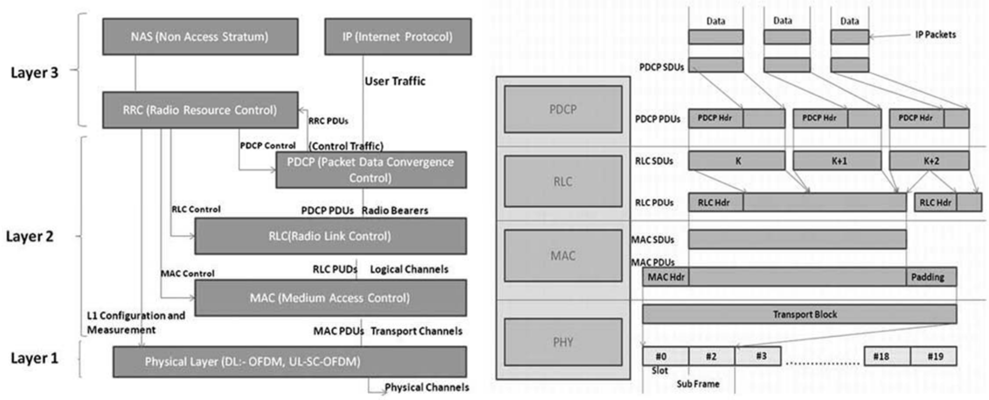
System Performance		LTE	LTE-Advanced
Peak rate	Downlink	100 Mbps @20 MHz	1 Gbps @100 MHz
	Uplink	50 Mbps @20 MHz	500 Mbps @100 MHz
Control plane delay	Idle to connected	<100 ms	< 50 ms
	Dormant to active	<50 ms	< 10 ms
User plane delay		< 5ms	Lower than LTE
Spectral efficiency (peak)	Downlink	5 bps/Hz @2×2	30 bps/Hz @8×8
	Uplink	2.5 bps/Hz @1×2	15 bps/Hz @4×4
Mobility		Up to 350 km/h	Up to 350—500 km/h

LTE development began in the 3G era and its initial releases provided 3G or enhanced 3G services. Beginning with release 10, LTE provides a 4G service, known as LTE-Advanced . Table 10.2 compares the performance goals of LTE and LTE-Advanced.



Per diferents raons d'eficiència, s'ha escollit OFDMA per a la baixada, i SC-FDMA per a la pujada com a tecnologies d'accés al medi.
S'observa com el medi és compartit per els diferents usuaris, representats per els diferents colors.
En l'accés de pujada, un terminal té assignat tota l'amplada de banda d'una part de l'espectre.

4G Protocols



Referència:

http://www.tutorialspoint.com/lte/lte_protocol_stack_layers.htm