Capítol 4. Xarxes d'accés

4.1 Parell de coure

4.2 Cable coaxial

4.3 Fibra òptica

4.5 Mòbils

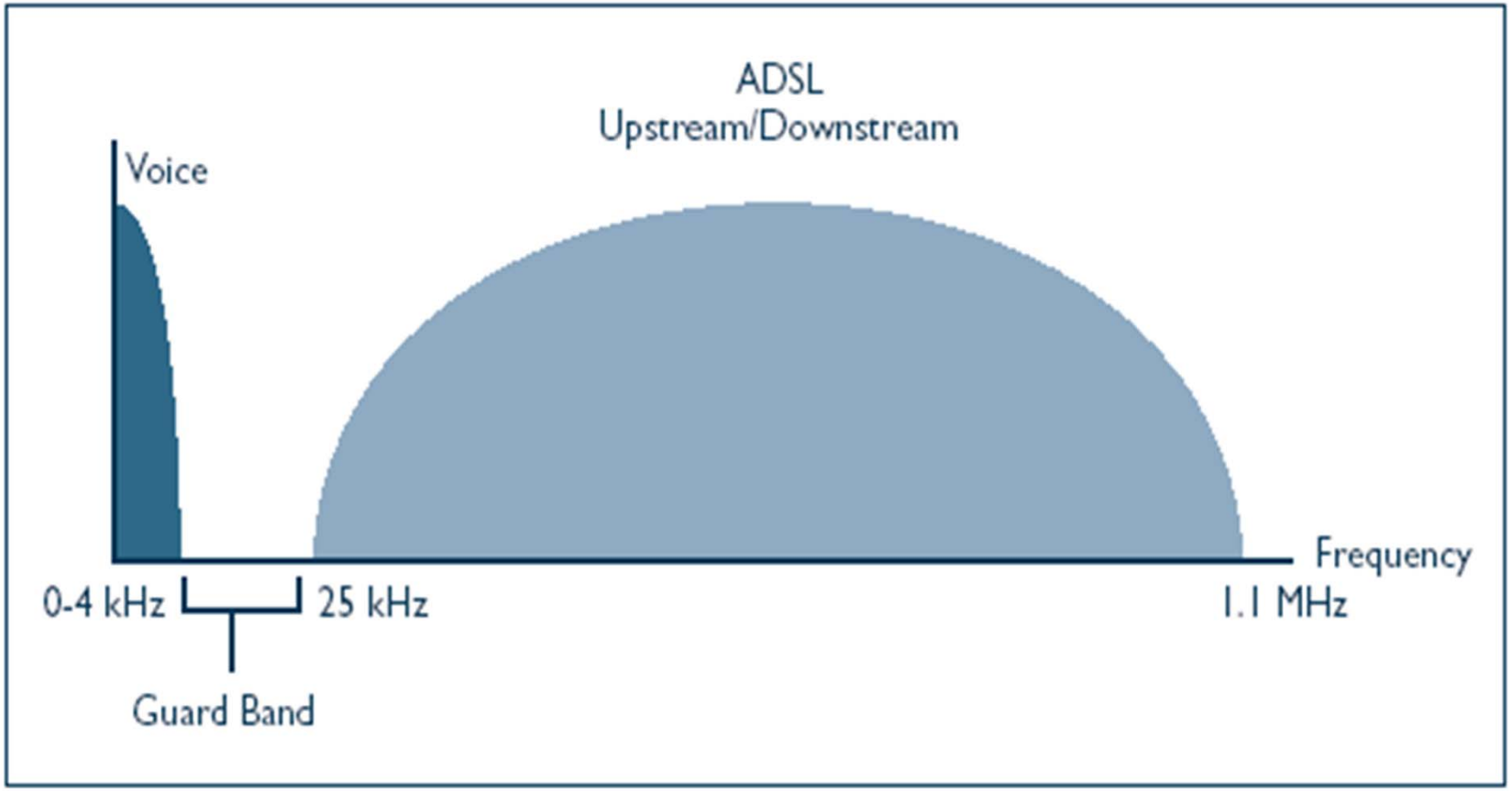
4.1 Parell de coure

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

xDSL technologies

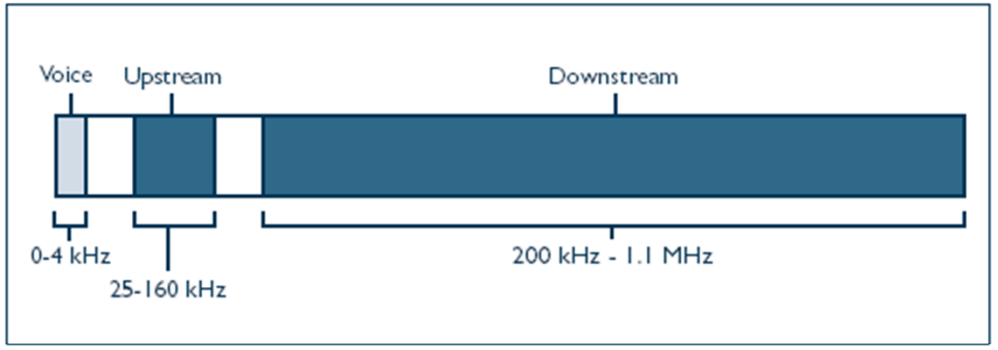
A whole family of technologies for data transmission over the copper pair is referred to as xDSL, where "x" is replaced starting in each case by the letters that distinguish each mode. In general xDSL is a set of technologies that provide high bandwidth over local loop copper wire without signal amplifiers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

Splitting the frequencies

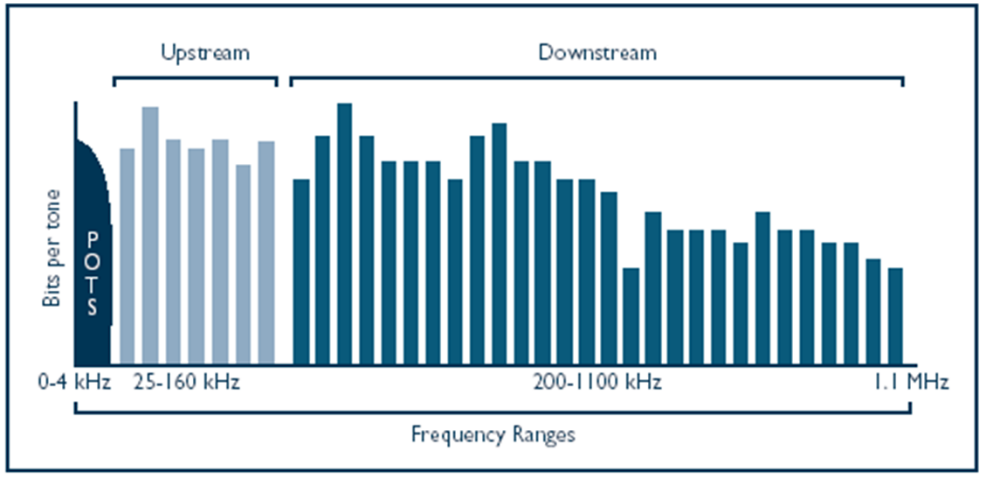


Modulation.

CAP



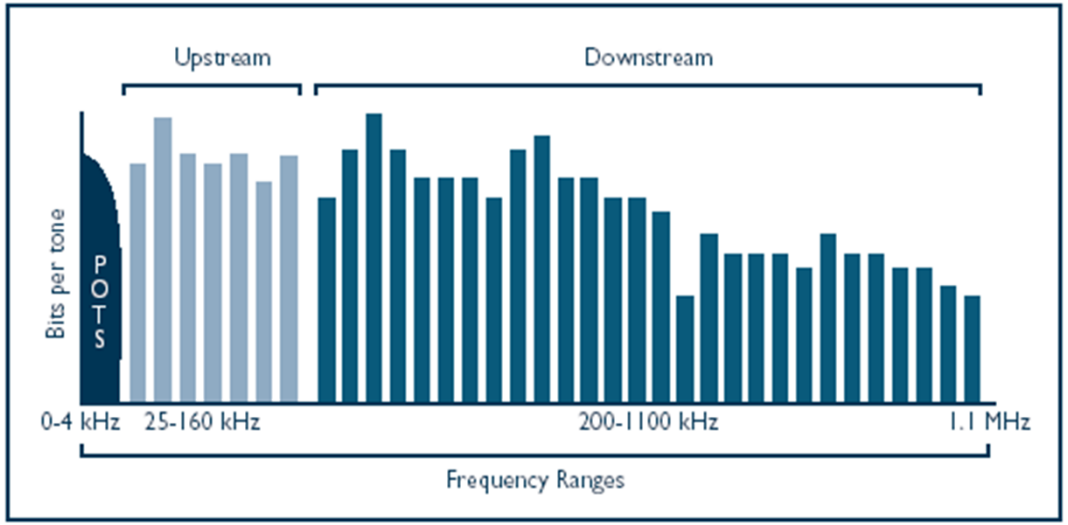
DMT



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.

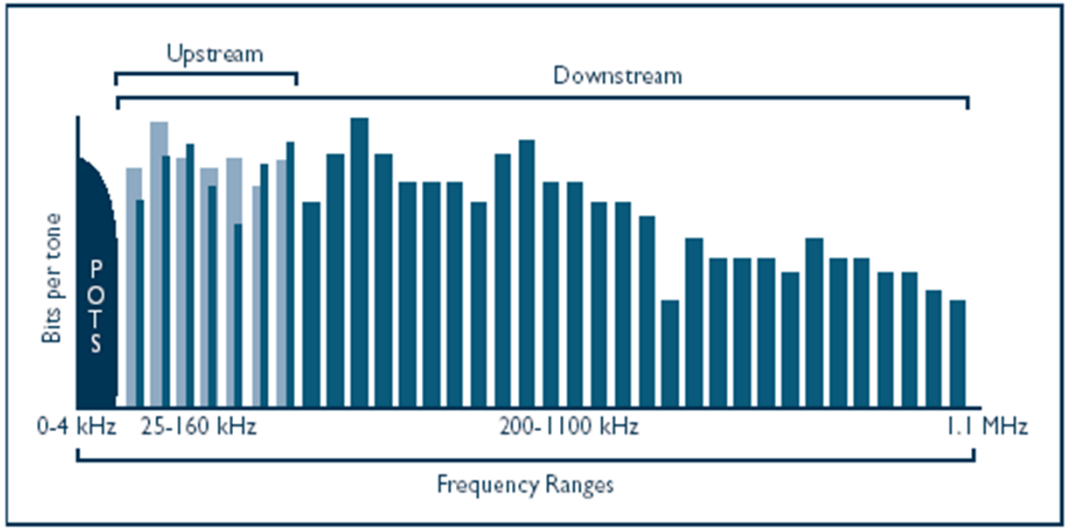
FDM and Echo cancellation

FDM



UP: 25 carriers
DW: 224 sub carriers

EC



UP: 25 carriers
DW: 250 sub carriers

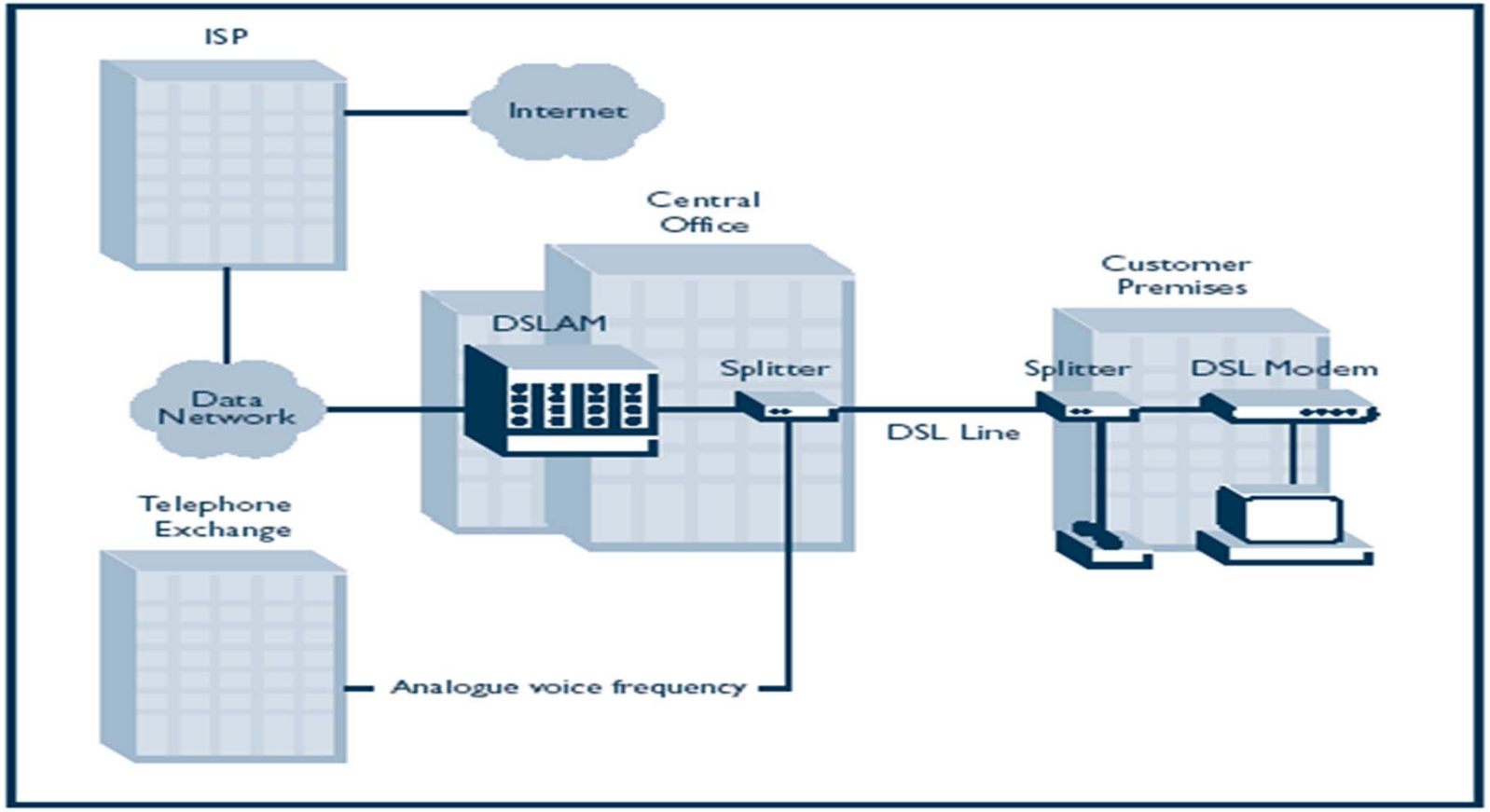
ADSL concept

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.

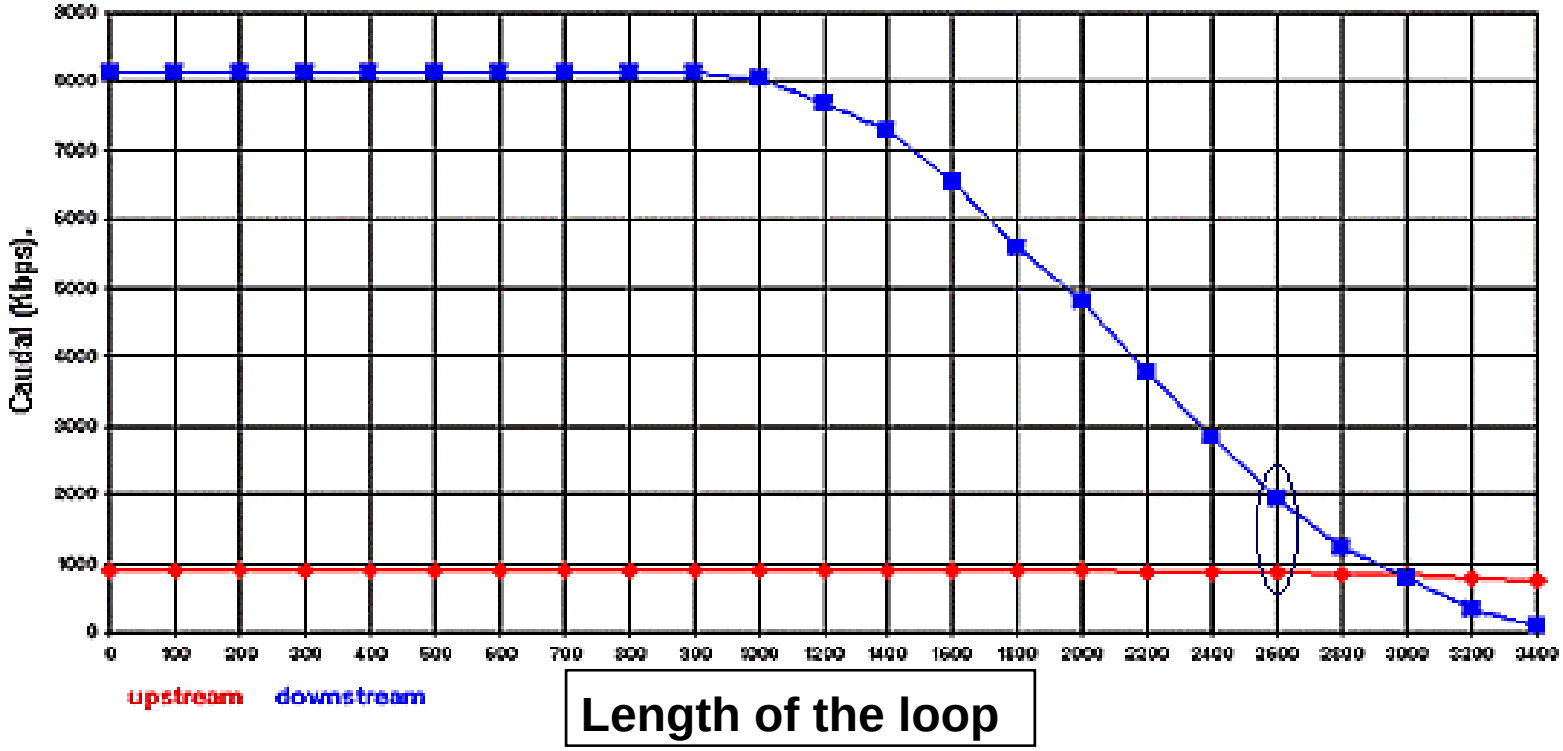
Standards

- 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.

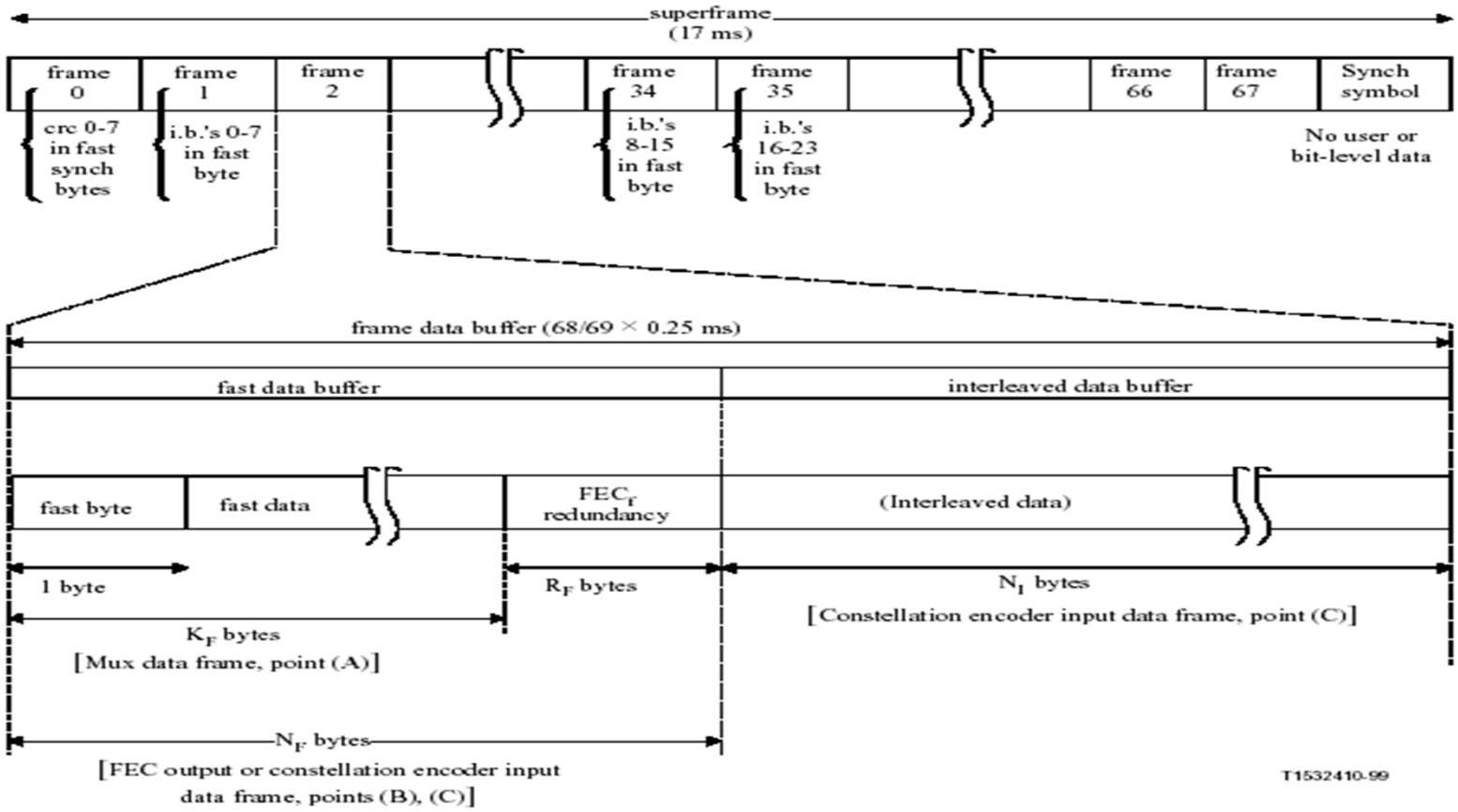
ADSL network setup



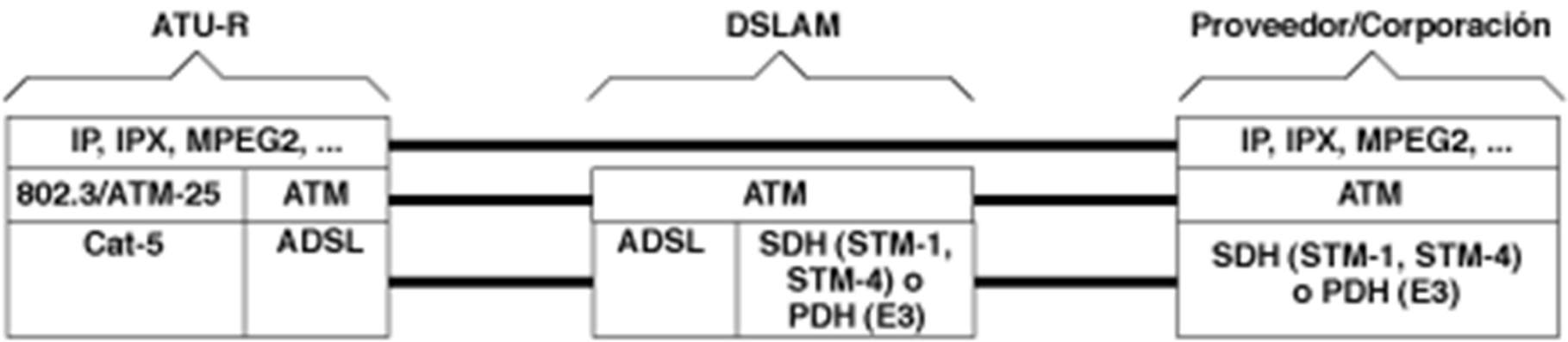
Performance of ADSL. Throughput



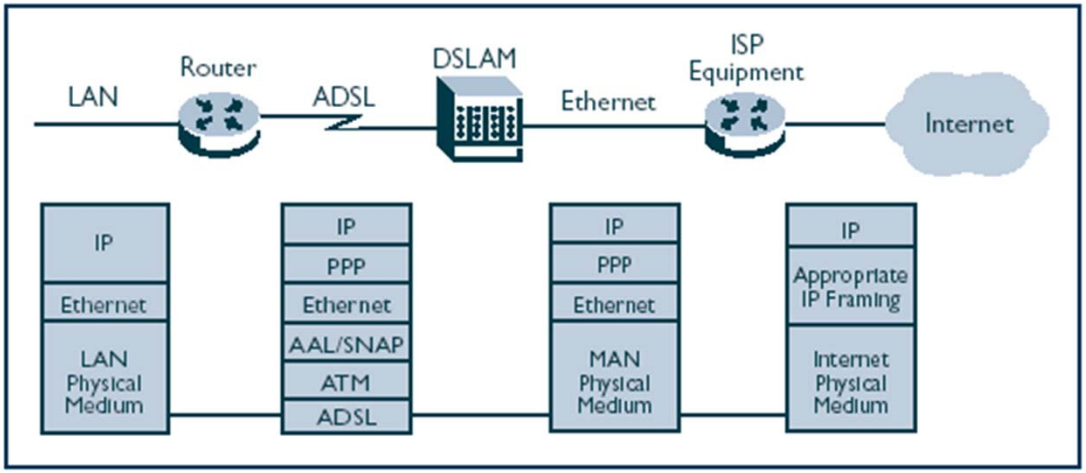
Super frame ADSL



OSI model



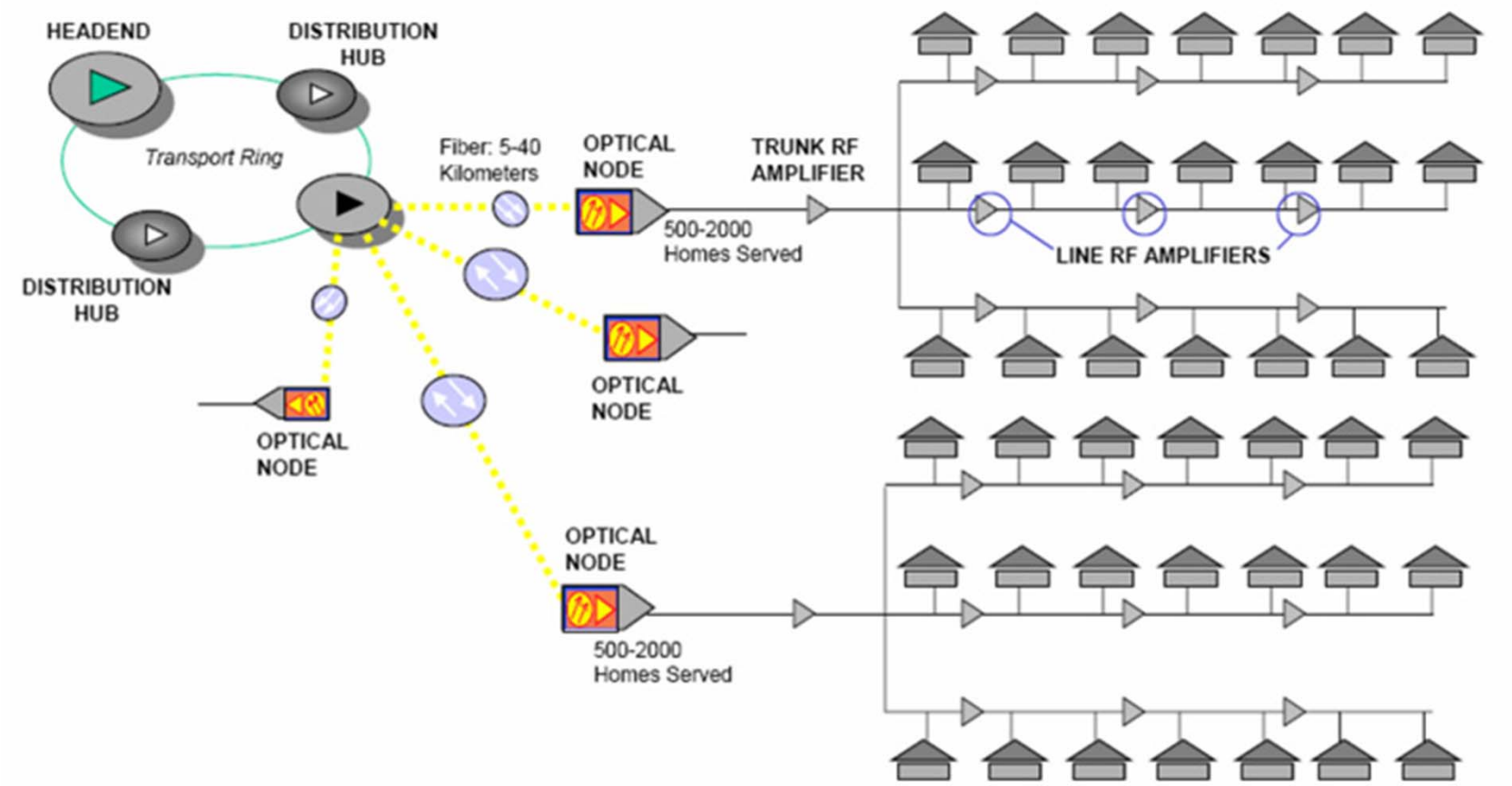
PPPoE / PPPoATM



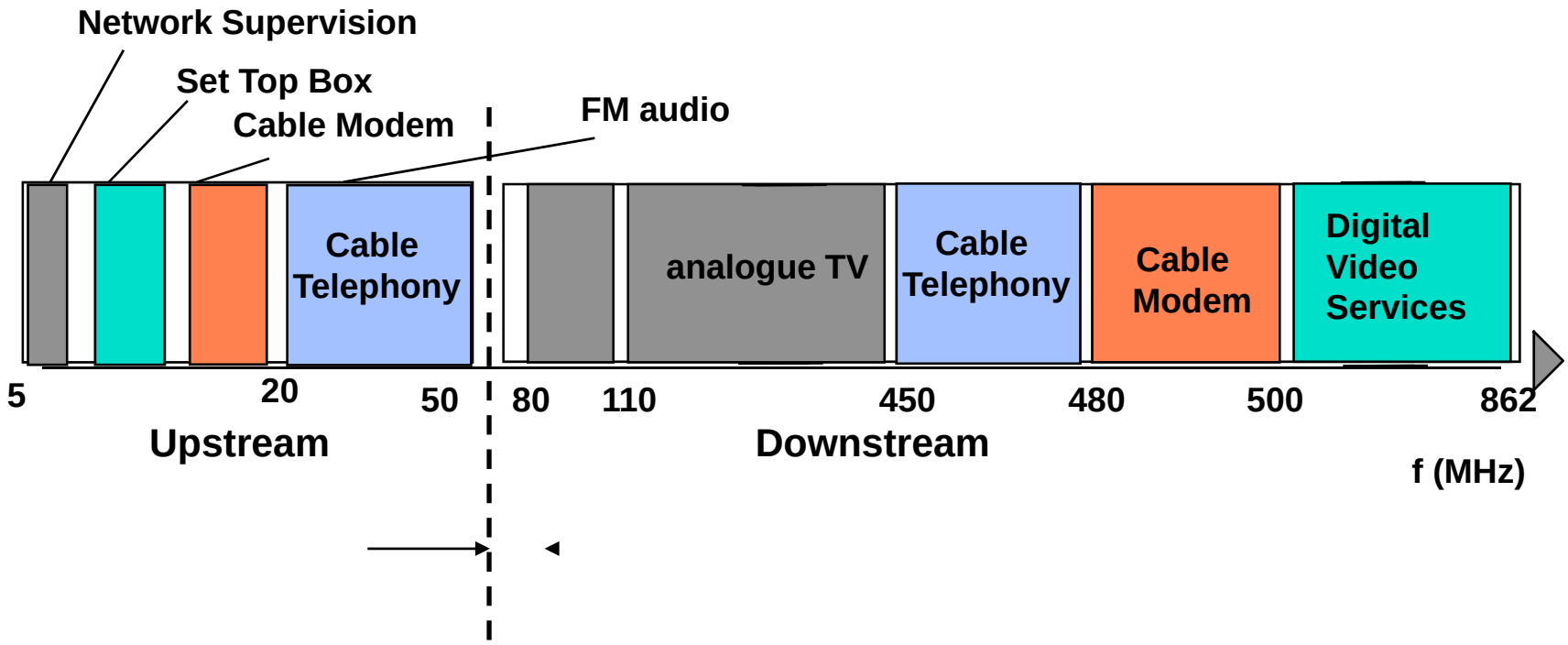
4.2 Cable coaxial

Source: Cablelabs
CM-SP-CMCIv3.0-I01-080320 Data-Over-Cable Service Interface Specifications
CM-SP-MULPIv3.0-I10-090529 MAC and Upper Layer Protocols Interface Specification

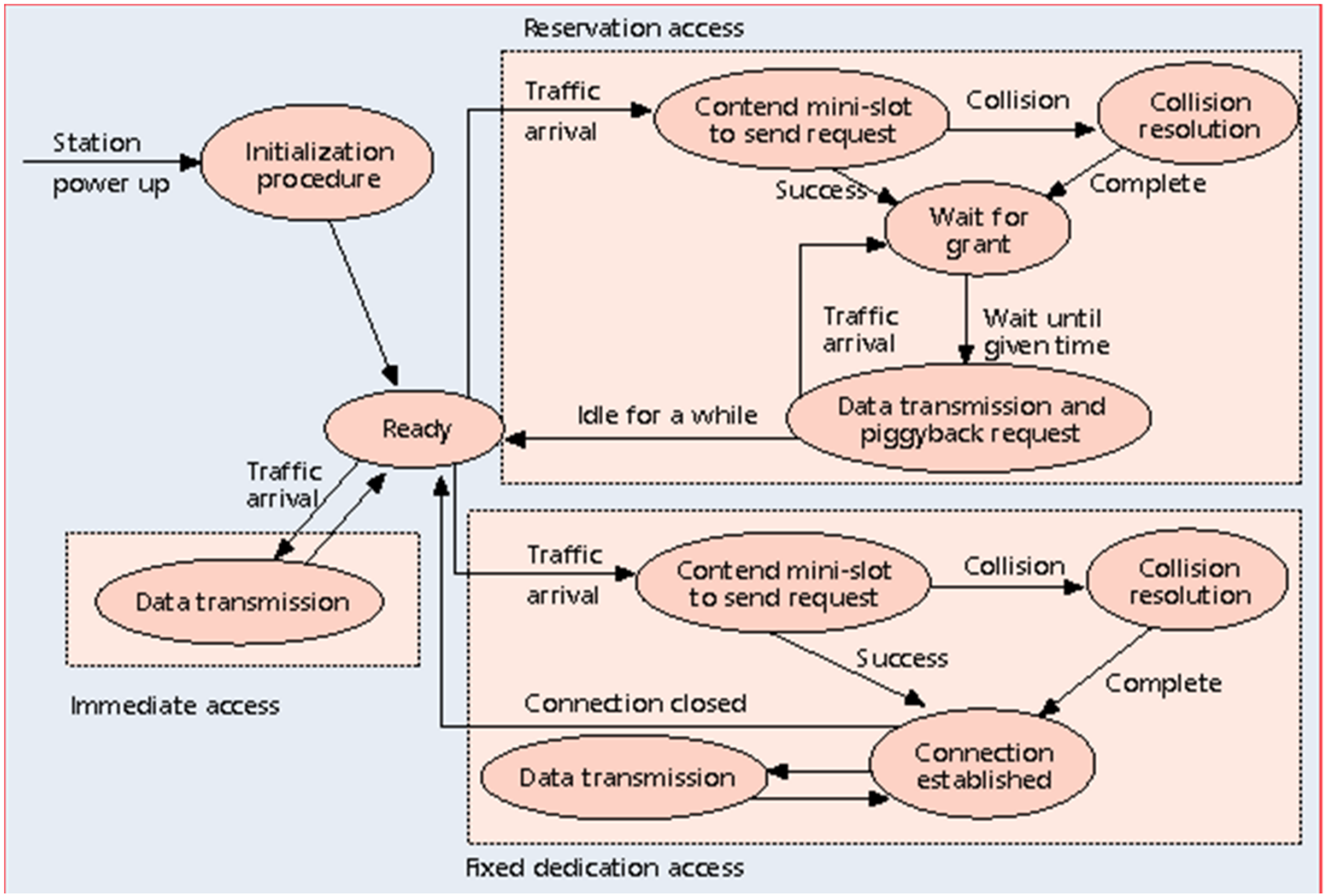
HFC Network


HEADEND
DISTRIBUTION HUB
Transport Ring
DISTRIBUTION HUB
Fiber: 5-40 Kilometers
OPTICAL NODE
TRUNK RF AMPLIFIER
500-2000 Homes Served
LINE RF AMPLIFIERS
OPTICAL NODE
OPTICAL NODE
OPTICAL NODE
500-2000 Homes Served

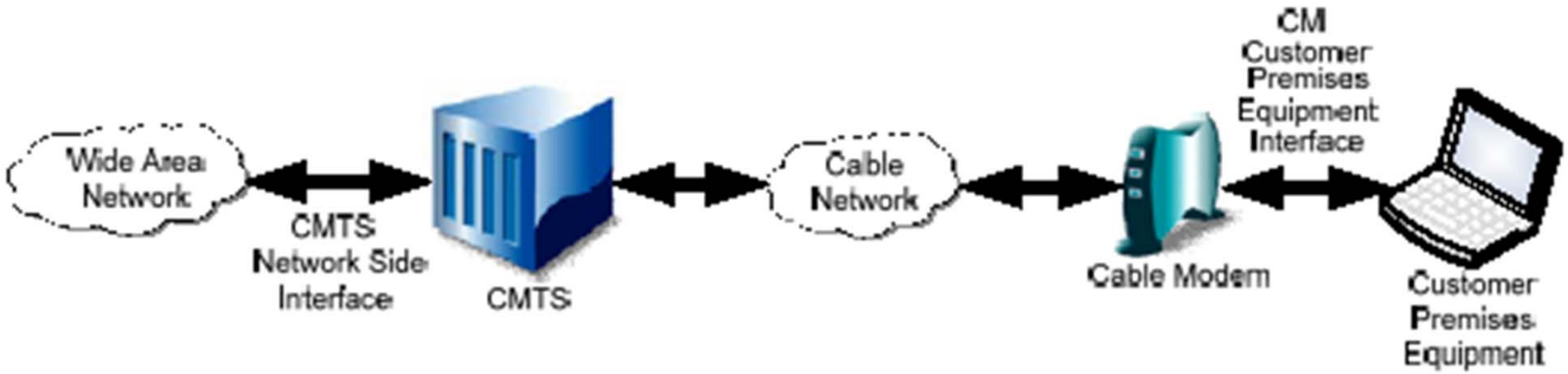
HFC Frequency plan



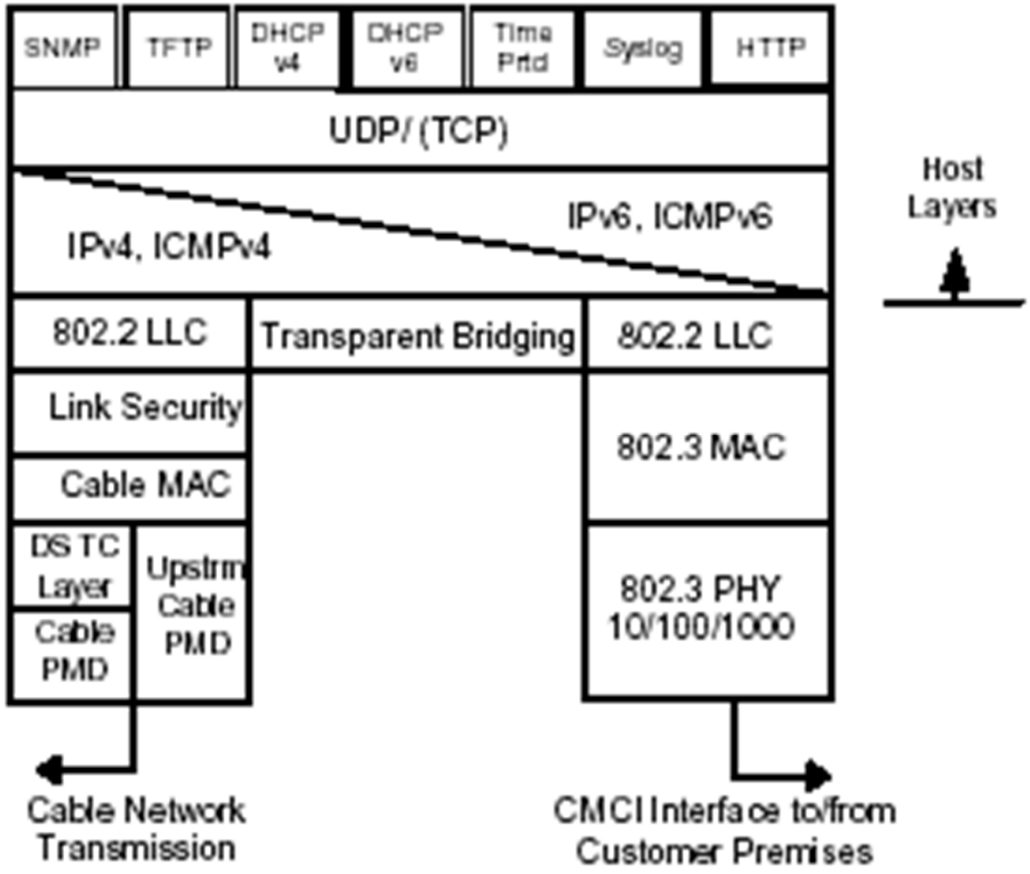
MAC access mode



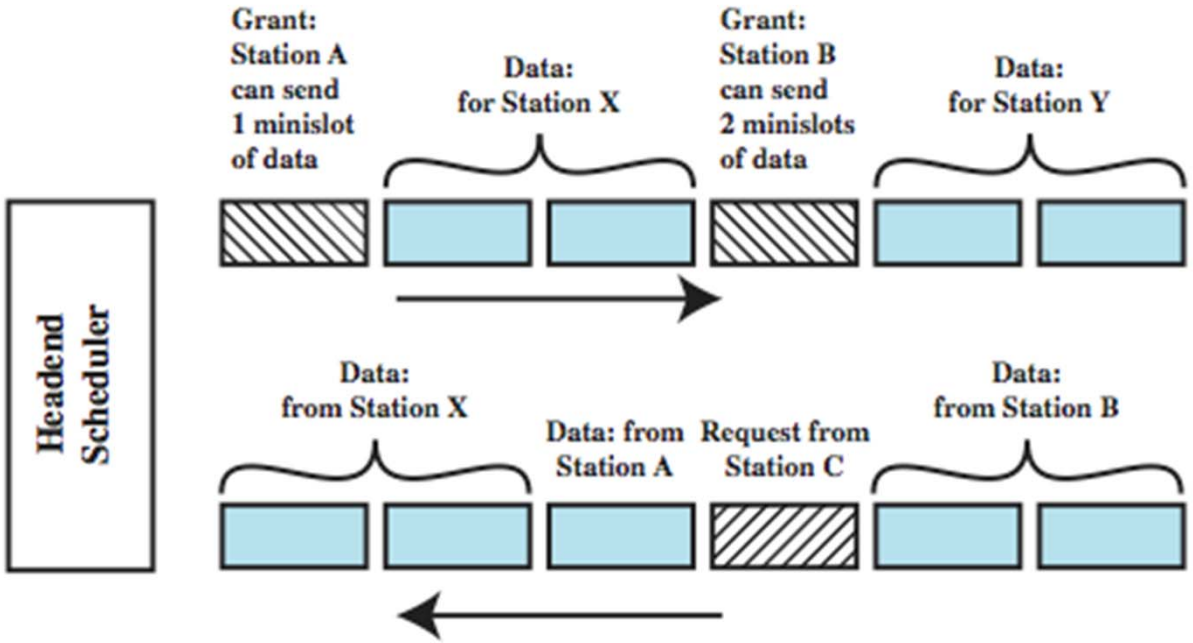
Transparent IP traffic



Docsis Cable Modem protocols stack



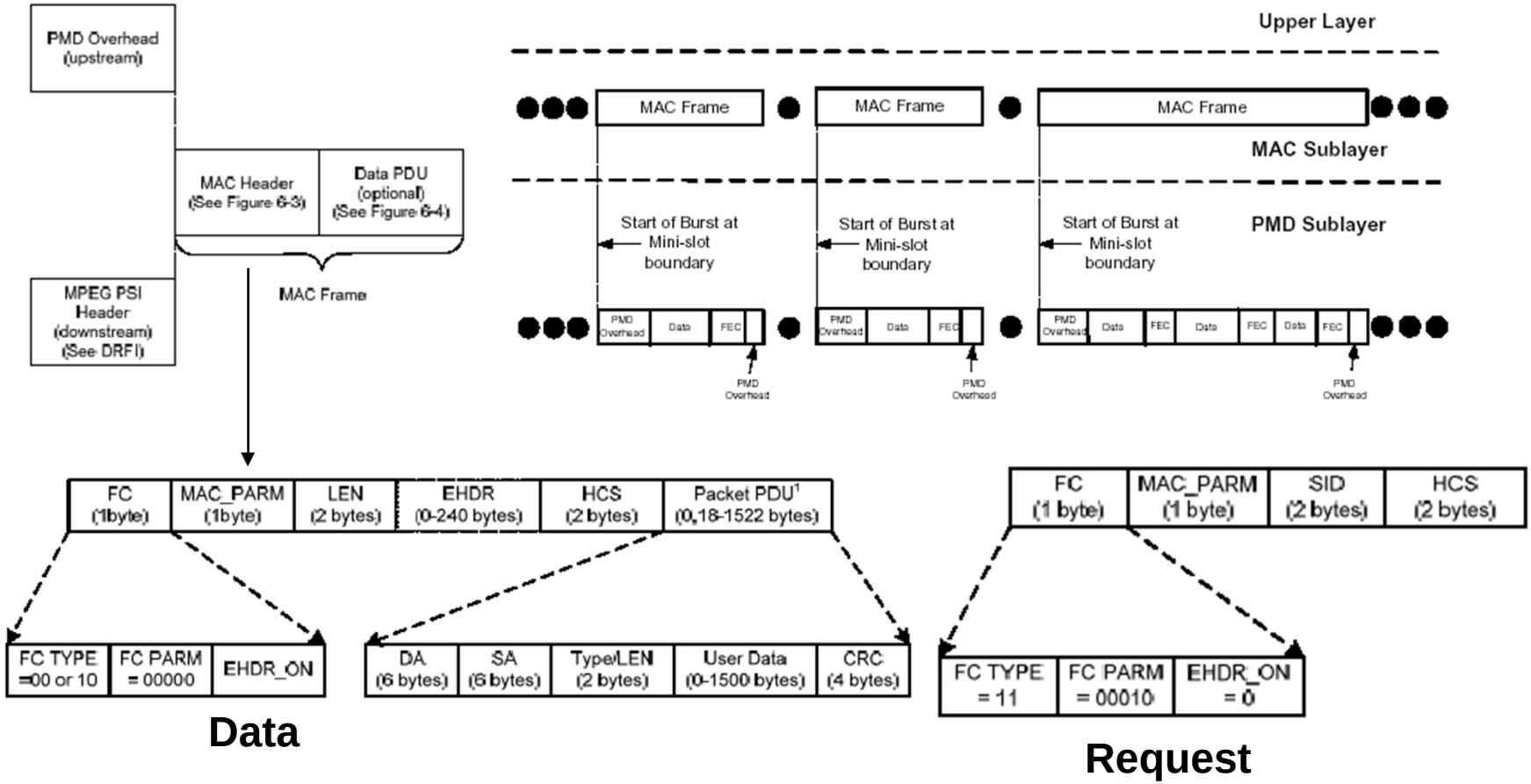
Cable Modem Scheme



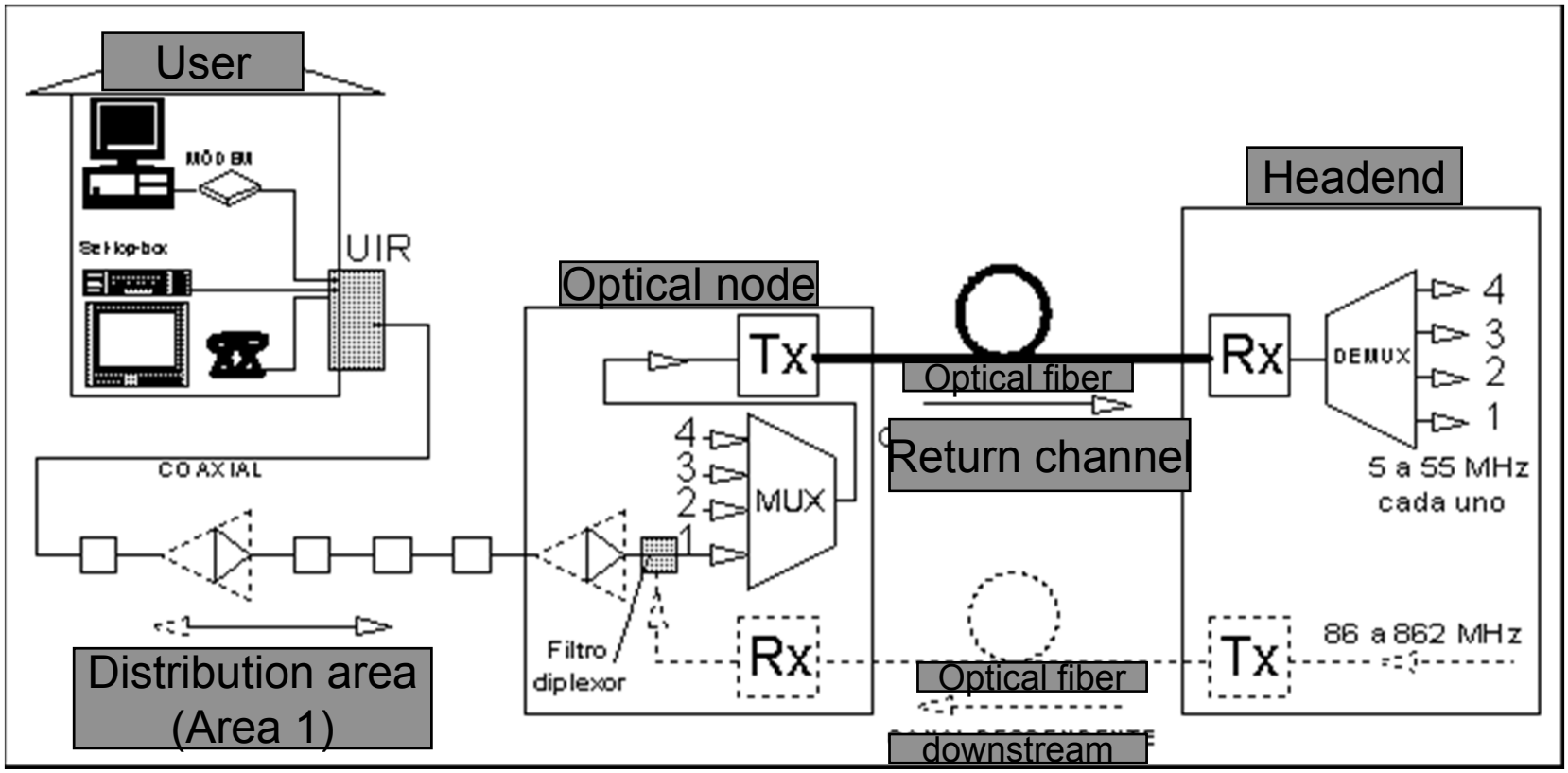
DOCSIS 3.0 keys

- **Downstream Channel Bonding with Multiple Receive Channels**
- **Upstream Channel Bonding with Multiple Transmit Channels**
- **IPv6**
- **Source-Specific Multicast**
- **Multicast QoS**

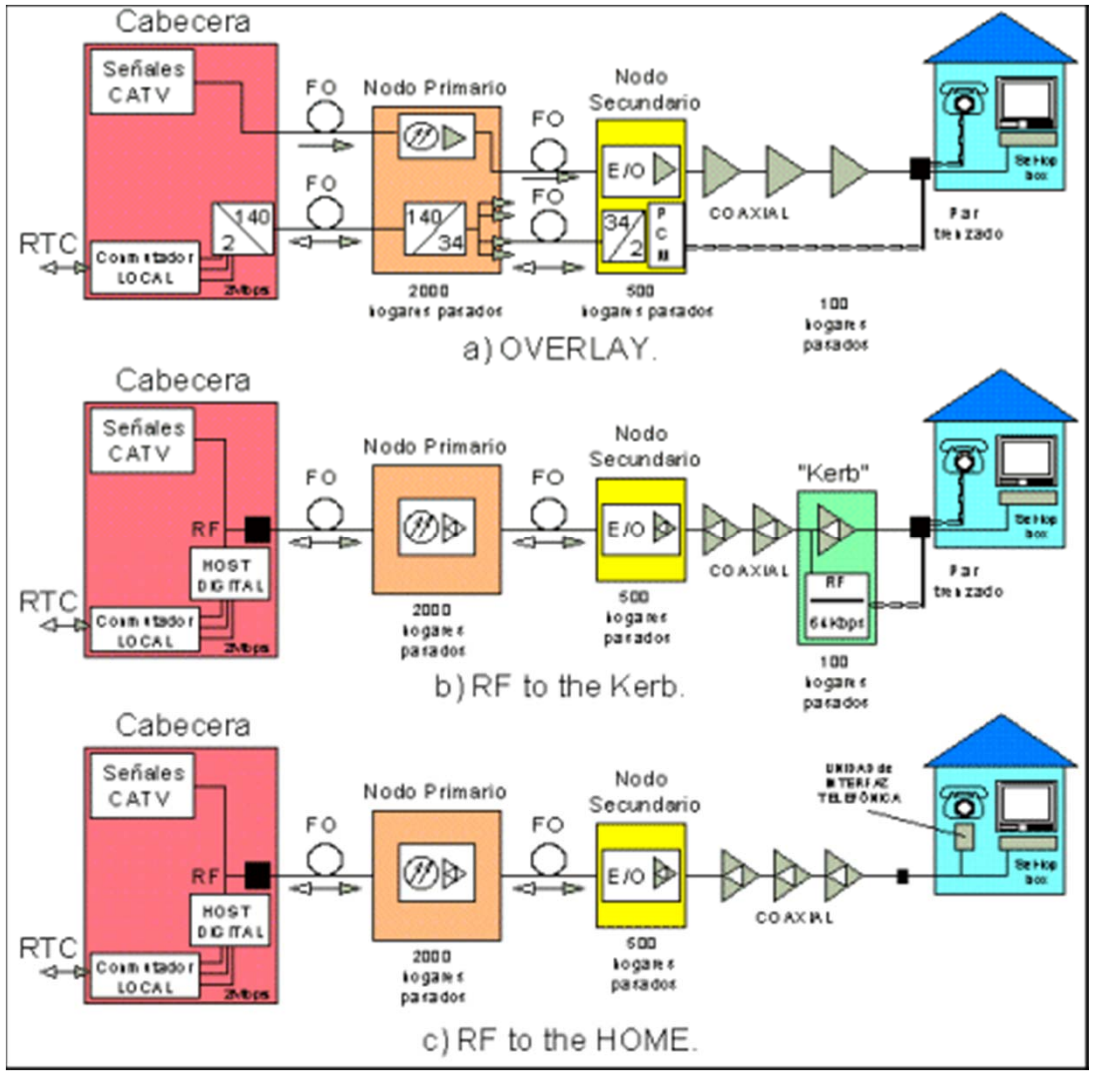
DOCSIS MAC format



HFC real network



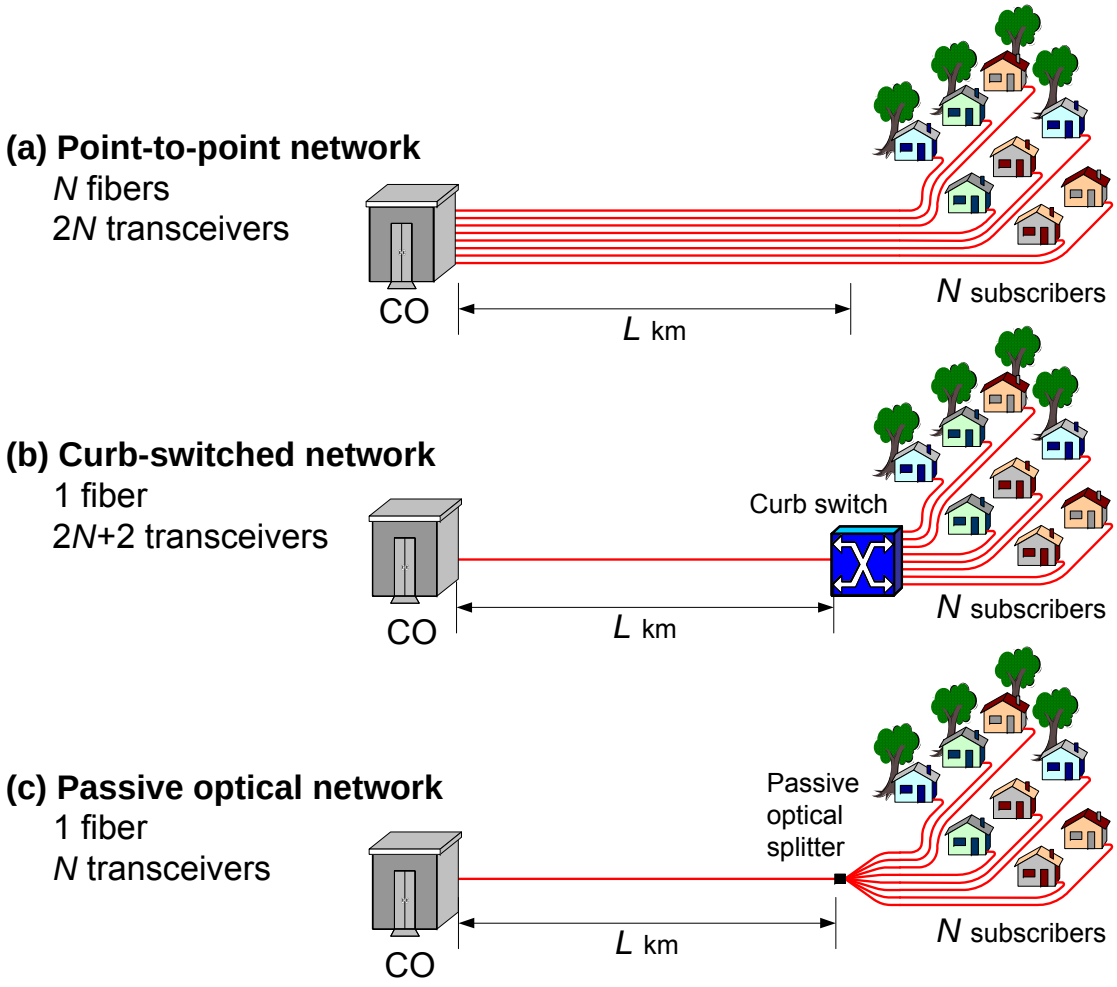
HFC telephone



4.3 Fibra òptica

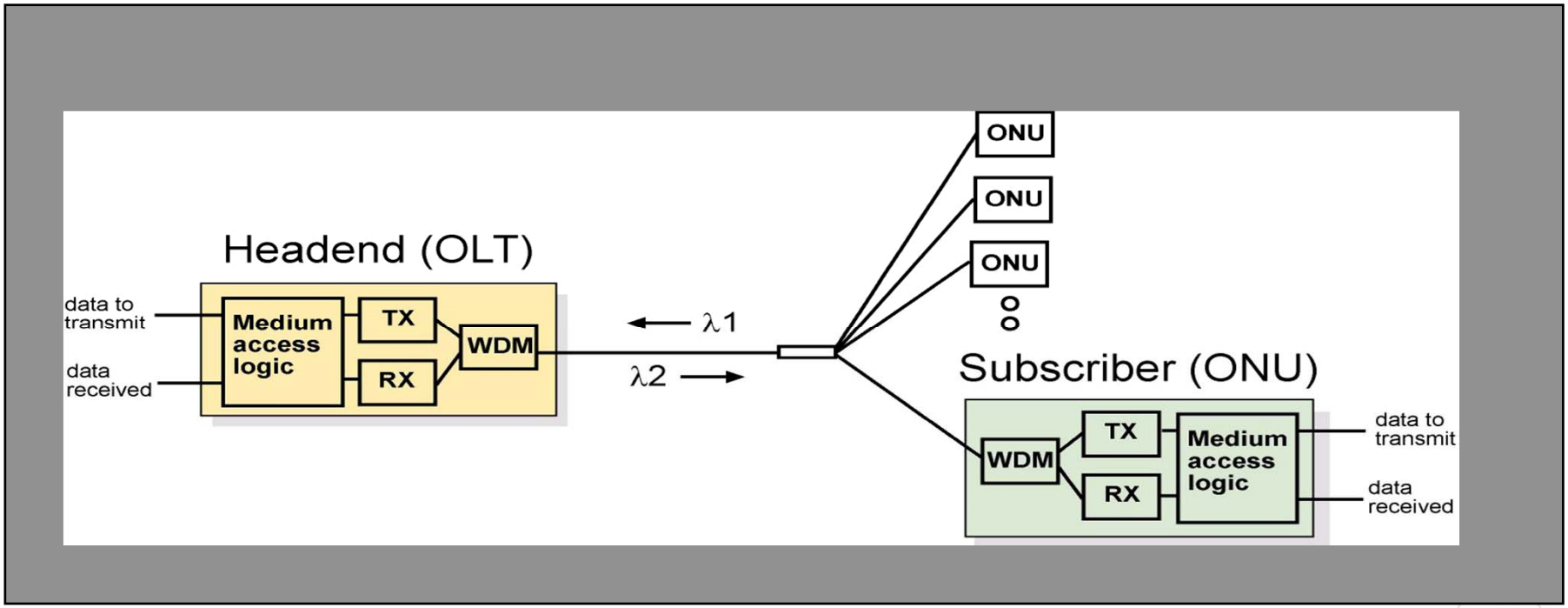
Source: ITU-T G.984.3

Topologies: Point-to-Point vs. PON



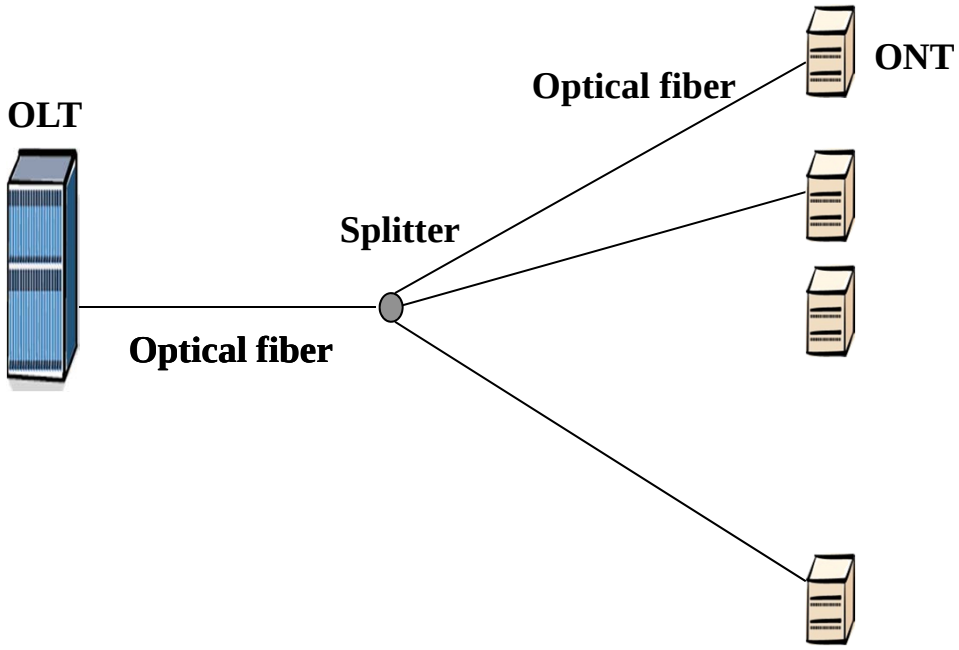
Single-Fiber PON

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



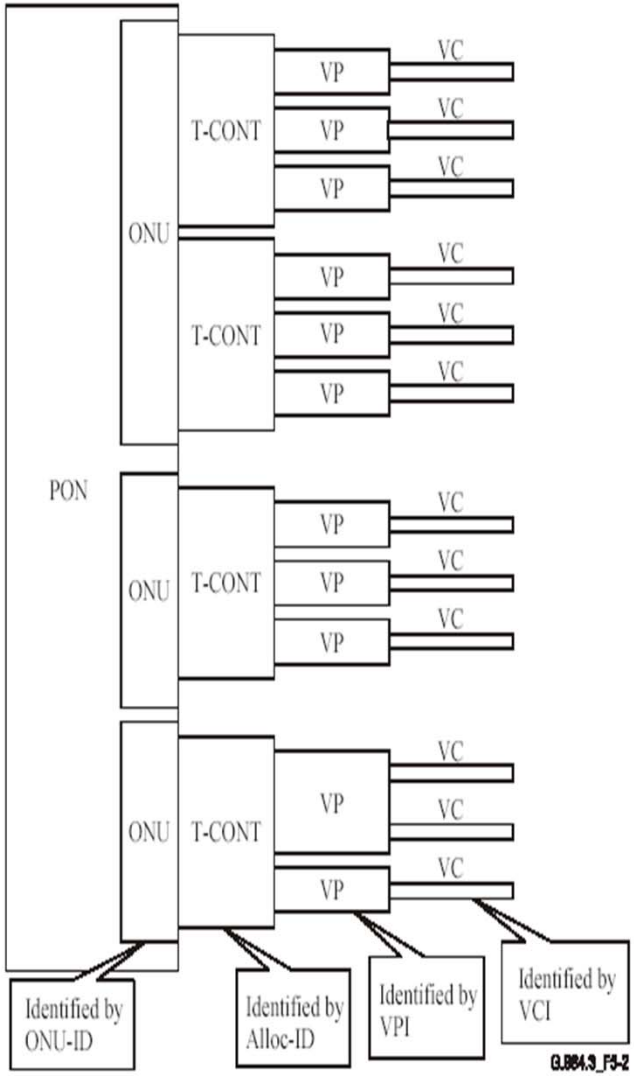
GPON Technology

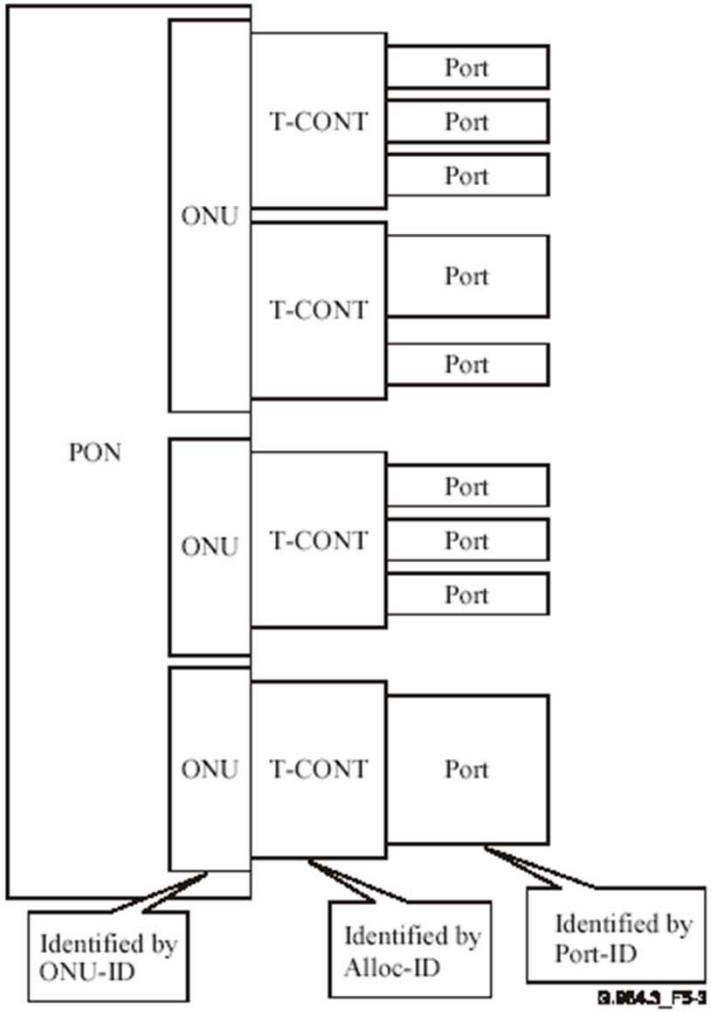
GPON: Gigabit Passive Optic Network



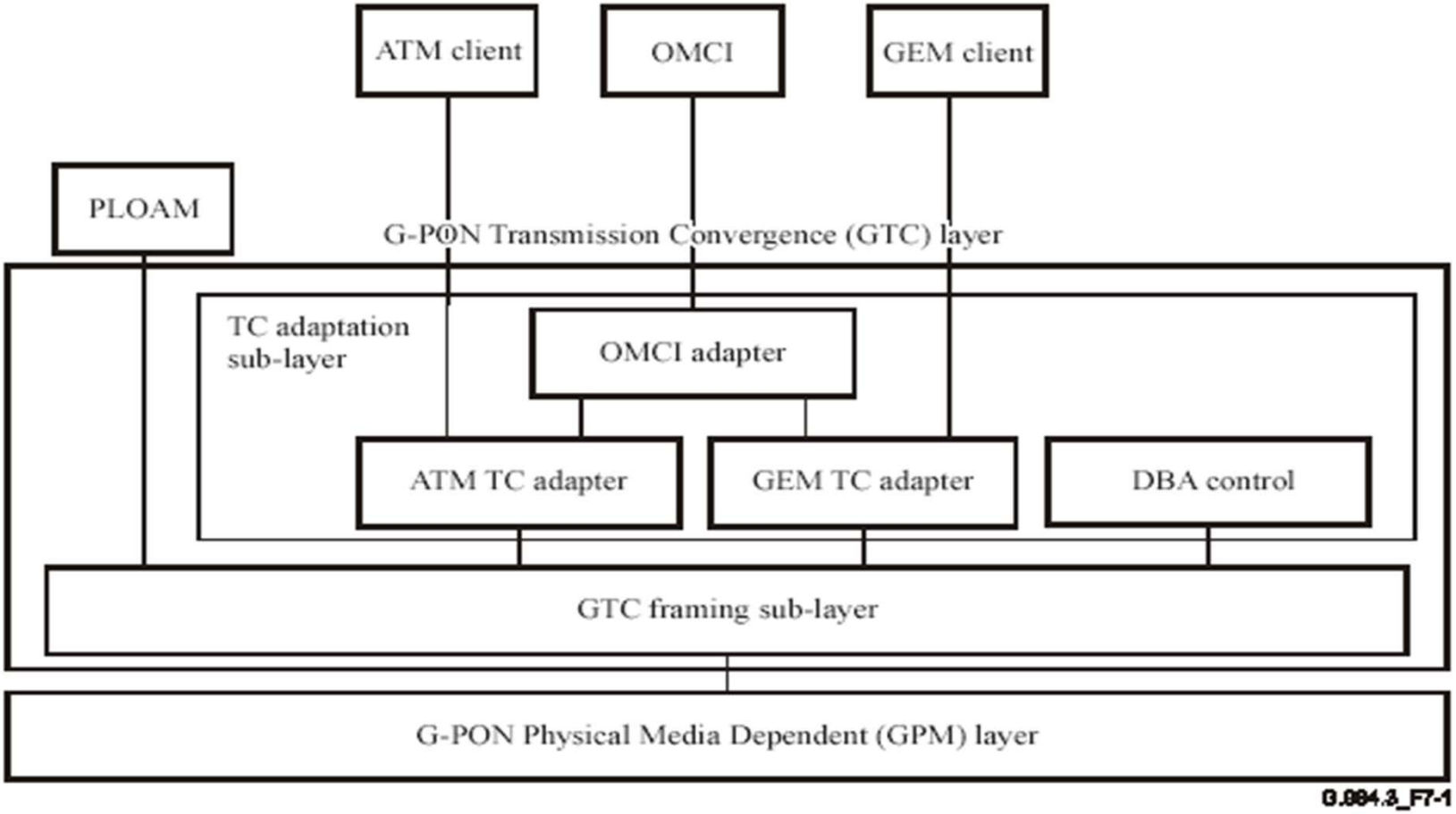
- Optical Fiber
- Point to multipoint
- Several levels of splitting
- 2.5 Gps DS and 1.25 Gbps US
- Up to 20 Km
- TDM DS and TDMA US

Multiplexed architecture

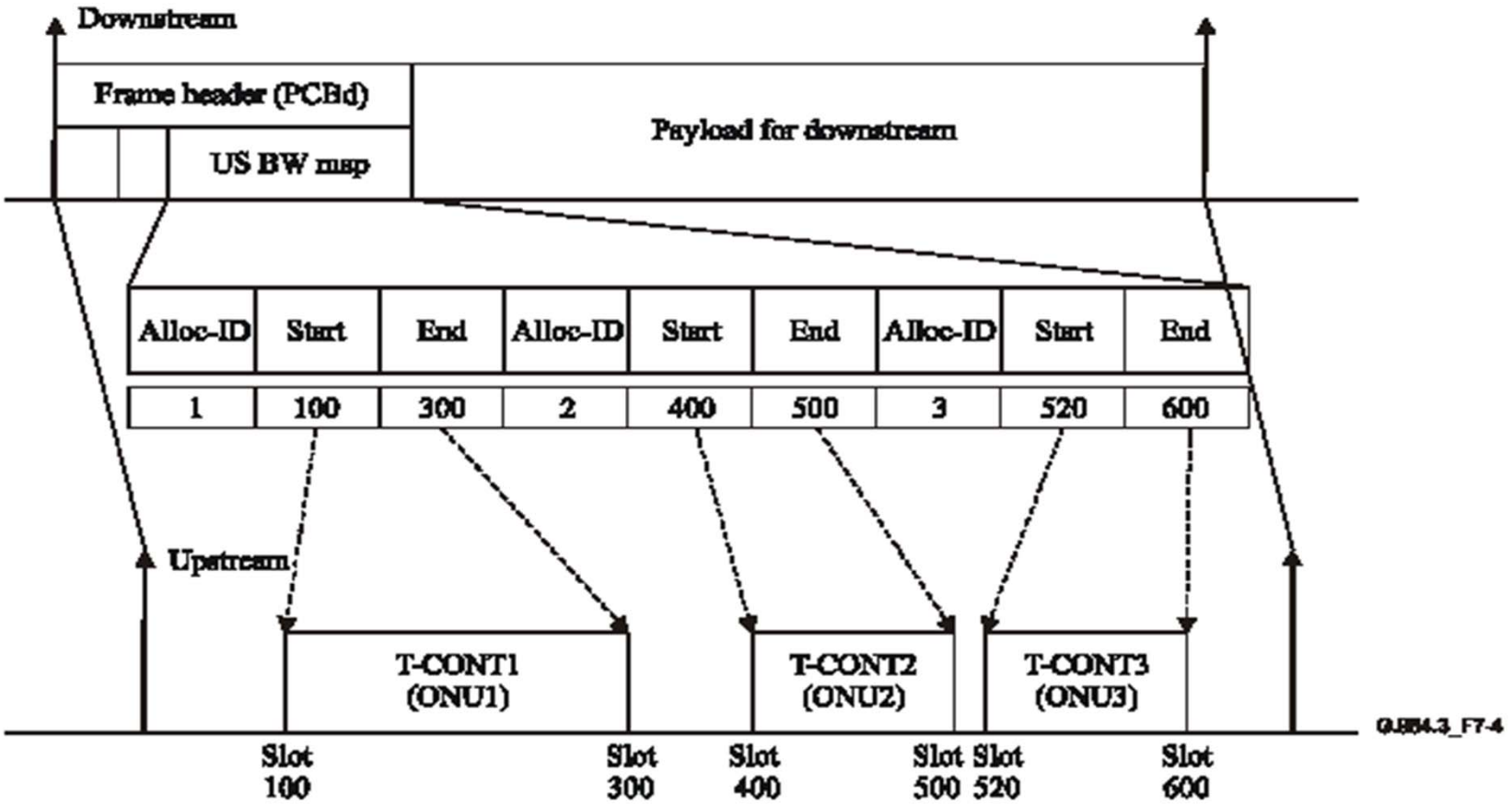




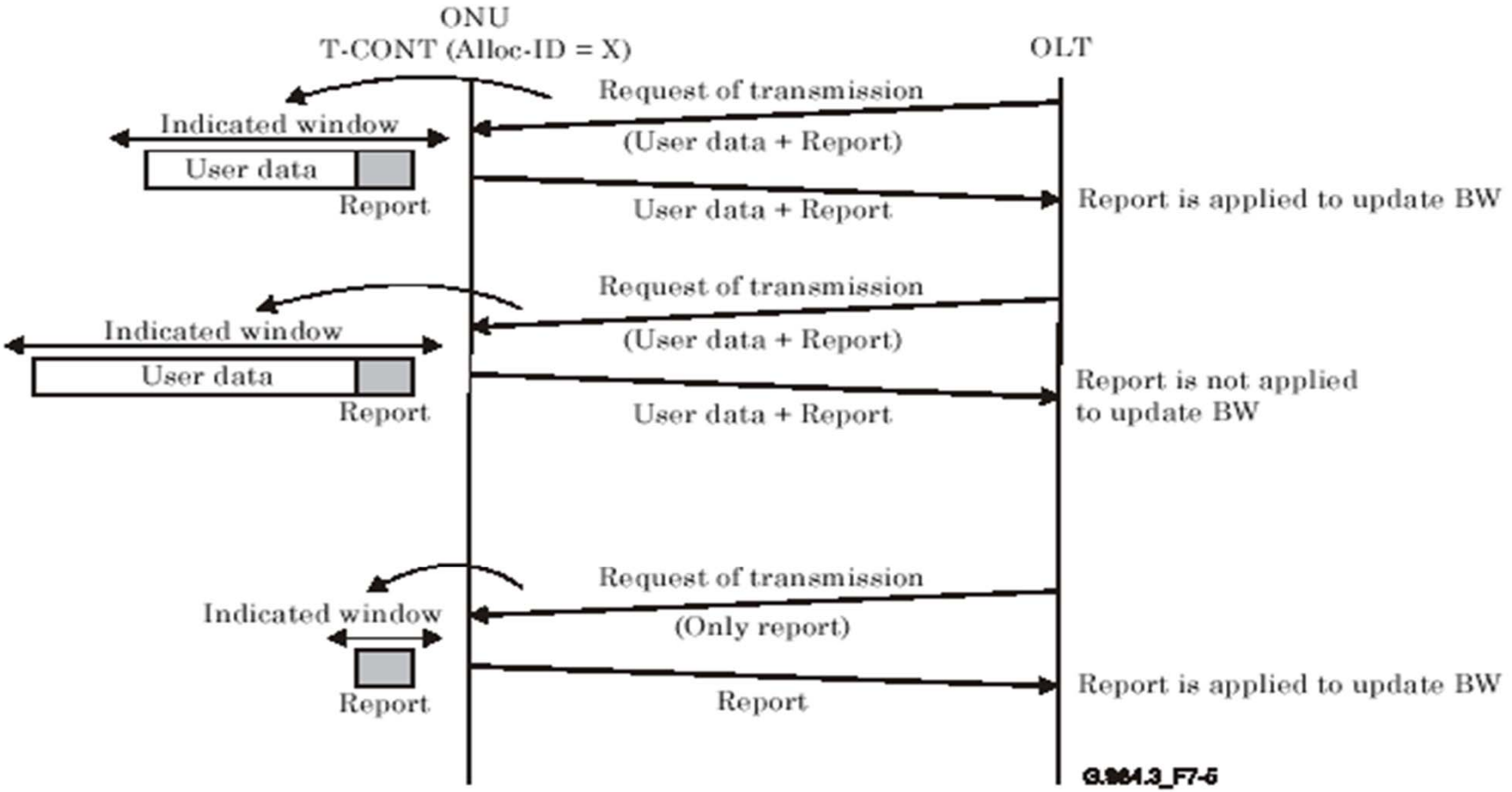
Protocol stack



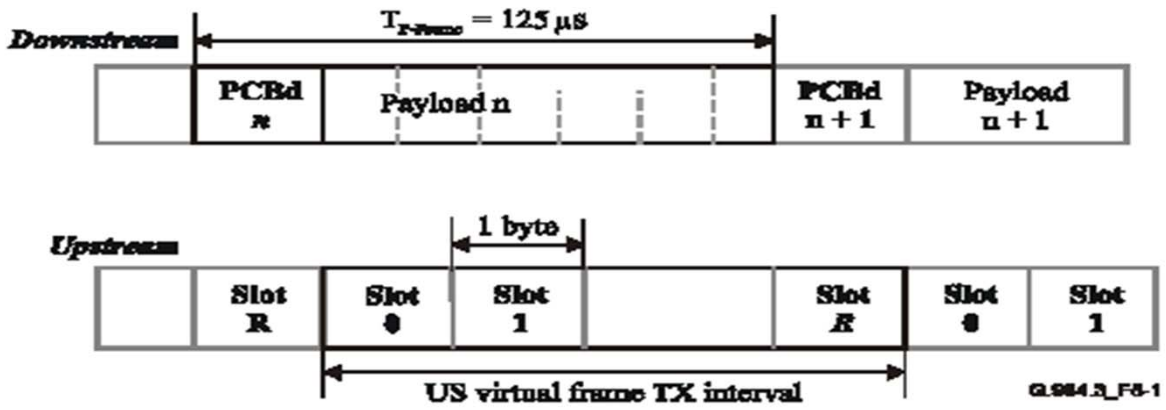
Media access control



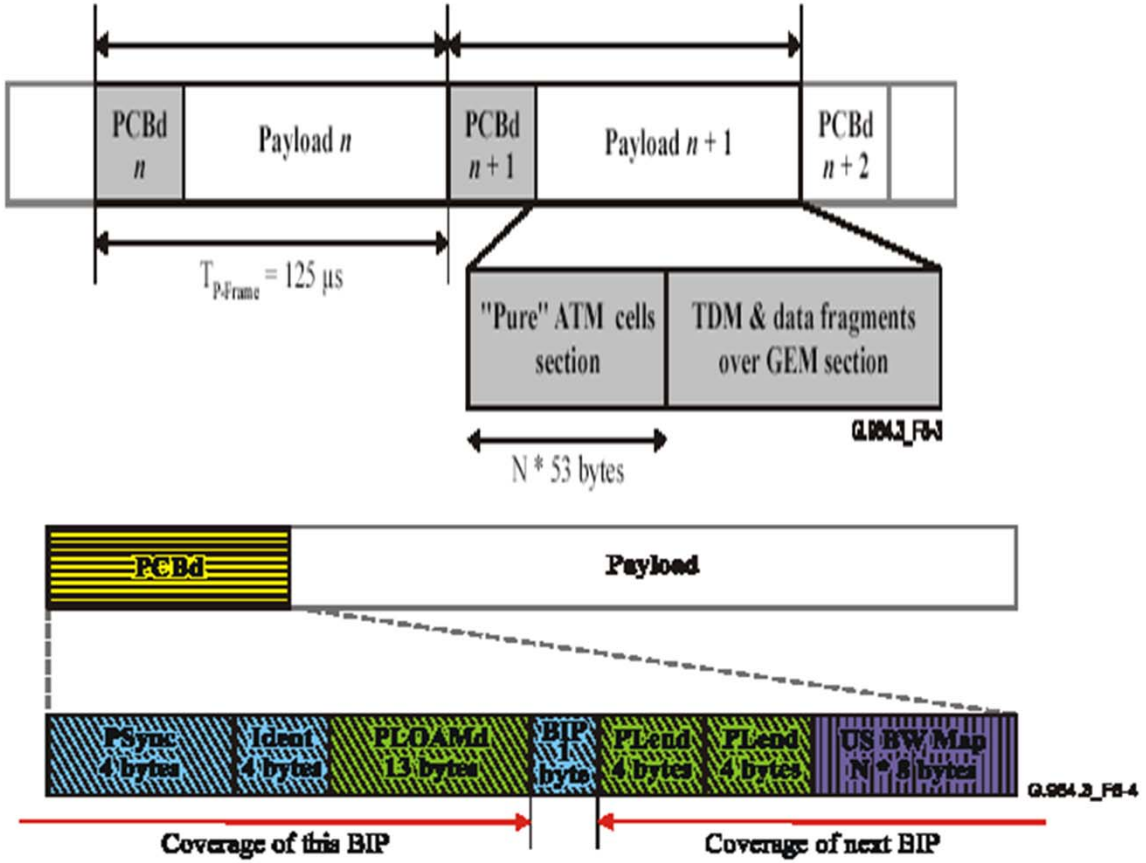
SR-DBA operation



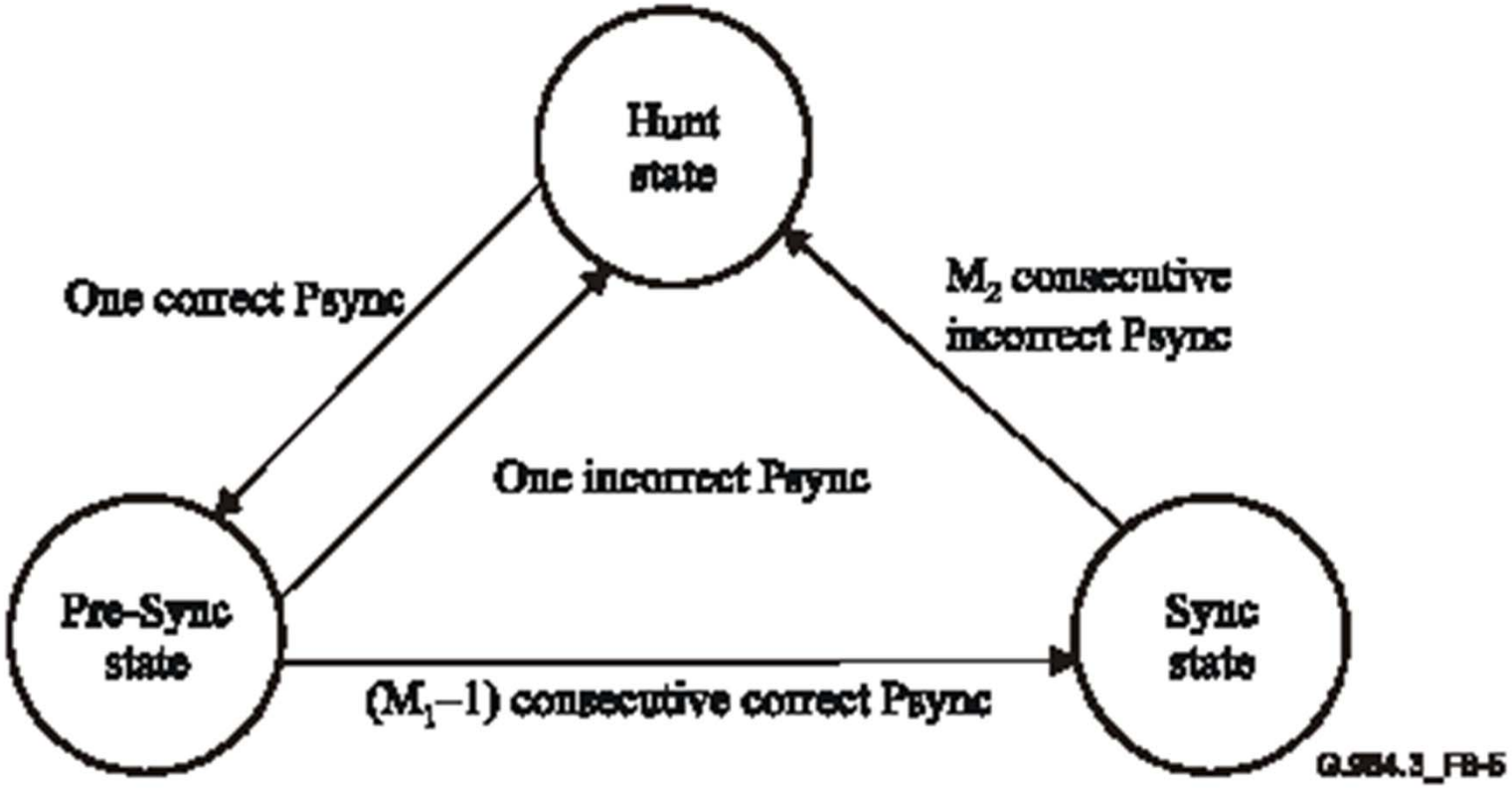
Frame structure



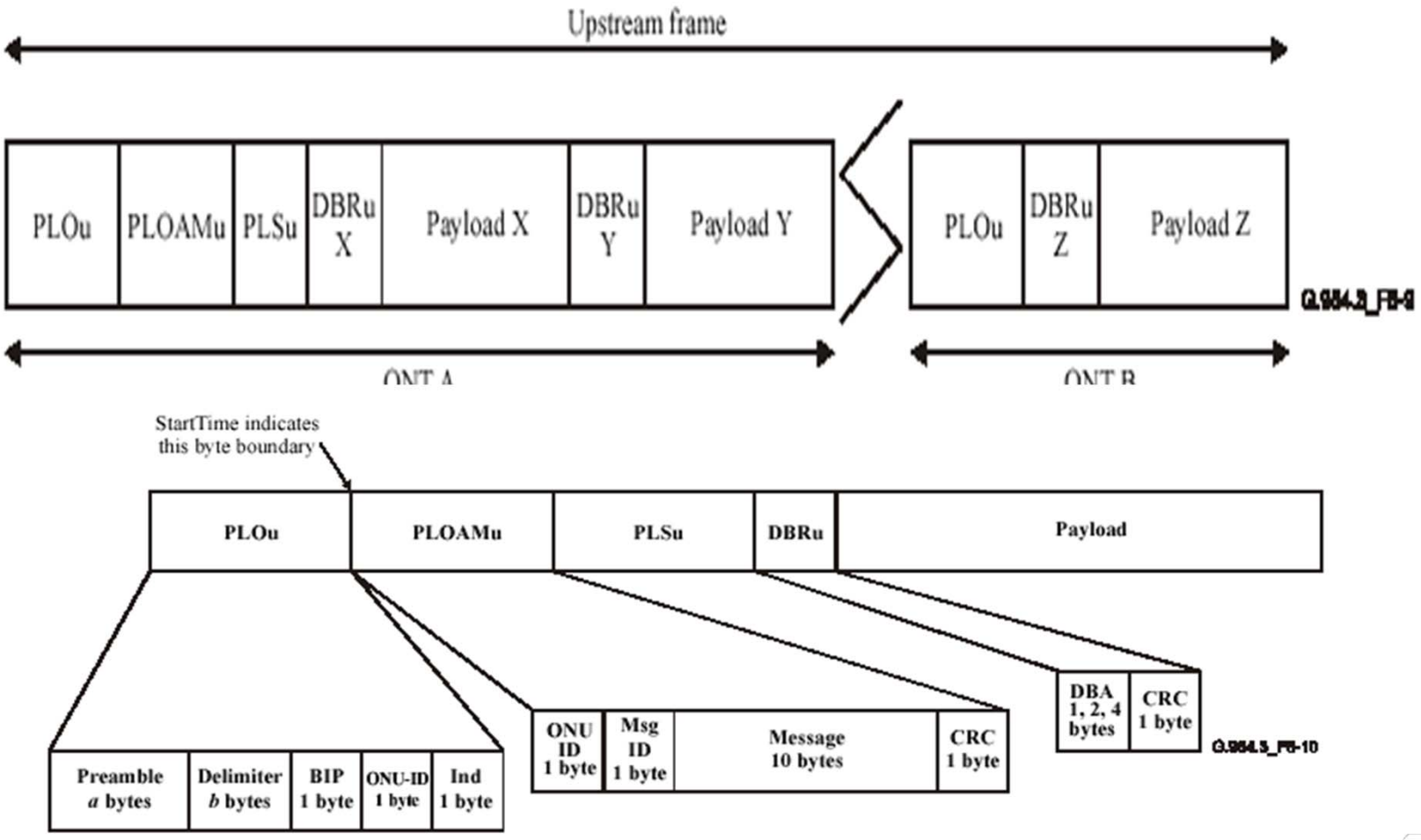
Downstream frame



Downstream synchronization



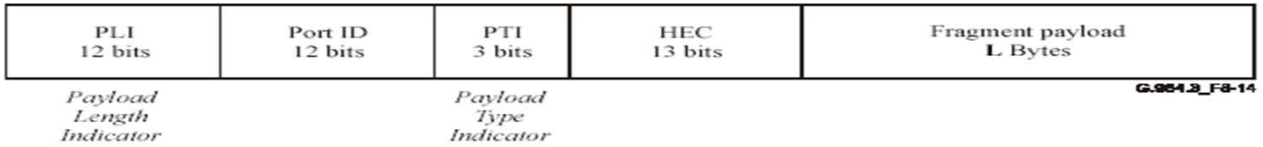
Upstream frame

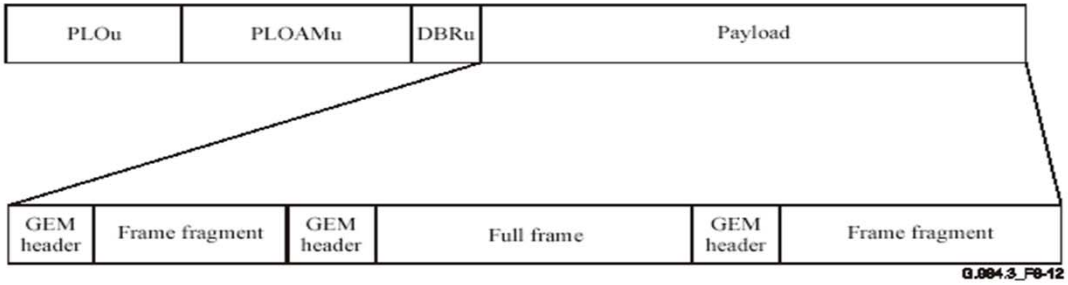


IND field

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

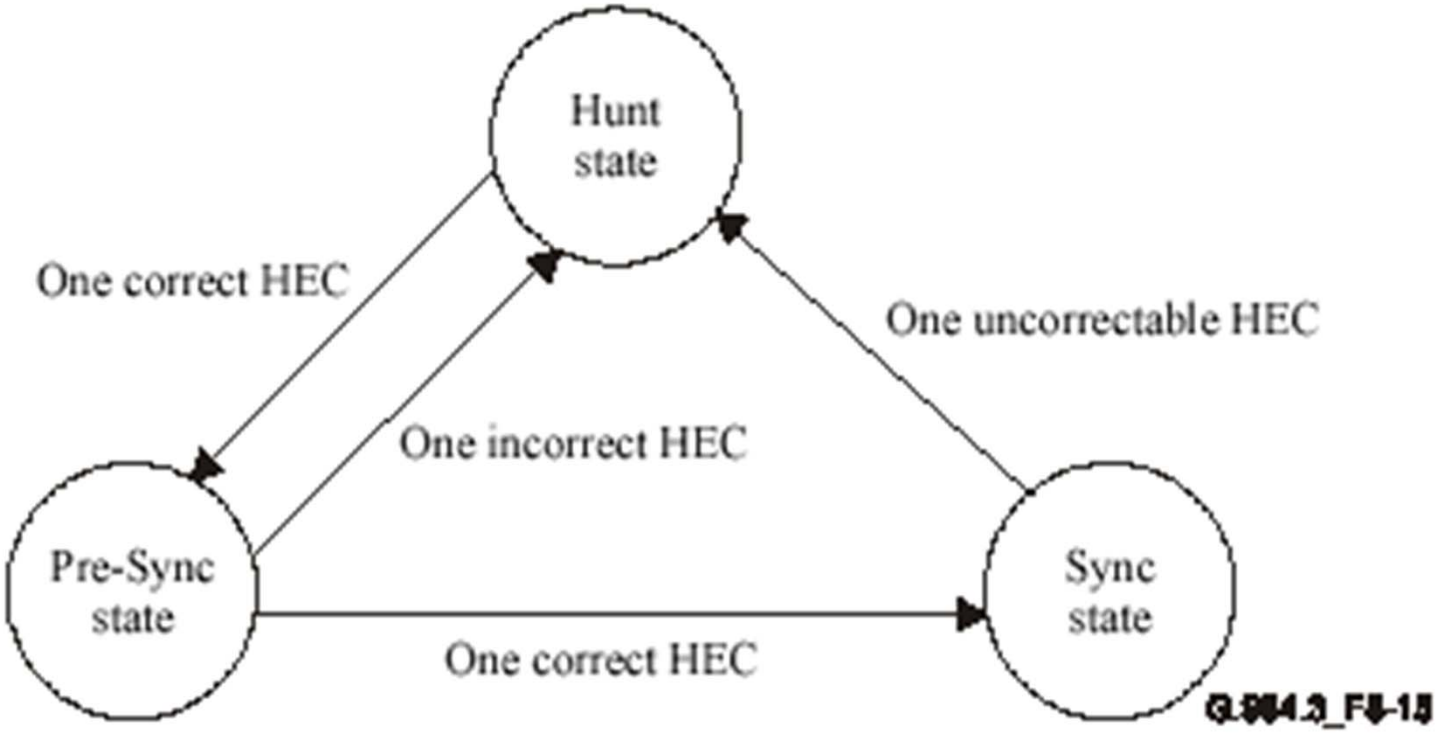
GEM upstream payload



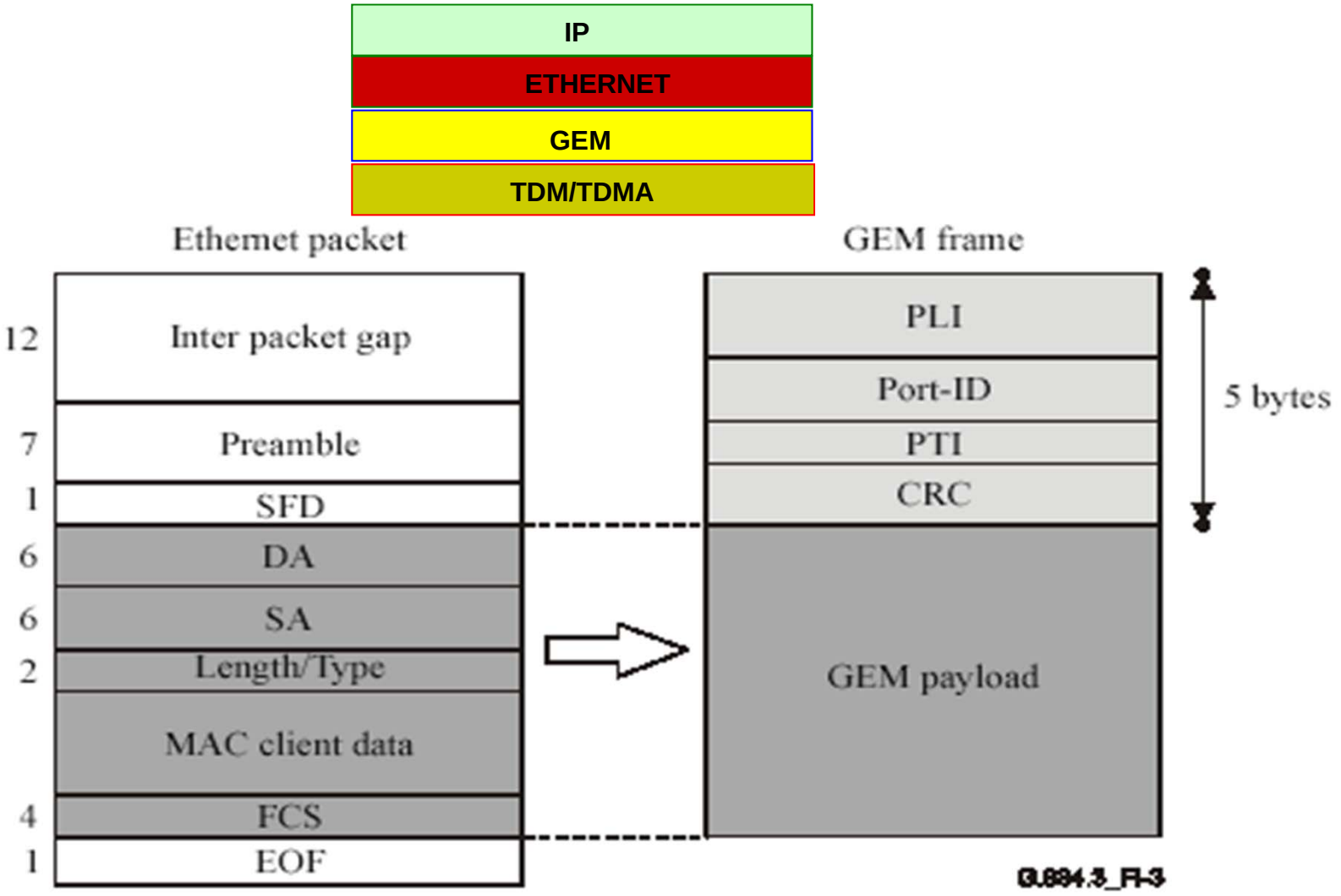


PTI code	Meaning
000	User data fragment, Congestion has Not occurred, Not the end of a frame
001	User data fragment, Congestion has Not occurred, End of a frame
010	User data fragment, Congestion Has occurred, Not the end of a frame
011	User data fragment, Congestion Has occurred, End of a frame
100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

GEM delineation



Ethernet over GEM



4.4 Mòbils

Source: Data and computer Communications Ed. 10, cap. 10, W. Stallings

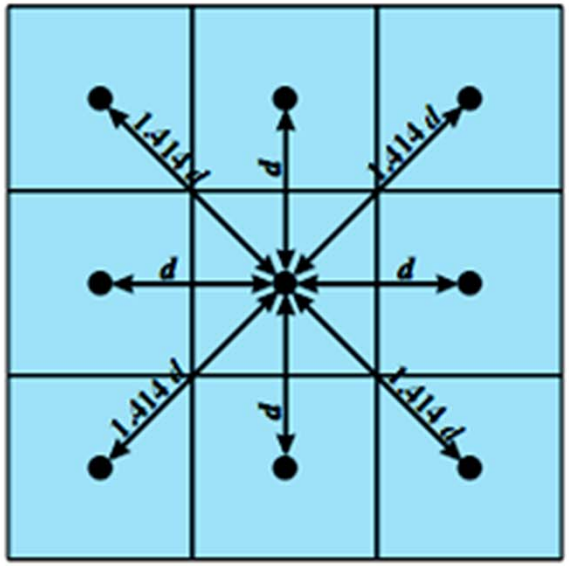
Principles of Cellular Networks

- 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

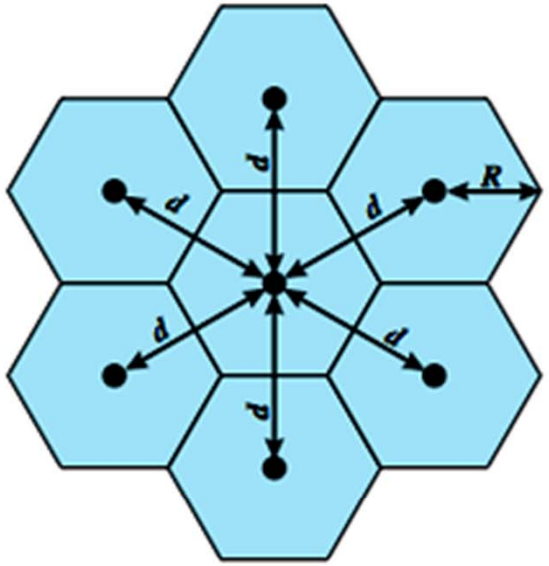
Cellular Network Organization

- Key for mobile technologies
- Based on the use of multiple low power transmitters
- Area divided into cells
  - In a tiling pattern to provide full coverage
  - Each one with its own antenna
  - Each is allocated its own range of frequencies
  - Served by a base station
    - *Consisting of transmitter, receiver, and control unit*
  - Adjacent cells are assigned different frequencies to avoid interference or crosstalk
    - *Cells sufficiently distant from each other can use the same frequency band*

Cellular Geometries



(a) Square pattern



(b) Hexagonal pattern

Frequency Reuse

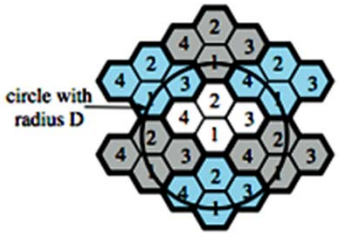
Object is to share nearby cell frequencies without interfering with each other

- **Allows multiple simultaneous conversations**
- **10 to 50 frequencies per cell**

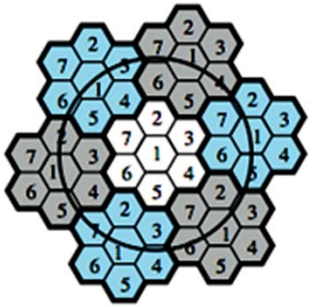
Power of base transceiver controlled

- **Allow communications within cell on given frequency**
- **Limit escaping power to adjacent cells**

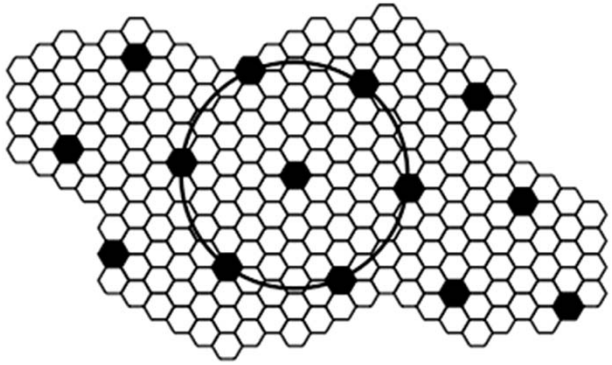
Frequency Reuse Patterns



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

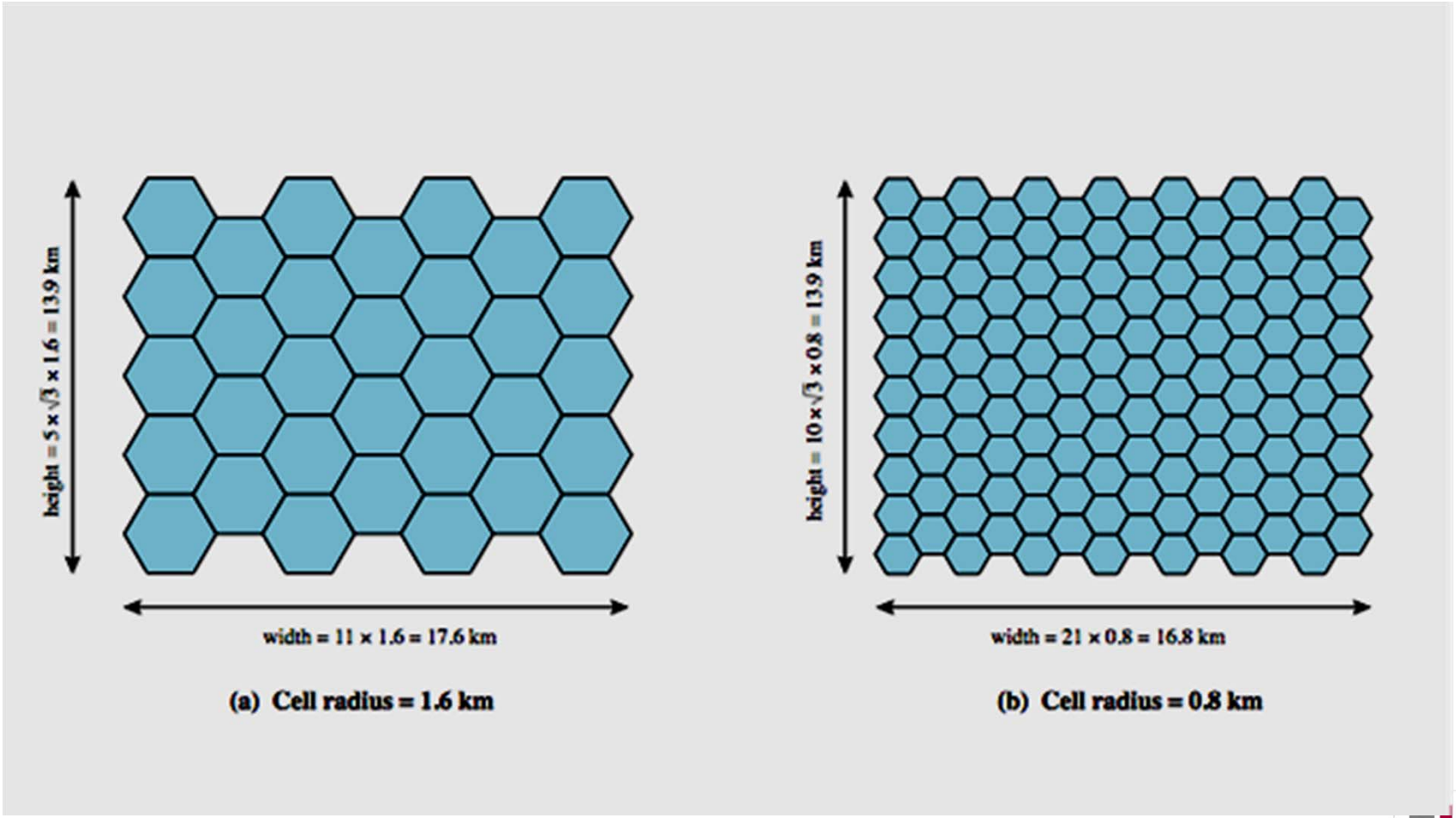


(b) Frequency reuse pattern for $N = 7$



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

Frequency Reuse Example



Cellular System Channels

Two types of channels are available between mobile unit and base station (BS)

- **Control Channels**
  - **Set up and maintain calls**
  - **Establish relationship between mobile unit and nearest base station**
- **Traffic Channels**
  - **Carry voice and data**

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

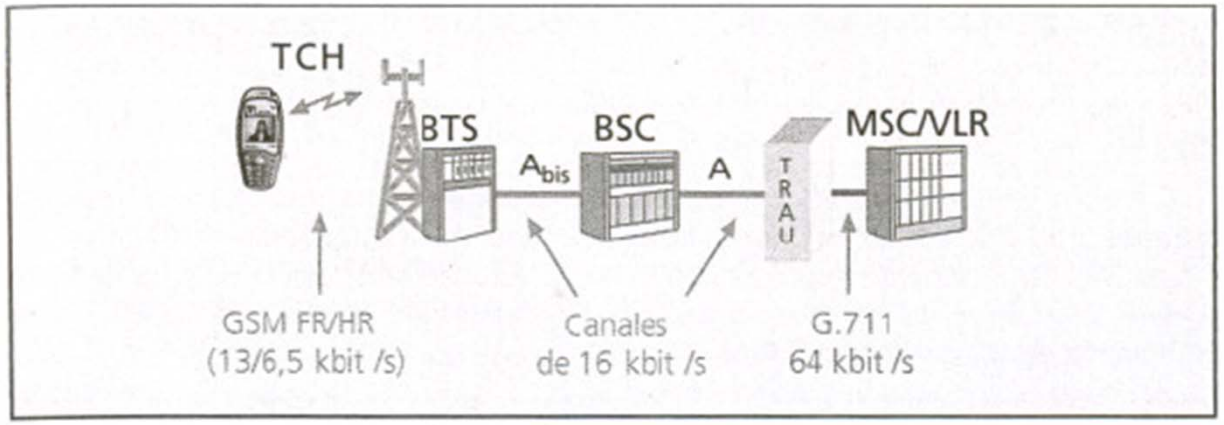
First Generation (1G)

- 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

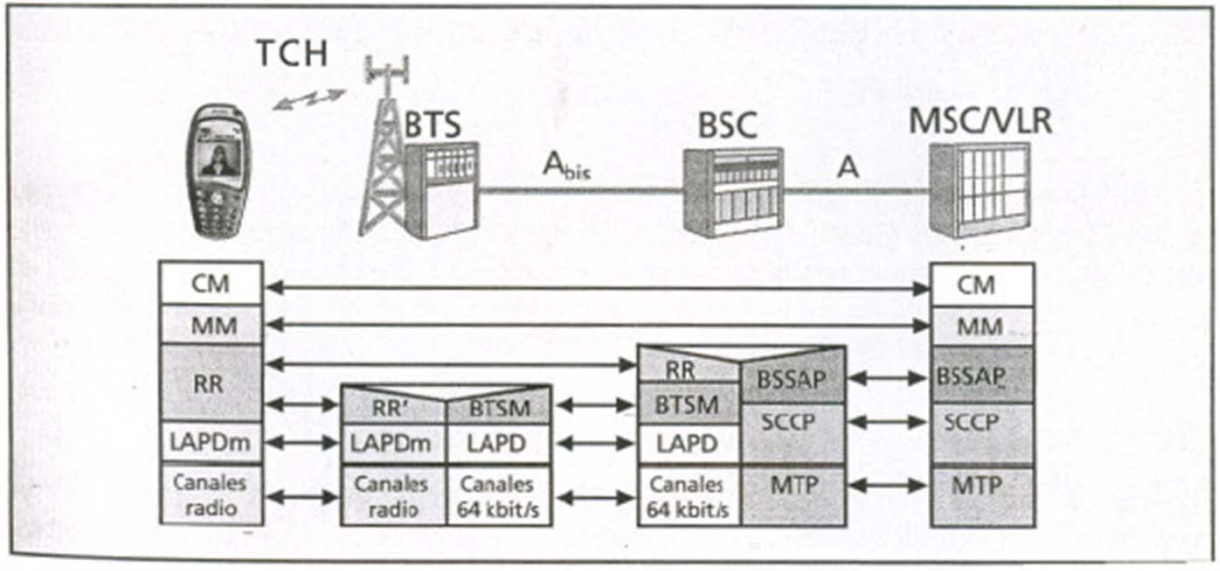
Second Generation (2G)

- 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)*

2G GSM

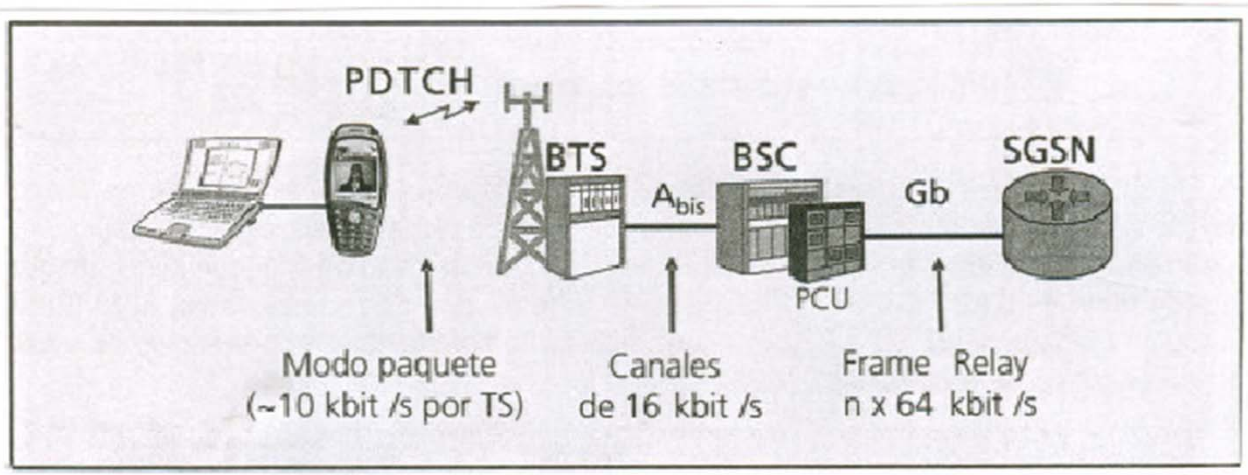


Voice transport GSM

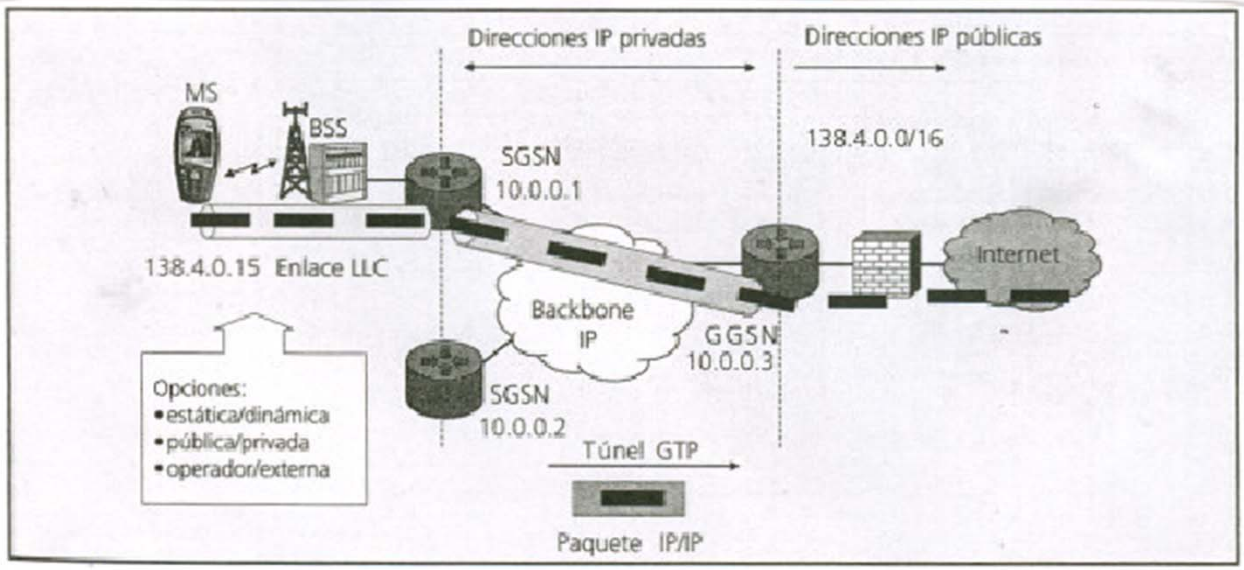


Signaling architecture GSM access network

2.5G GPRS

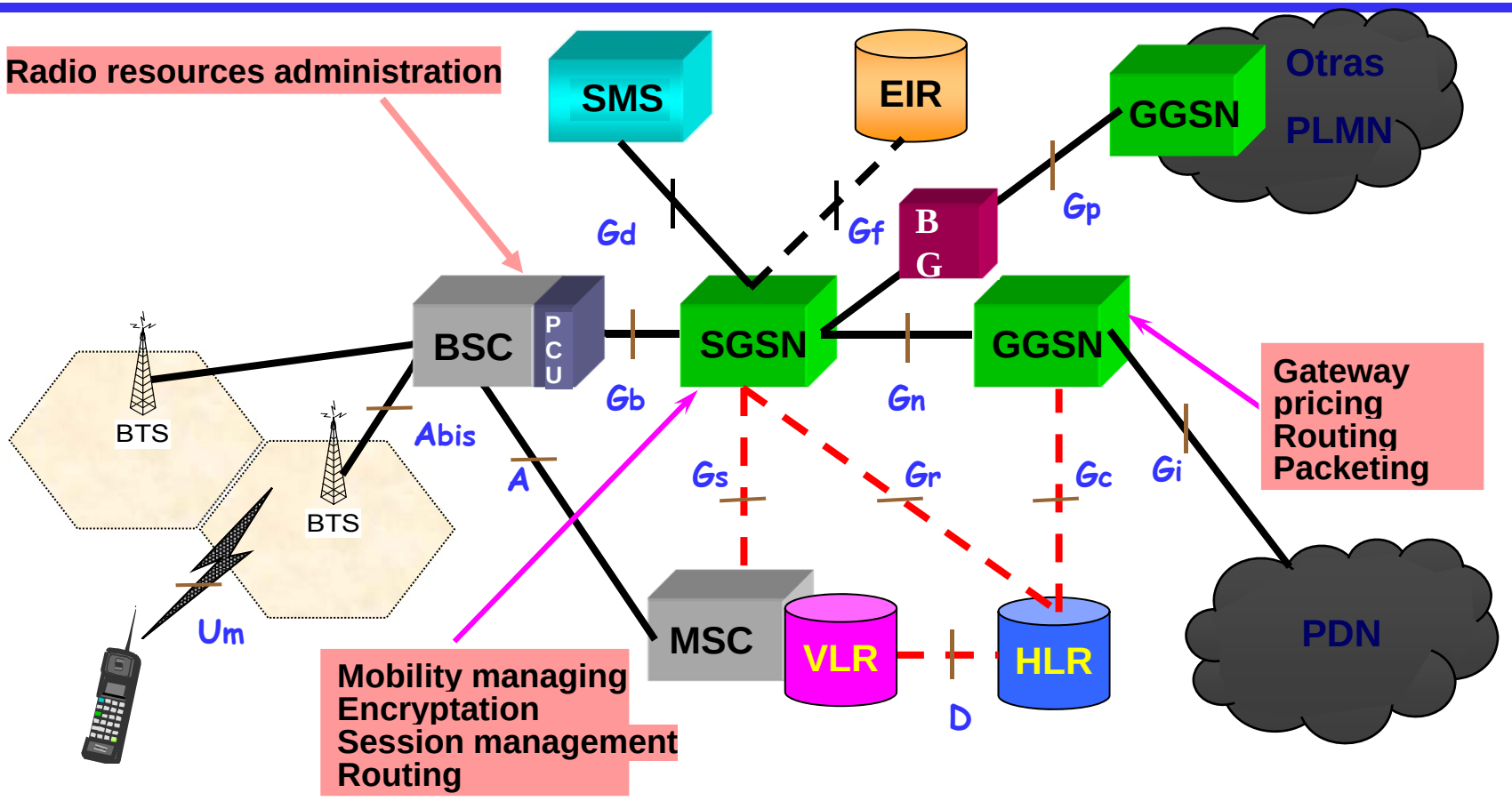


Data transport



Tunneling

2.5G GPRS system architecture



User data and signaling

Signaling

SGSN Serving GPRS Support Node

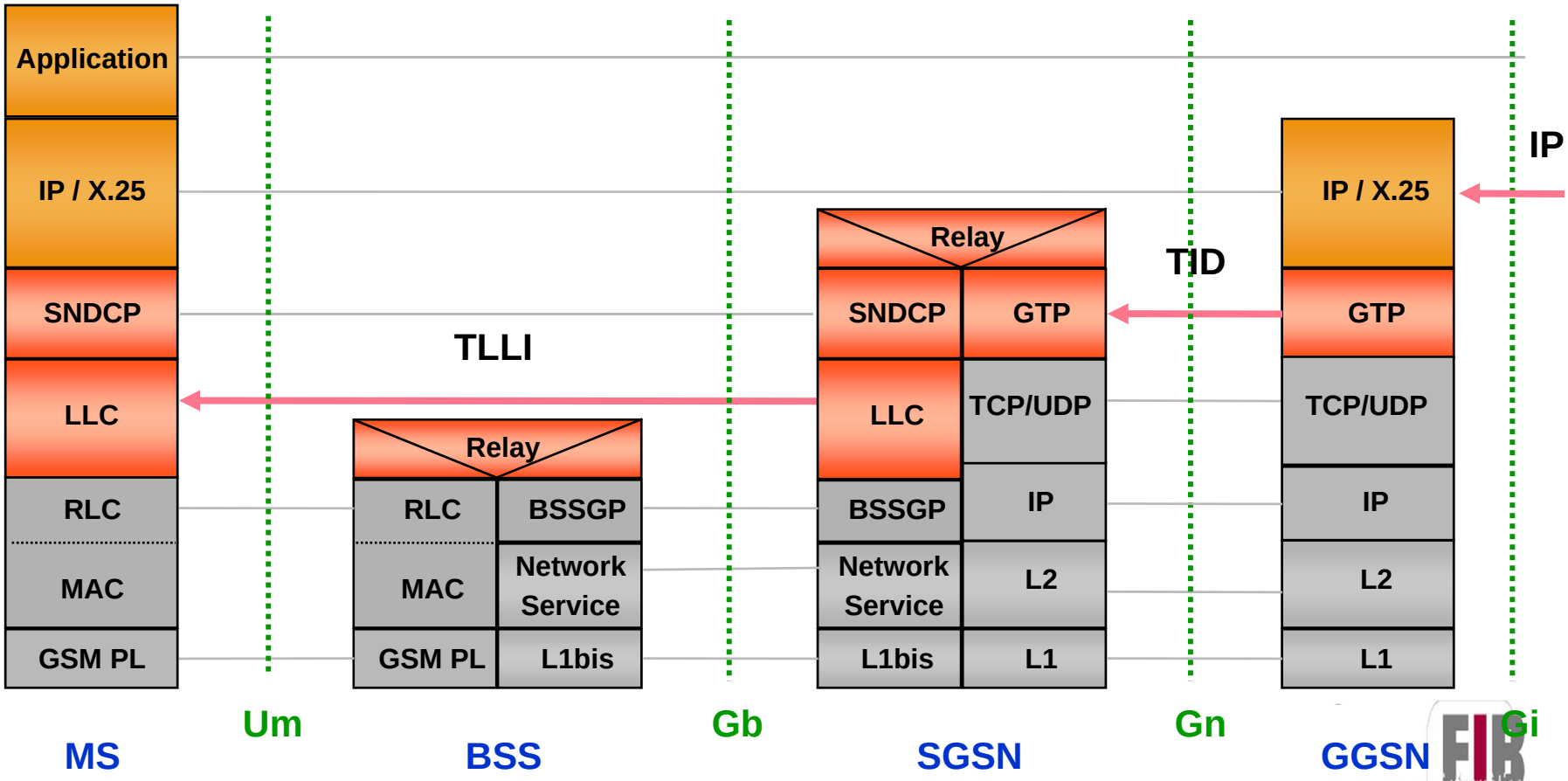
GGSN Gateway GPRS Support Node

PDN Packet Data Network

PCU Packet Control Unit

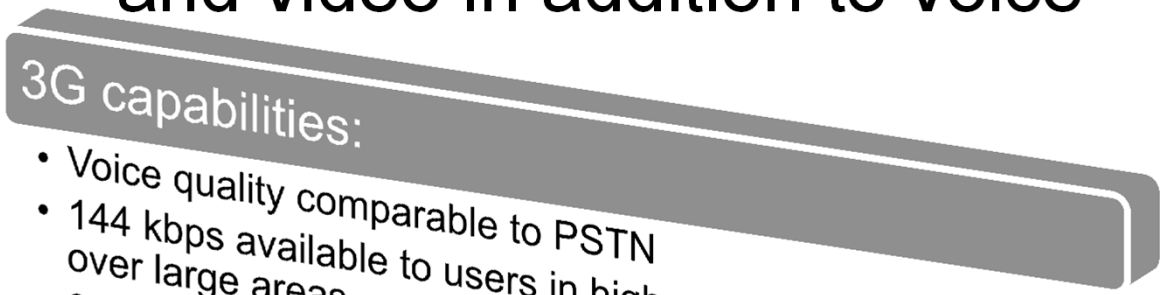
2.5G Protocol stack

- User plane



Third Generation (3G)

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

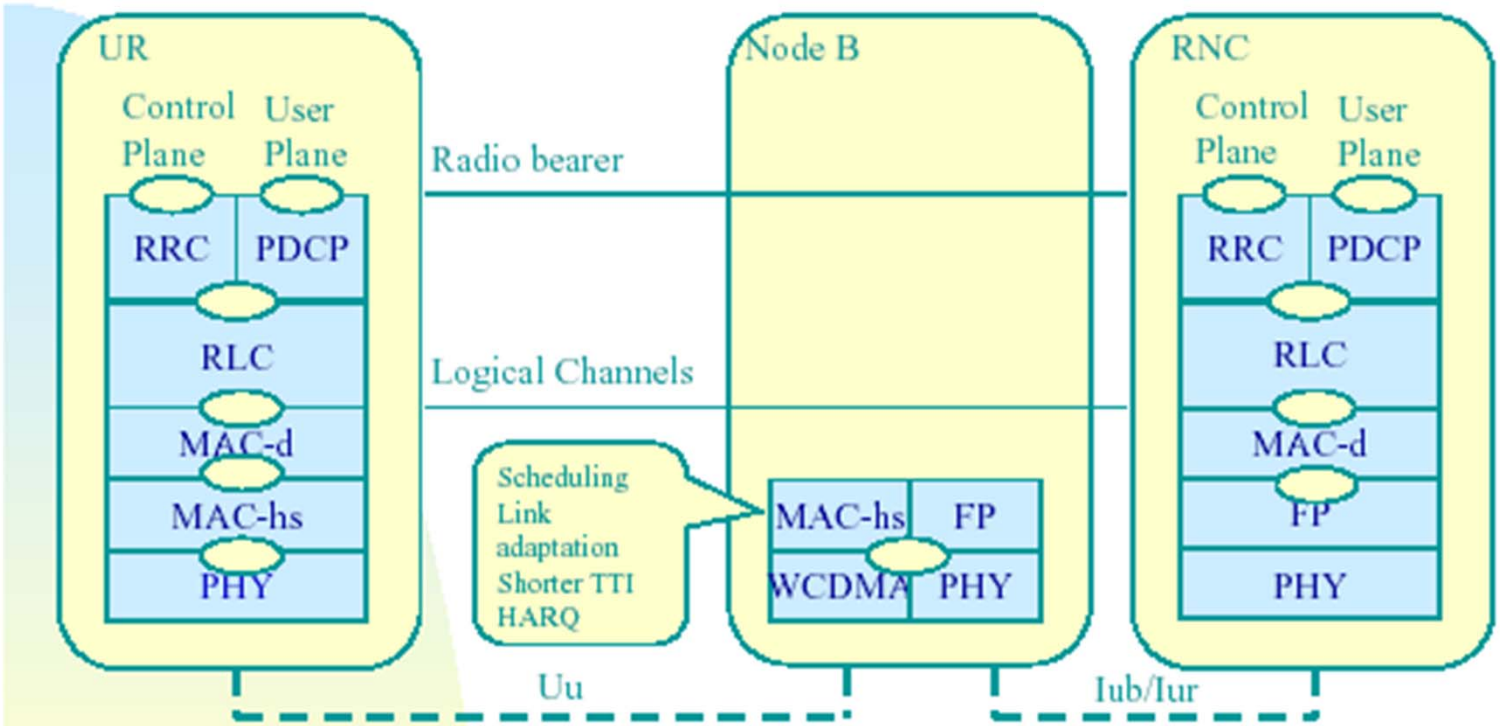


- Voice quality comparable to PSTN
- 144 kbps available to users in high-speed motor vehicles over large areas
- 384 kbps available to pedestrians standing or moving slowly over small areas
- Support for 2.048 Mbps for office use
- Symmetrical and asymmetrical data rates
- Support for both packet-switched 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

3.5G HSPA (High Speed Packet Access)

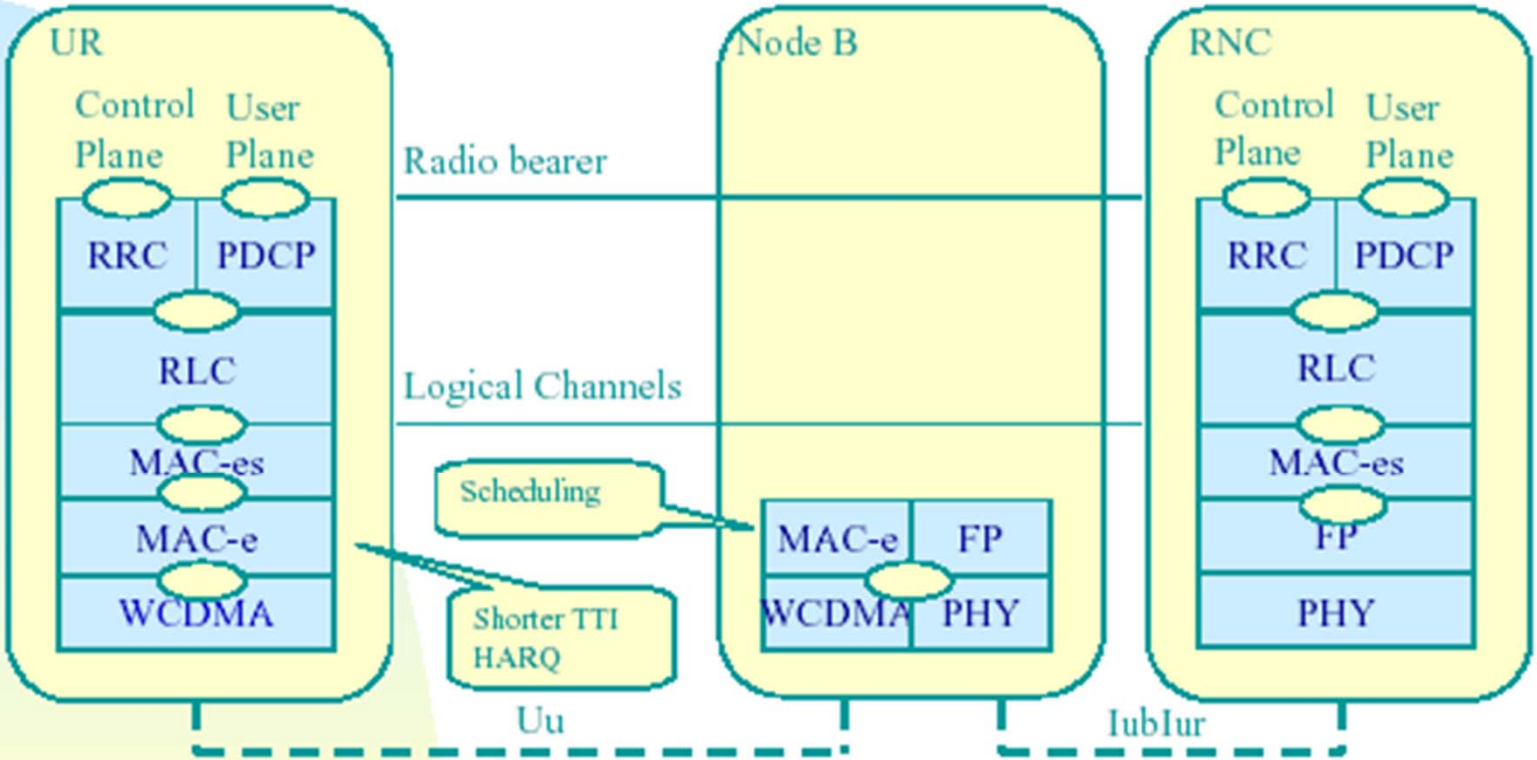
- In order to improve the packet data performance, the UMTS systems have been enhanced with HSPA.
- HSPA consists of two components, HSDPA and HSUPA:
- In the DL a new shared transport channel, the HS-DSCH
  - It allows to assign all available resource to one or more users in an efficient manner.
  - 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.

HSDPA: Protocol architecture



- Most of the features of HSDPA are implemented in the Node B:
  - Physical layer implementation
  - MAC-hs implements the HARQ protocol, making scheduling decisions as well as for the fast link adaptation.

HSUPA: Protocol architecture



- Most of the features of HSUPA are implemented in the Node B:
  - Physical layer implementation
  - MAC-e implements the HARQ protocol, making scheduling decisions aw well as for the fast link adaptation.

Fourth Generation (4G)

Provide ultra-broadband Internet access for a variety of mobile devices including laptops, smartphones, and tablet PCs

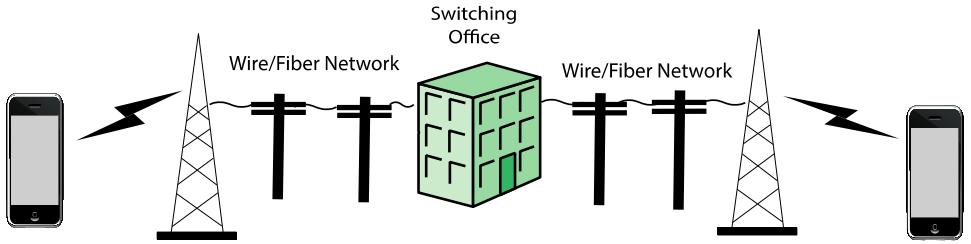
Minimum requirements:

- 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

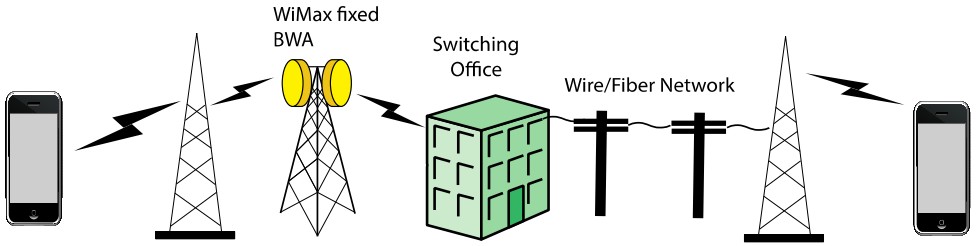
Support Mobile Web access and high-bandwidth applications such as high-definition mobile TV, mobile video conferencing, and gaming services

Designed to maximize bandwidth and throughput while also maximizing spectral efficiency

3G and 4G



(a) Third Generation (3G) Cellular Network

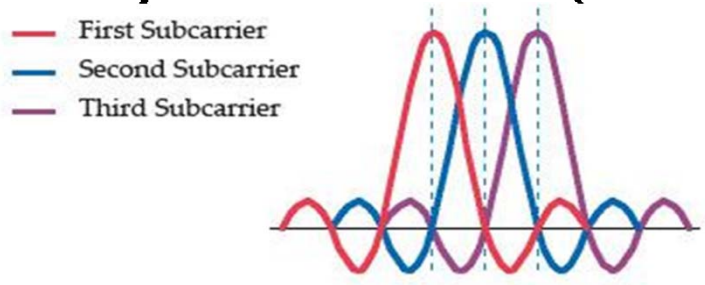


(b) Fourth Generation (4G) Cellular Network

Figure 10.9 Third vs. Fourth Generation Cellular Networks

LTE - Advanced

- Based on use of orthogonal frequency division multiple access (OFDMA)



Two candidates have emerged for 4G standardization:

Long Term Evolution (LTE)

Developed by the Third Generation Partnership Project (3GPP), a consortium of North American, Asian, and European telecommunications standards organizations

WiMax

(from the IEEE 802.16 committee)

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

Femtocells

- A low-power, short range, self-contained base station
- Term has expanded to encompass higher capacity units for enterprise, rural and metropolitan areas
- By far the most numerous type of small cells
- Now outnumber macrocells

- Key attributes include:
  - IP backhaul
  - Self-optimization
  - Low power consumption

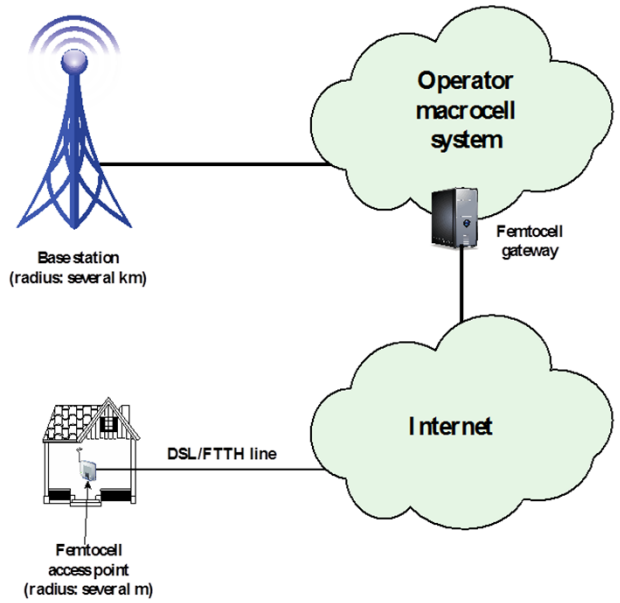
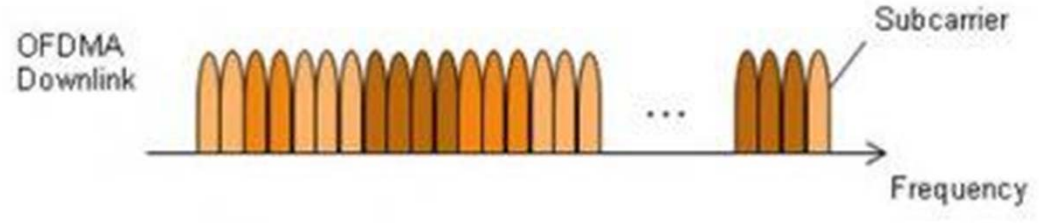


Figure 10.11 The Role of Femtocells

4G OFDMA, SC-FDMA

Downlink: Orthogonal Frecuency Division Multiple Access



Uplink: Single-carrier Frecuency Division Multiple Access

- Peak to average power ratio small (important factor for battery power equipment)

4G Protocols