Capítol 4. Xarxes d'accés

4.1 Fibra òptica FTTH

4.2 Mòbils

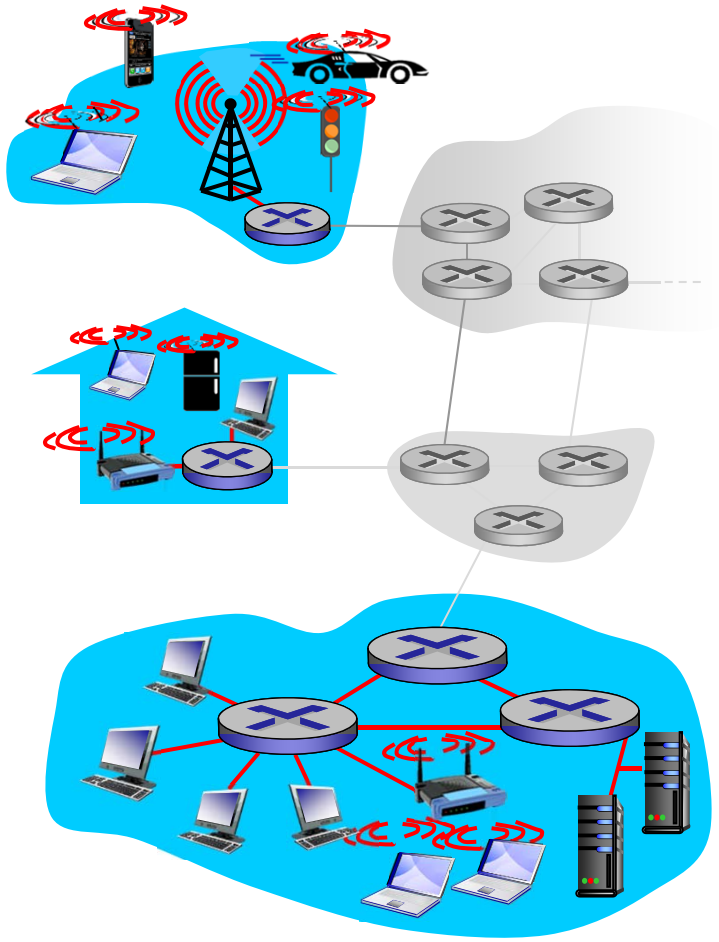
Access networks and physical media

Q: How to connect end systems to edge router?

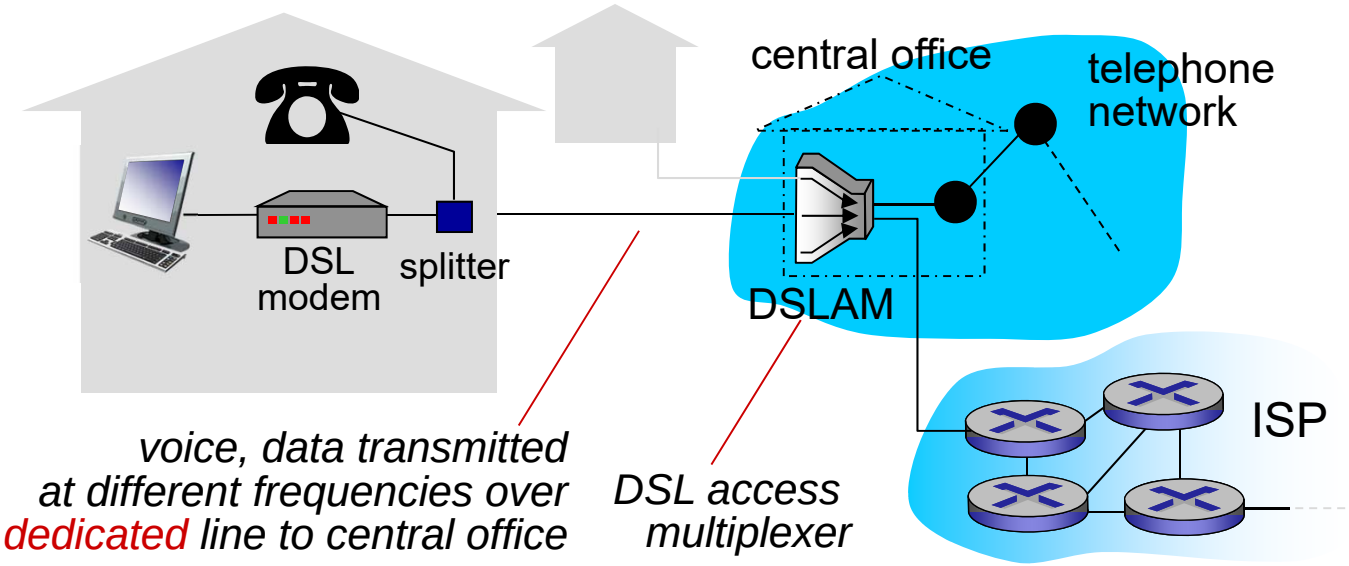
- residential access nets
- institutional access networks (school, company)
- mobile access networks

keep in mind:

- bandwidth (bits per second) of access network?
- shared or dedicated?

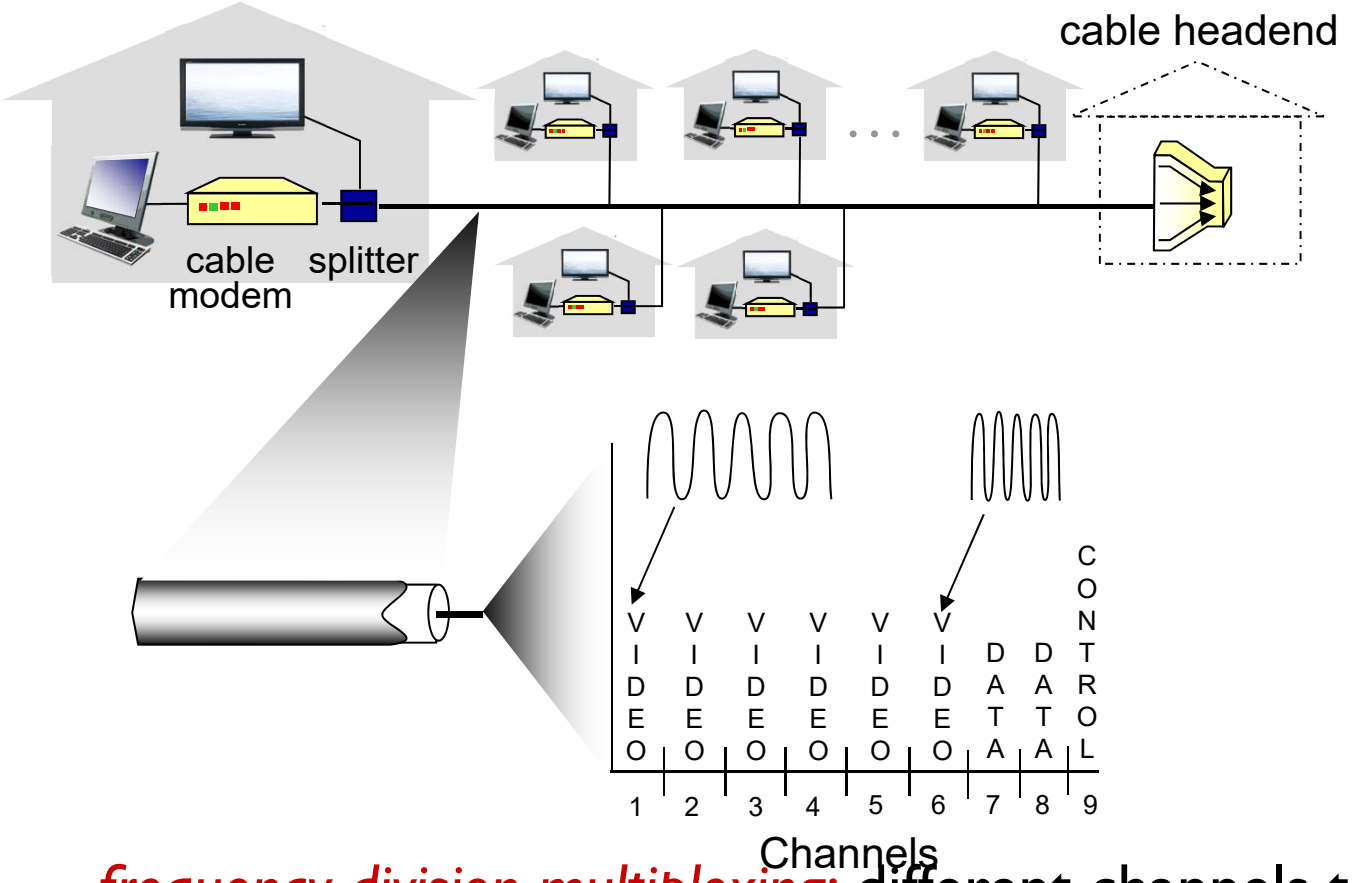


Access network: digital subscriber line (DSL)



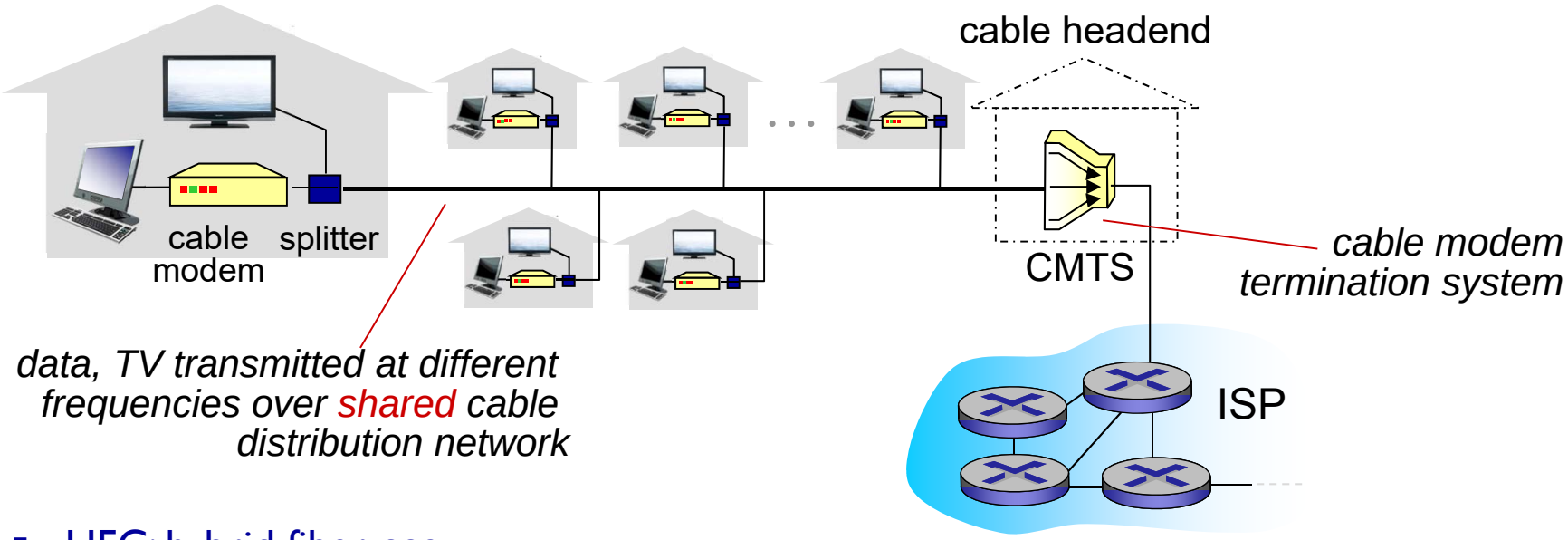
- use *existing* telephone line to central office DSLAM
  - data over DSL phone line goes to Internet
  - voice over DSL phone line goes to telephone net
- < 2.5 Mbps upstream transmission rate (typically < 1 Mbps)
- < 24 Mbps downstream transmission rate (typically < 10 Mbps)

Access network: cable network



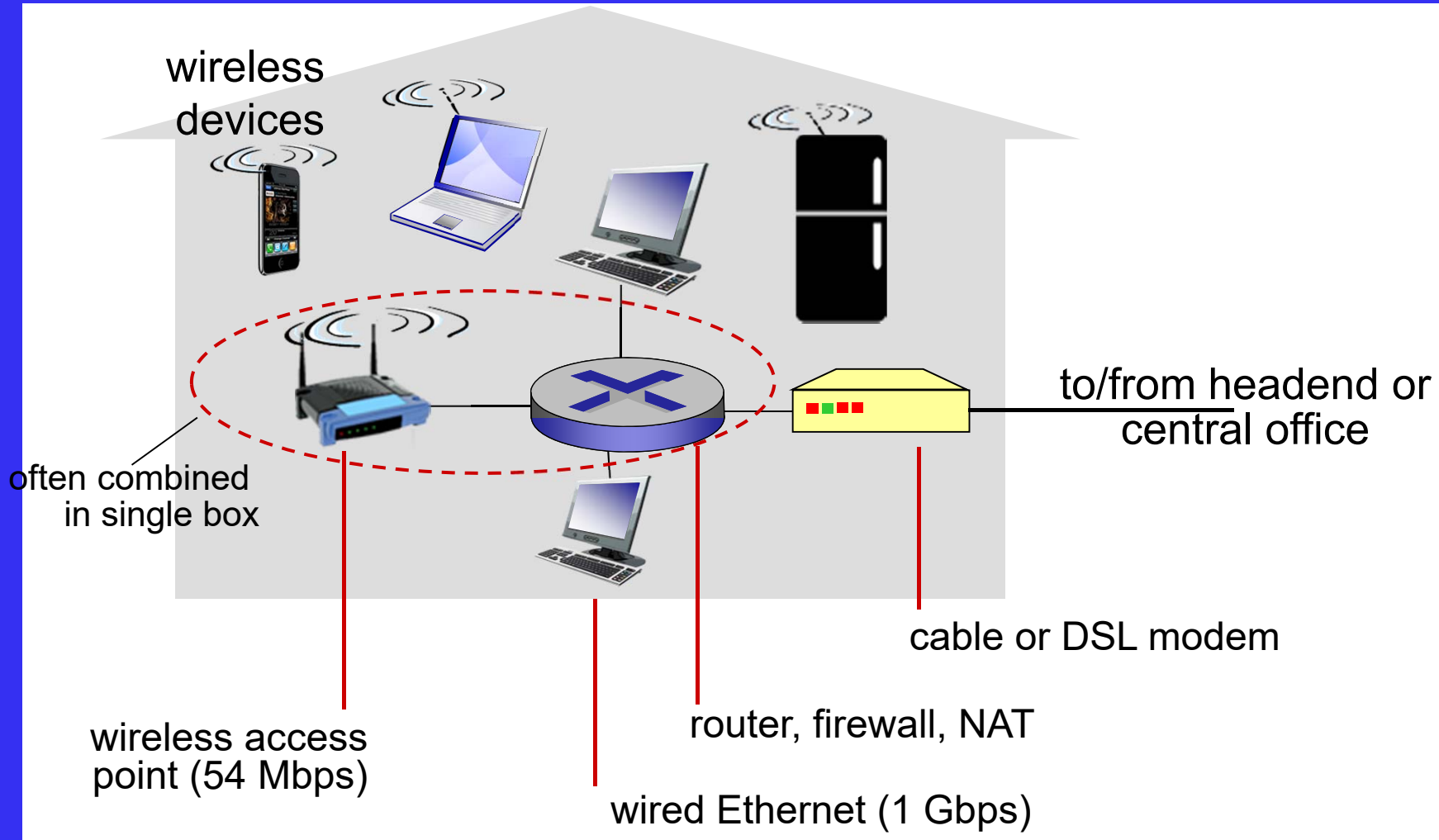
frequency division multiplexing: different channels transmitted in different frequency bands

Access network: cable network

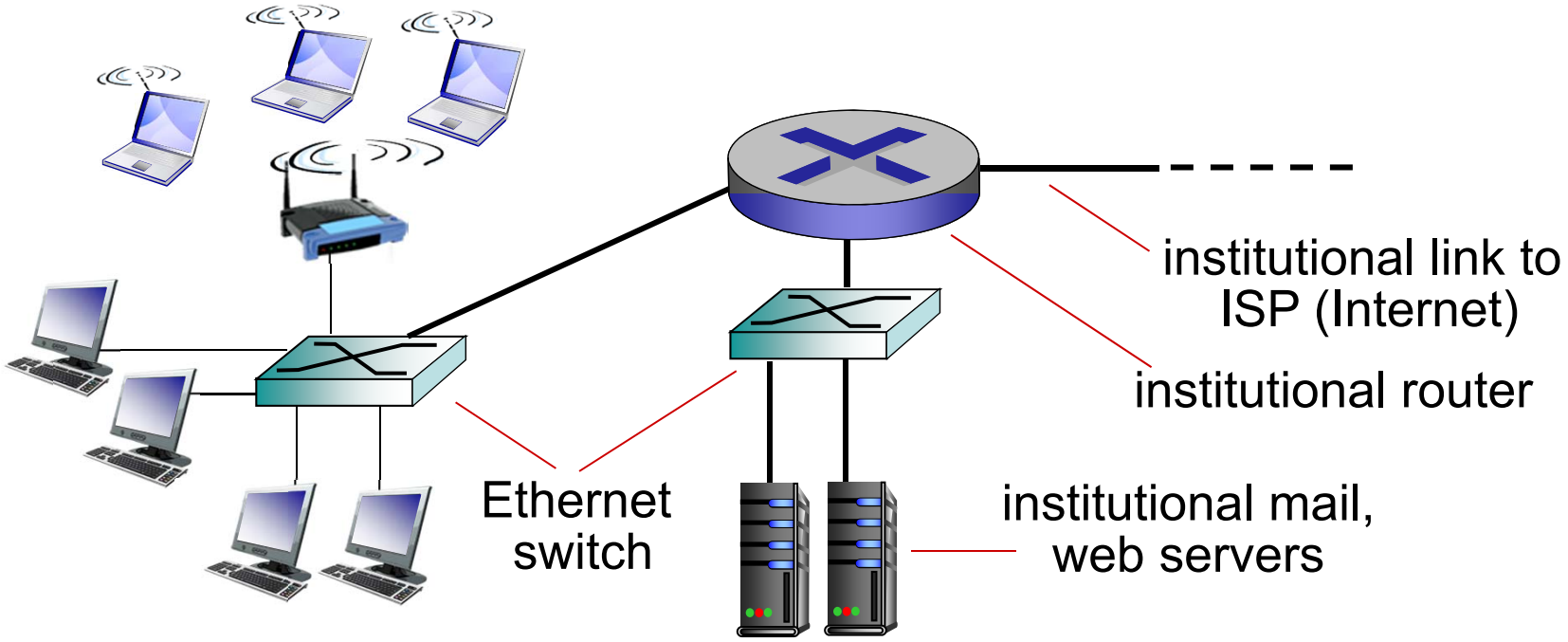


- HFC: hybrid fiber coax
  - asymmetric: up to 30Mbps downstream transmission rate, 2 Mbps upstream transmission rate
- network of cable, fiber attaches homes to ISP router
  - homes *share access network* to cable headend
  - unlike DSL, which has dedicated access to central office

Access network: home network



Enterprise access networks (Ethernet)



- typically used in companies, universities, etc.
- 10 Mbps, 100Mbps, 1Gbps, 10Gbps transmission rates
- today, end systems typically connect into Ethernet switch

Wireless access networks

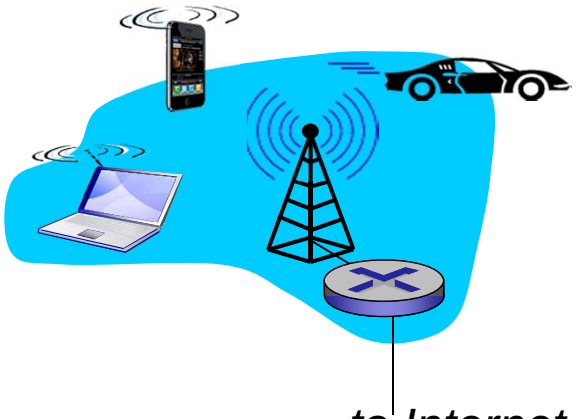
- shared *wireless* access network connects end system to router

wireless LANs:

- within building (100 ft.)
- 802.11b/g/n (WiFi): 11, 54, 450 Mbps transmission rate

wide-area wireless access

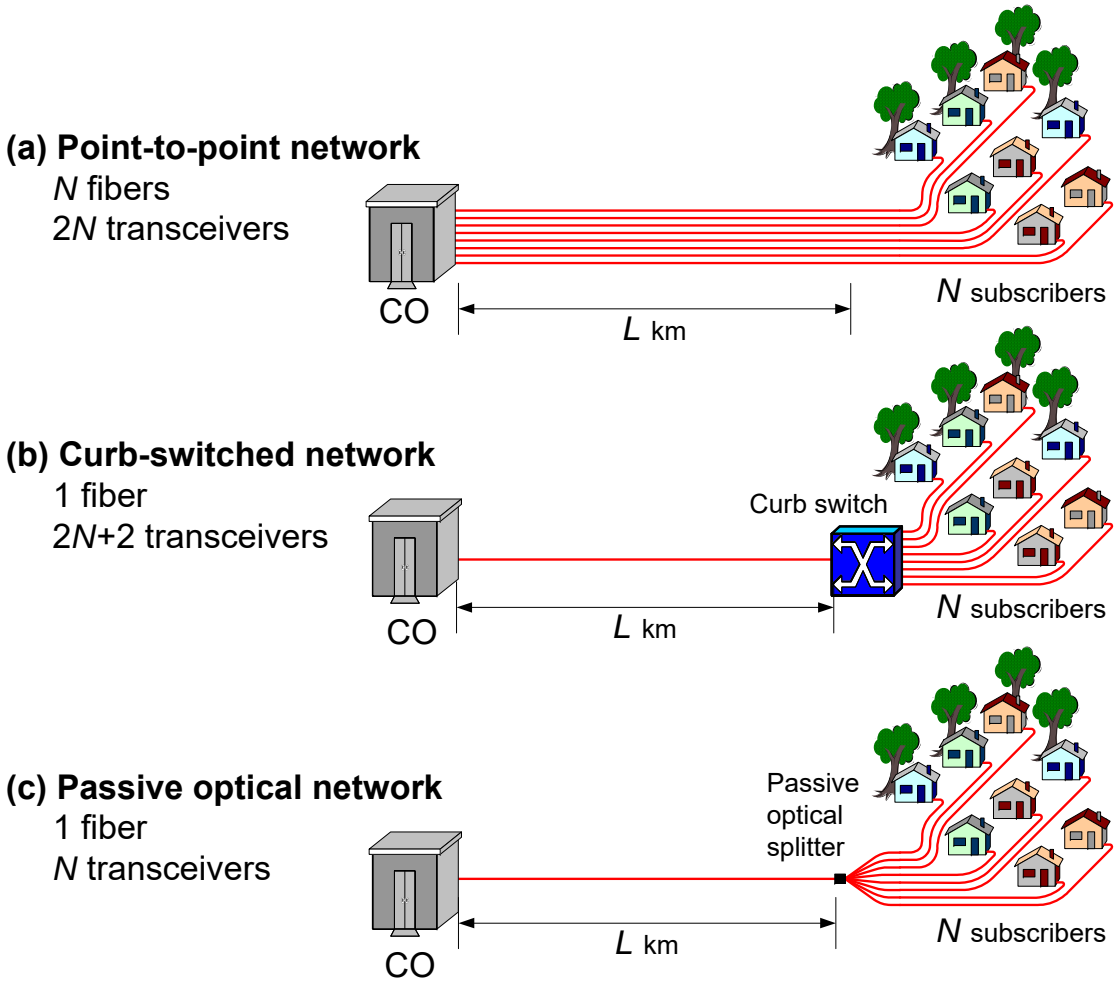
- provided by telco (cellular) operator, 10's km
- between 1 and 10 Mbps
- 3G, 4G: LTE



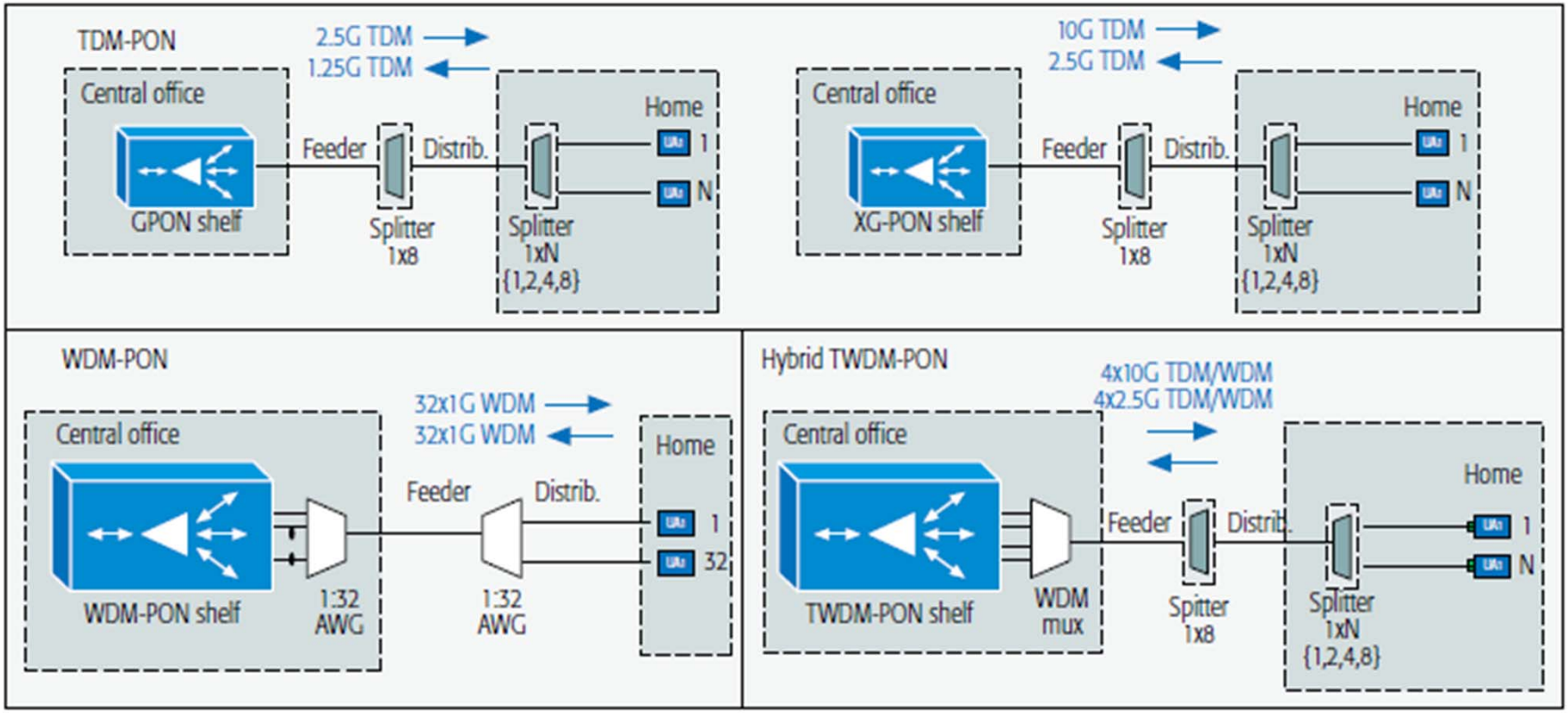
4.2 Fibra òptica FTTH

Source: ITU-T G.984.3

Topologies: Point-to-Point vs. PON



PON evolution



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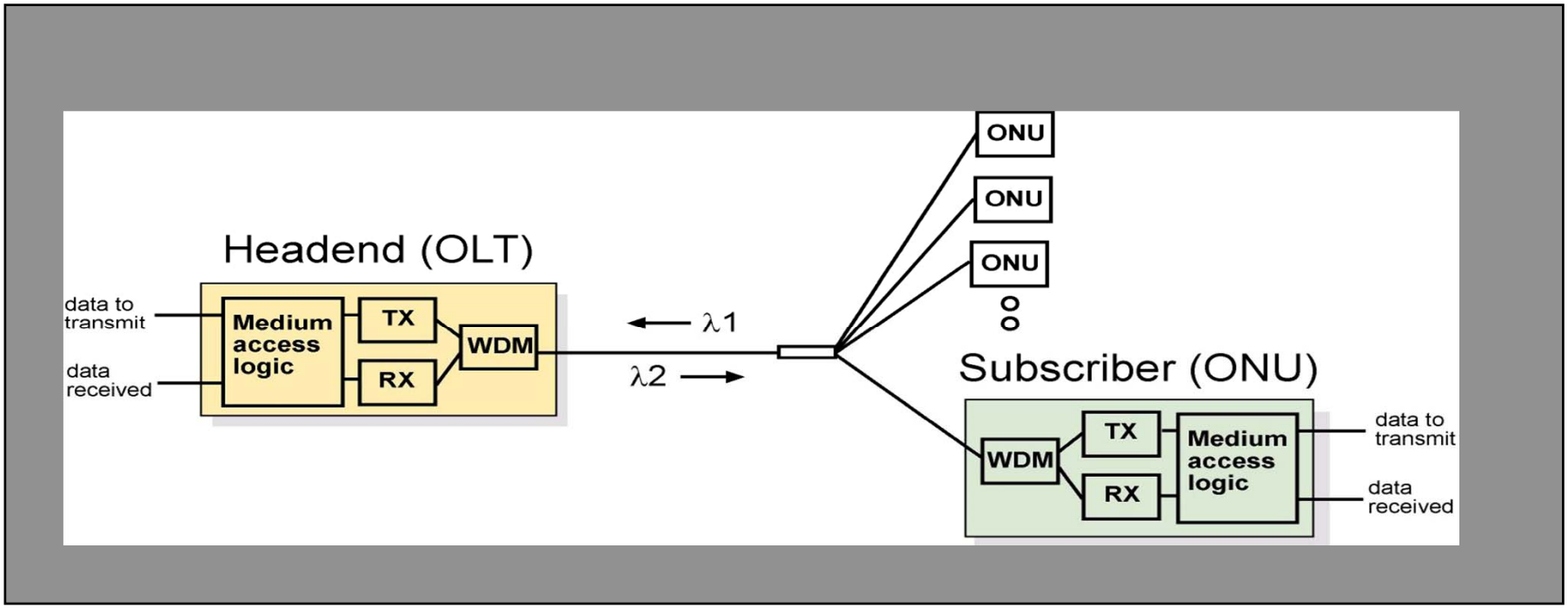
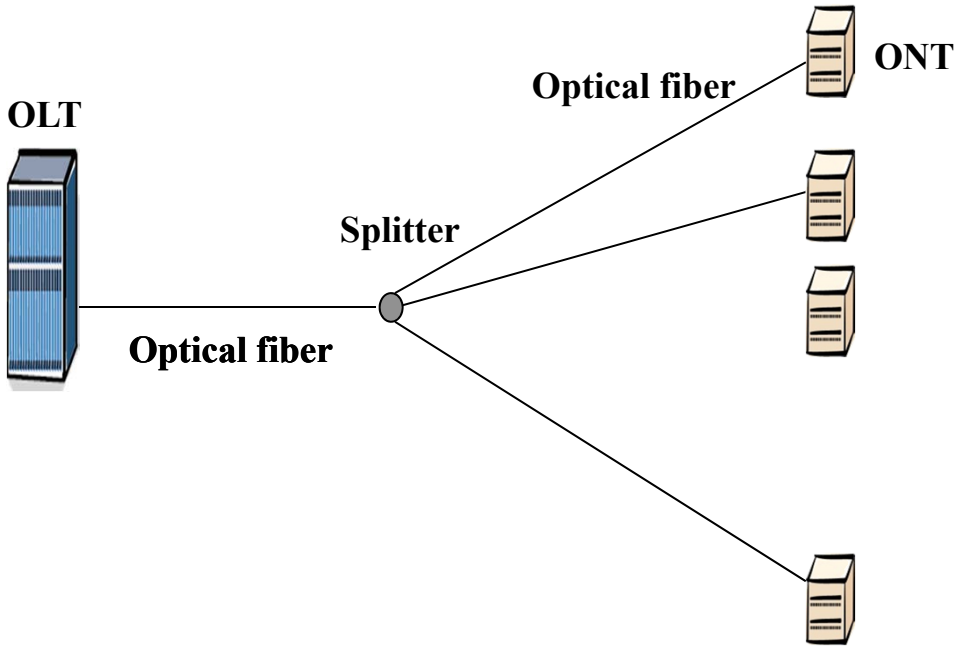
Single-Fiber PON

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



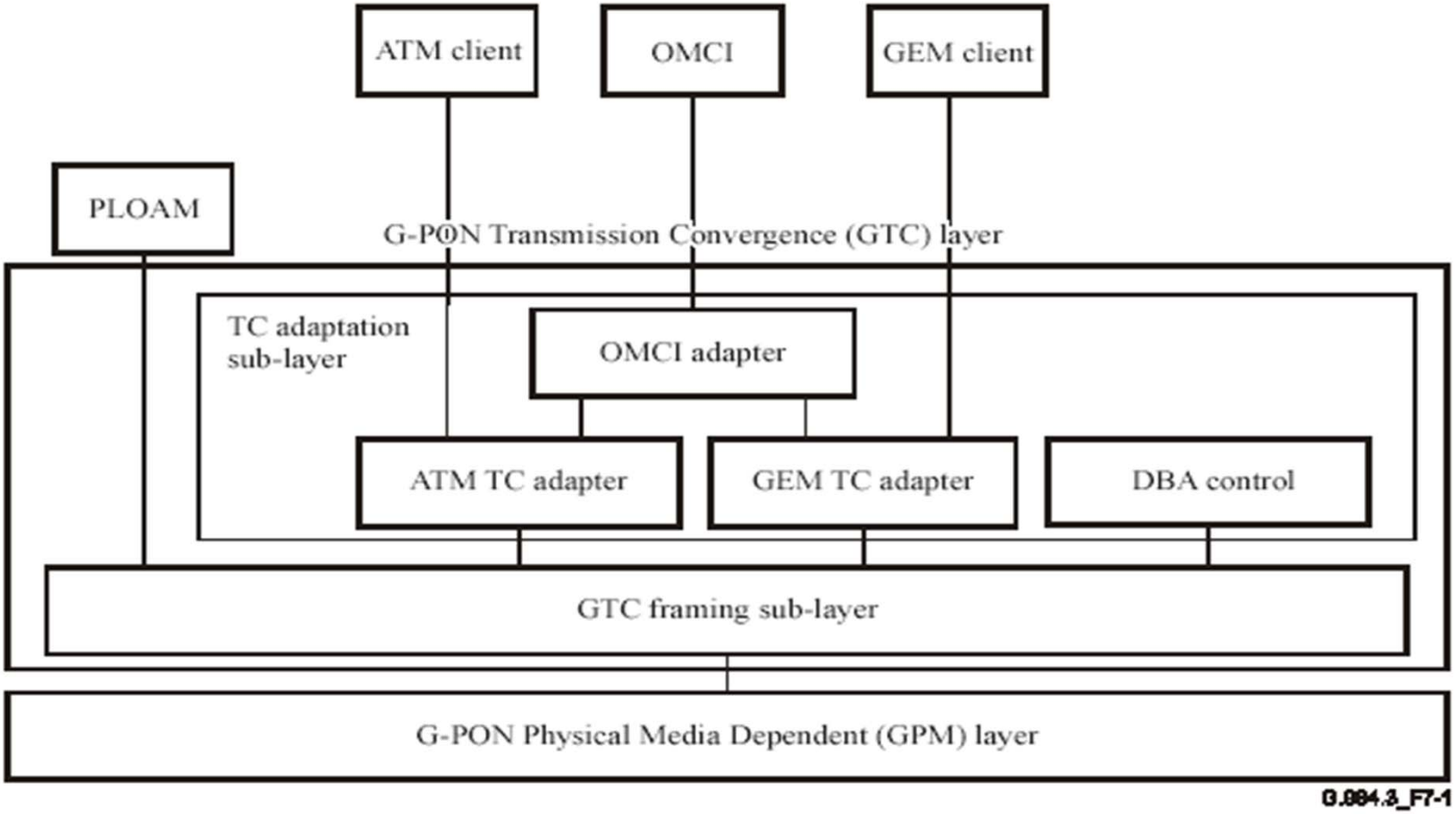
GPON Technology

GPON: Gigabit Passive Optic Network

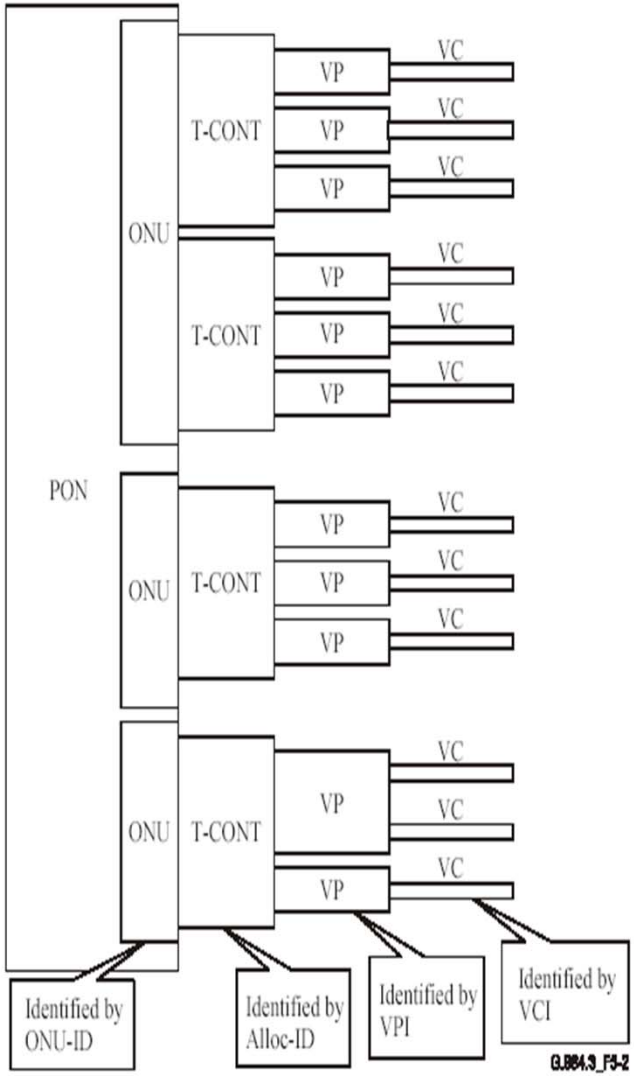


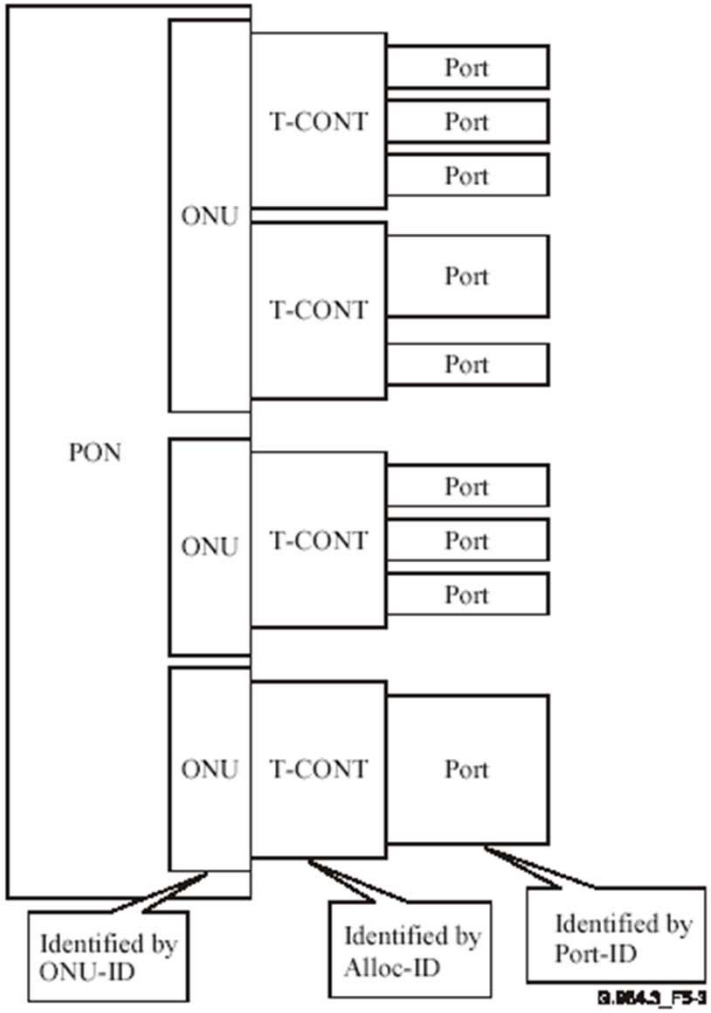
- Optical Fiber
- Point to multipoint
- Several levels of splitting
- 2.5 Gps DS and 1.25 Gbps US
- Up to 20 Km
- TDM DS and TDMA US

Protocol stack

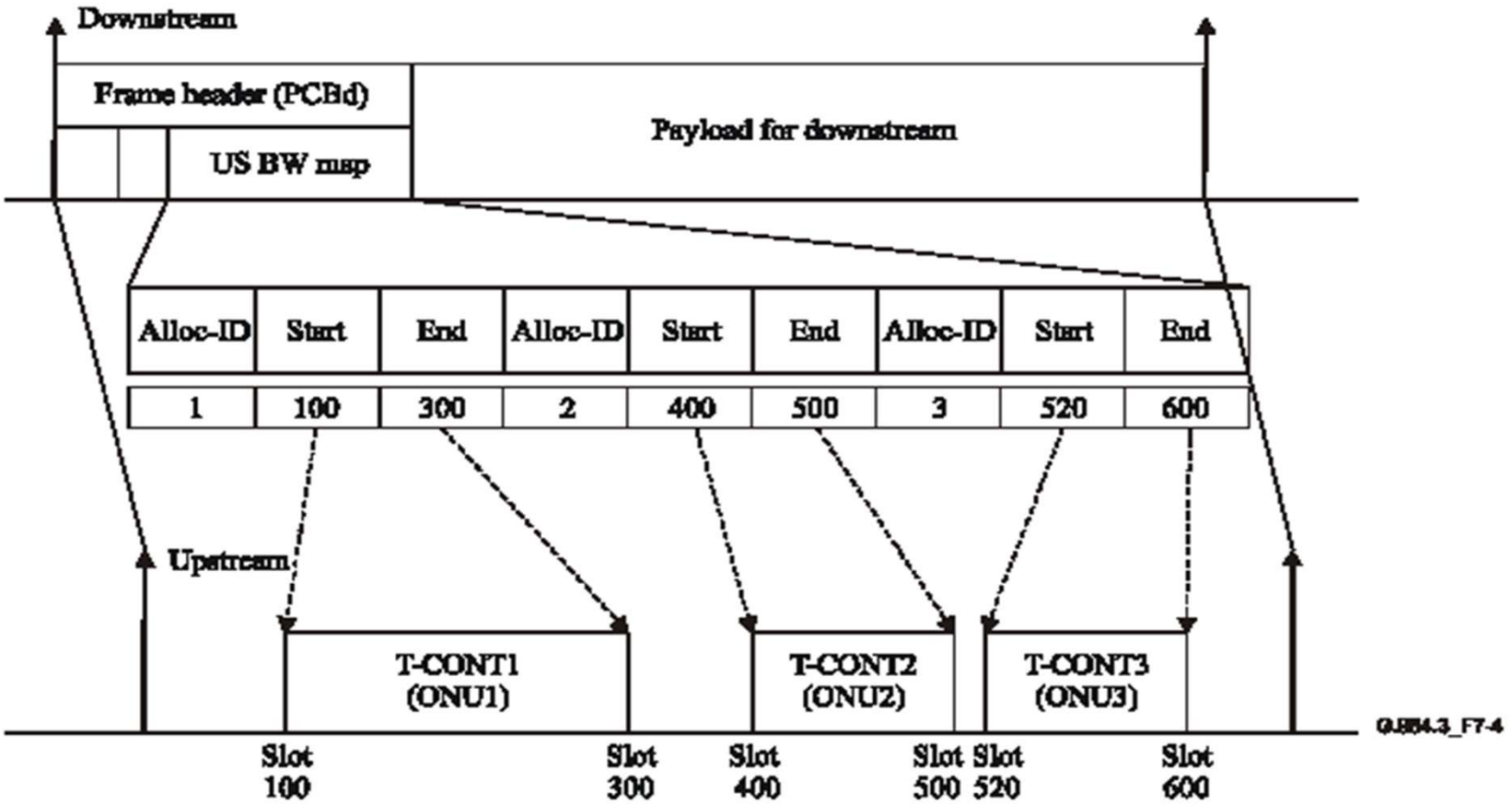


Multiplexed architecture

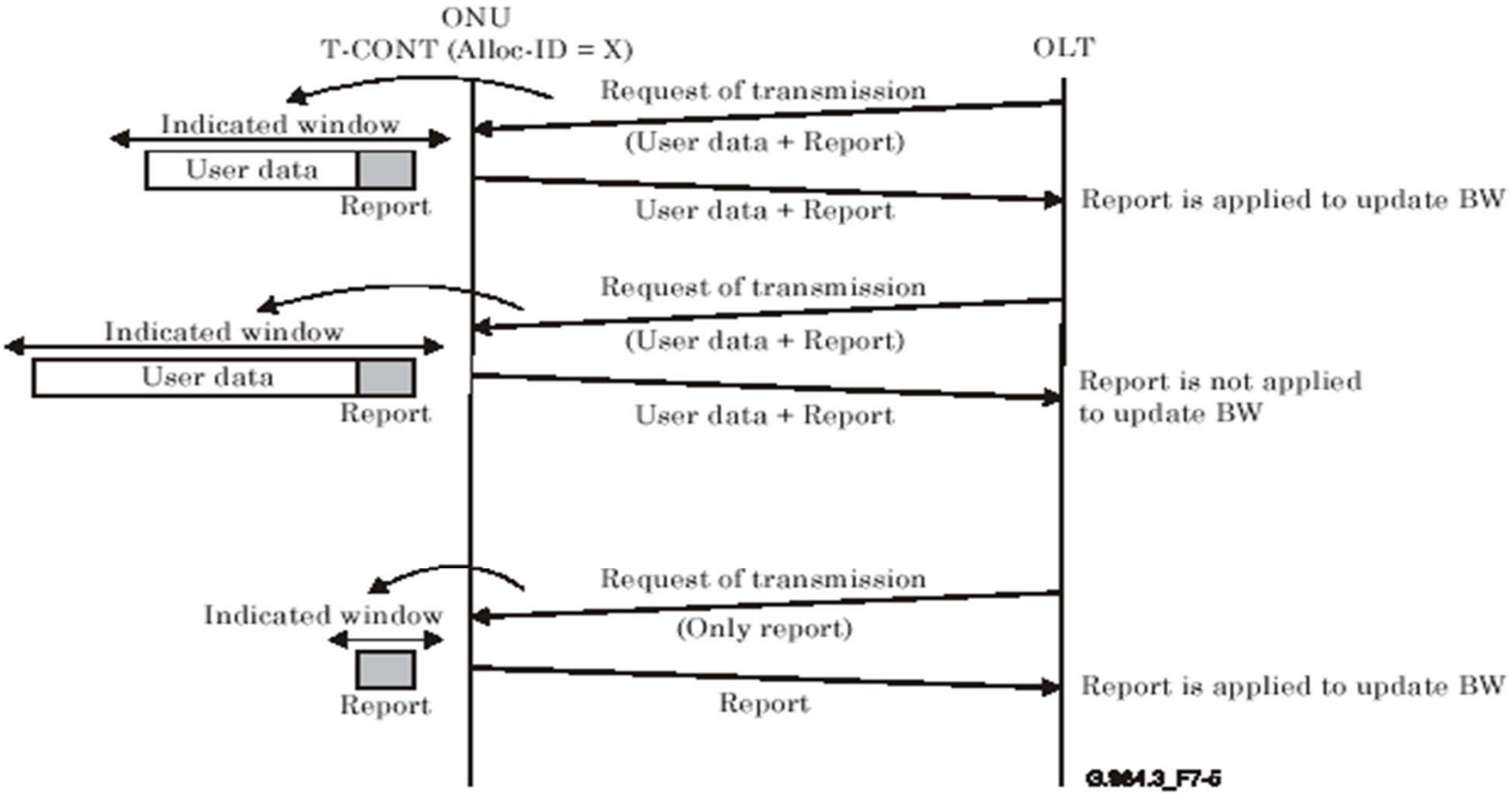




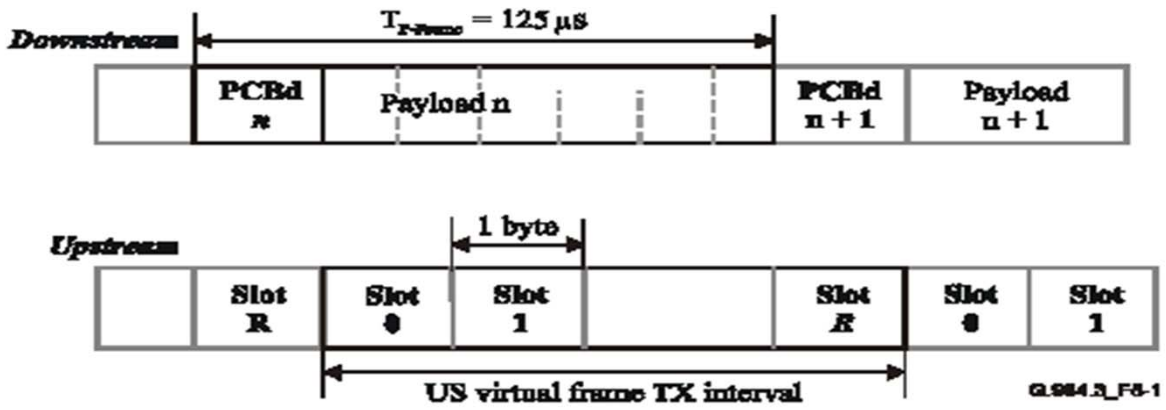
Media access control



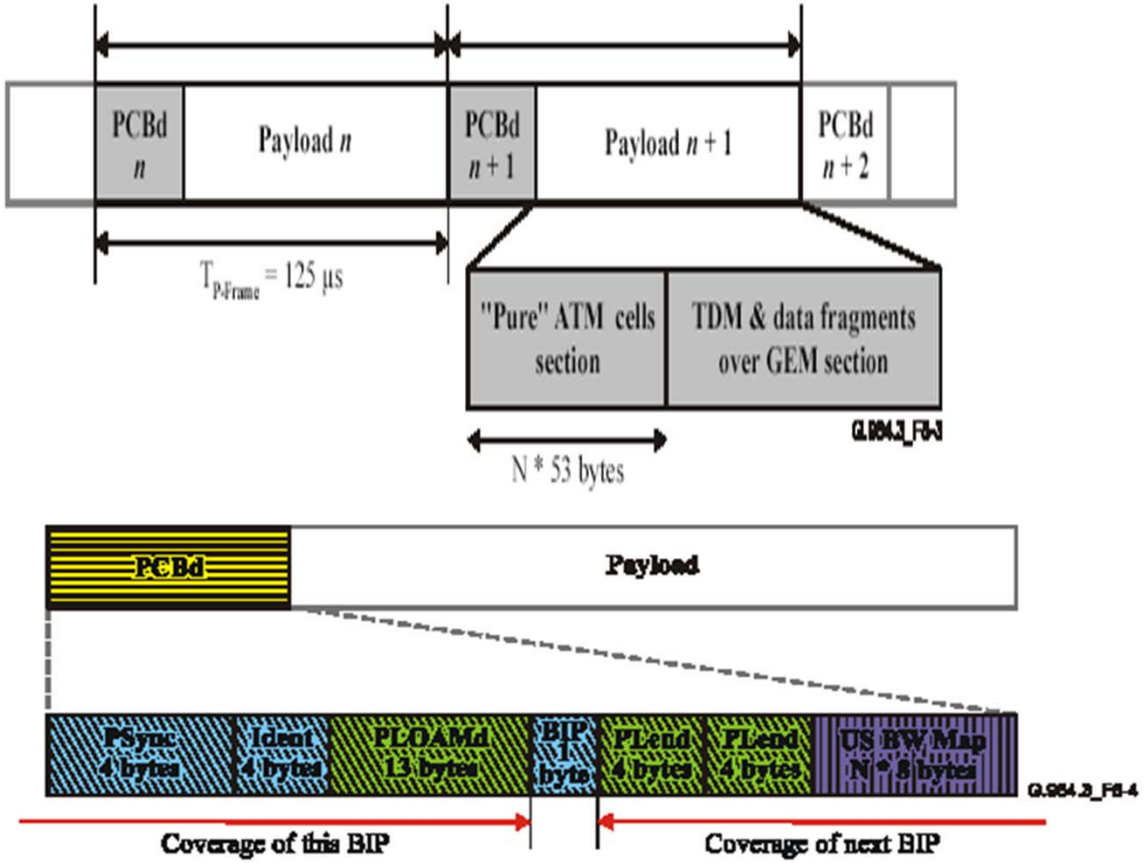
SR-DBA operation



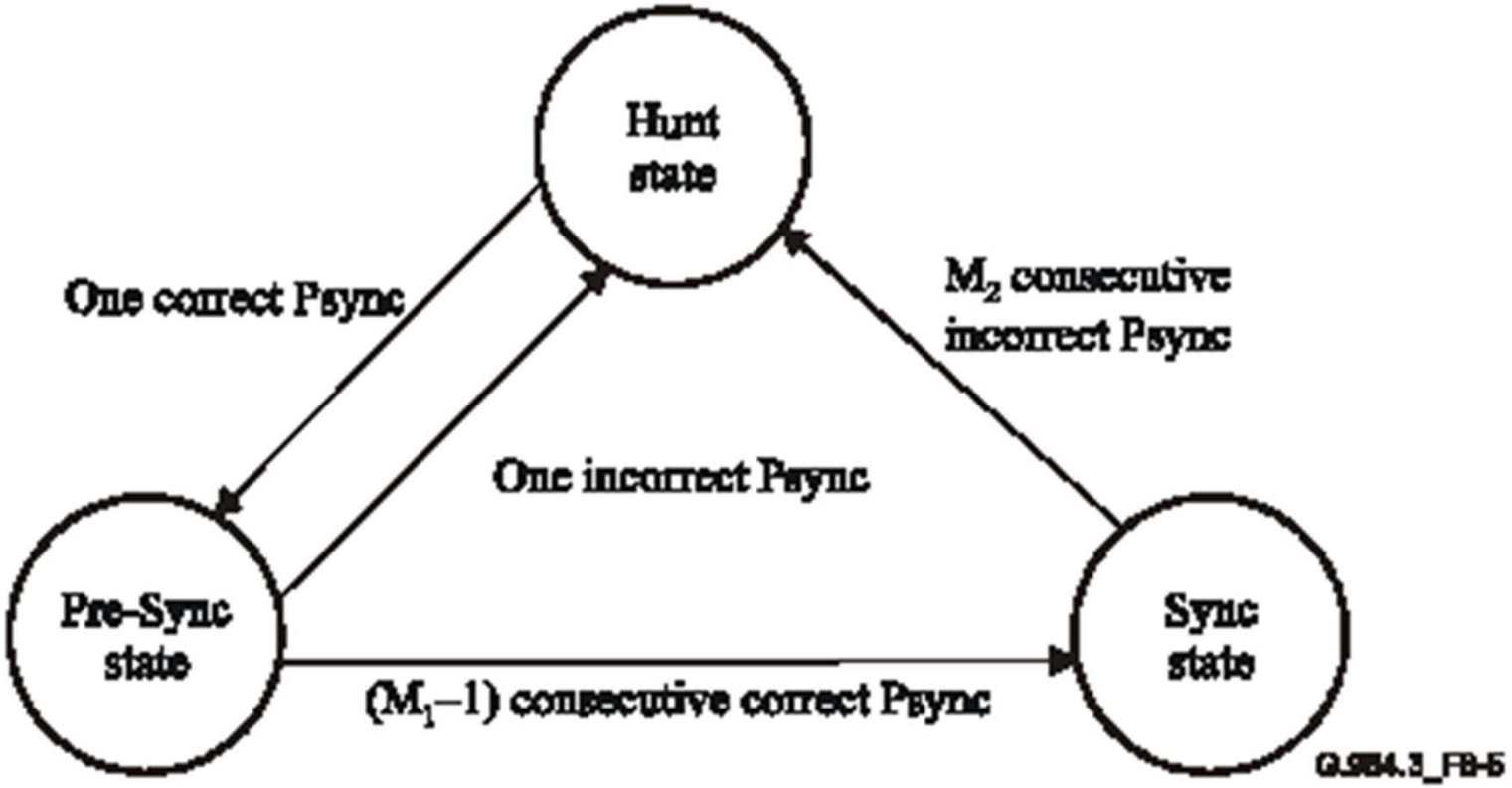
Frame structure



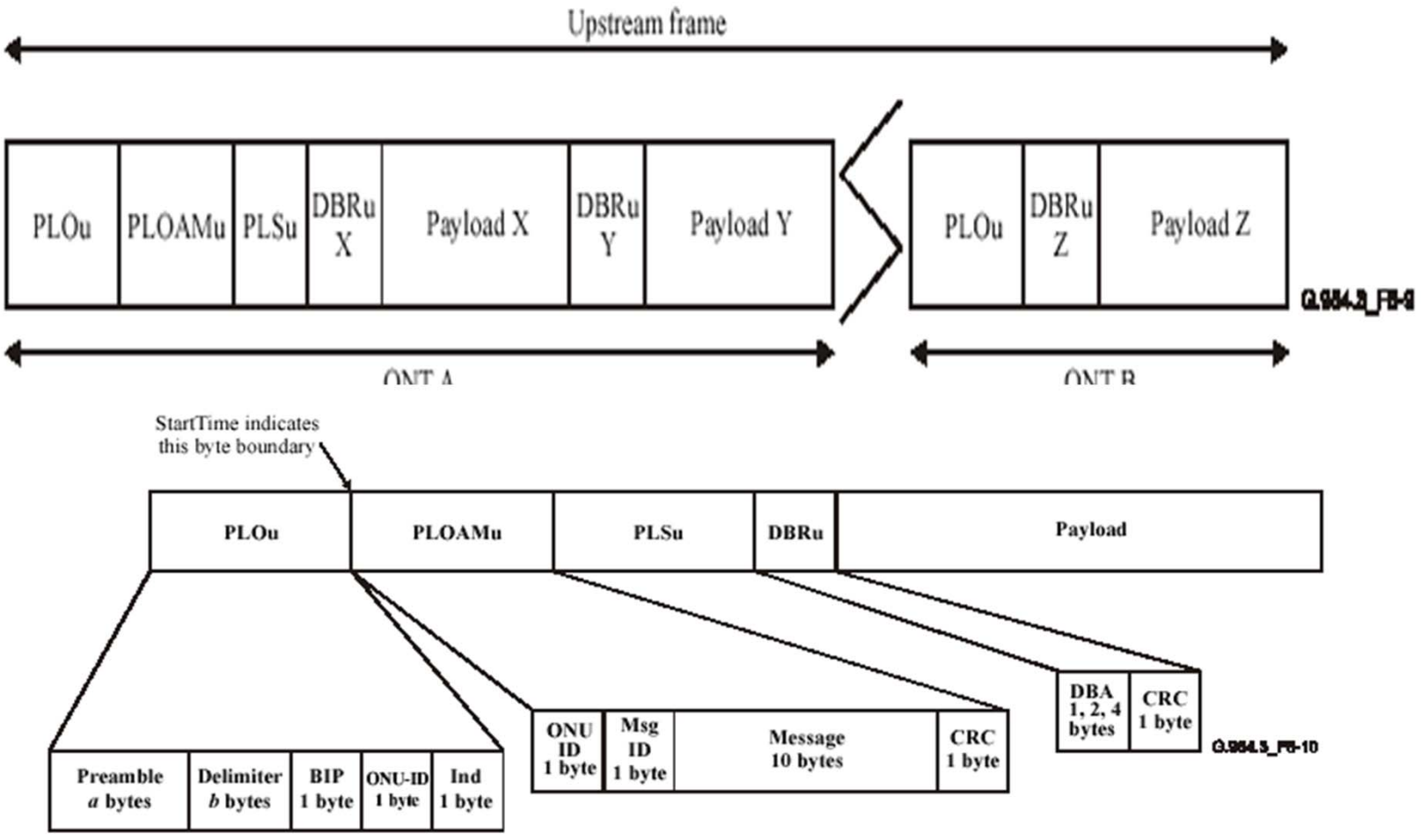
Downstream frame



Downstream synchronization



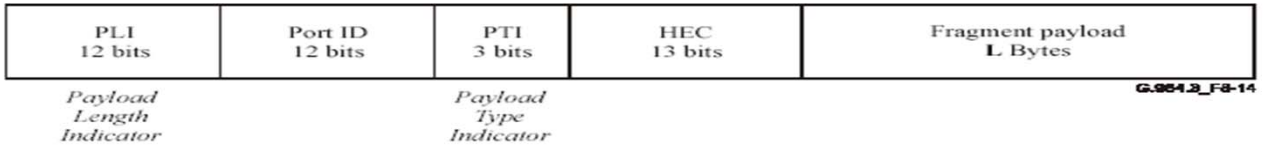
Upstream frame

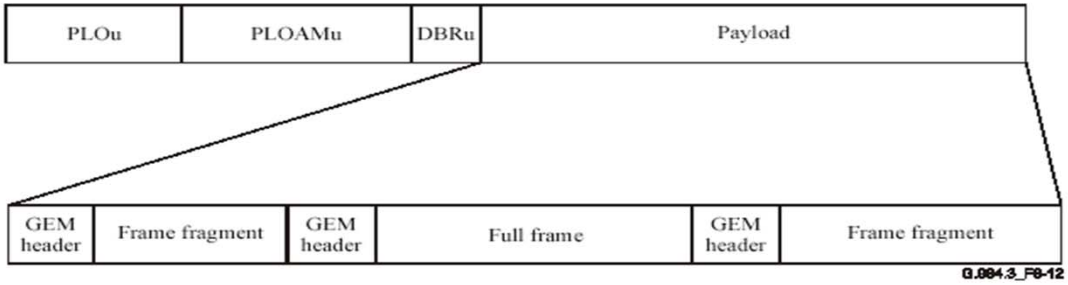


IND field

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

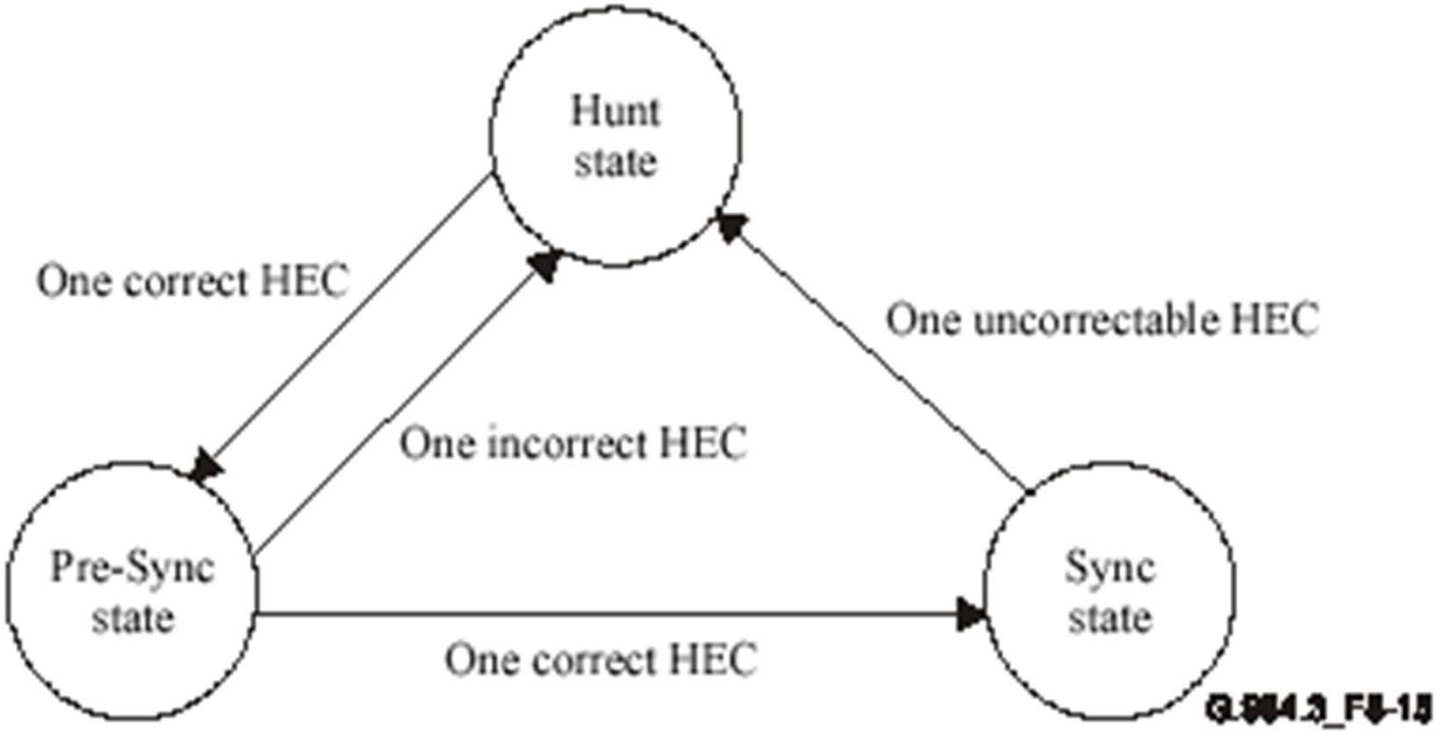
GEM upstream payload



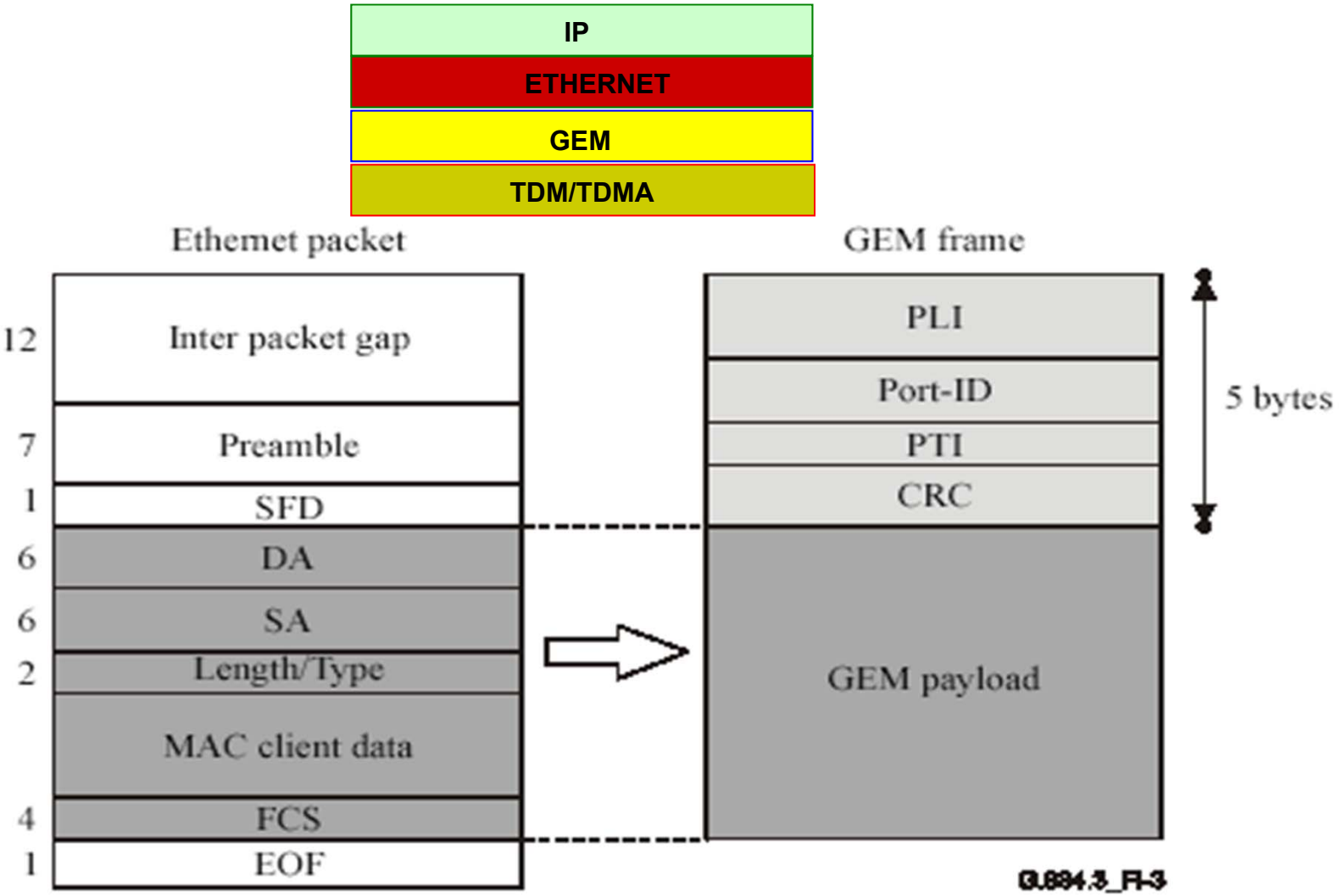


PTI code	Meaning
000	User data fragment, Congestion has Not occurred, Not the end of a frame
001	User data fragment, Congestion has Not occurred, End of a frame
010	User data fragment, Congestion Has occurred, Not the end of a frame
011	User data fragment, Congestion Has occurred, End of a frame
100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

GEM delineation



Ethernet over GEM



4.3 Mòbils

Xarxes mòbils Espanya (2022)

Reparto de espectro radioeléctrico en España para telefonía móvil

	700 MHz (Banda 28) 5G	800 MHz (Banda 20) 4G	900 MHz (Banda 8) 2G y 3G	1.800 MHz (Banda 3) 2G y 4G	2.100 MHz (Banda 1) 3G y 4G	2.6 GHz (Banda 7 y 38) 4G y 5G DSS	3.5 GHz (Banda 78) 5G
Movistar	20 MHz FDD	20 MHz FDD	30 MHz FDD	40 MHz FDD	30 MHz FDD 5 MHz TDD	40 MHz FDD 10 MHz FDD en Madrid y Melilla	100 MHz T (40 MHz válidos hasta 2 (60 MHz válidos hasta 2
vodafone	20 MHz FDD	20 MHz FDD	20 MHz FDD	40 MHz FDD	30 MHz FDD 5 MHz TDD	40 MHz FDD 20 MHz TDD	90 MHz TD (validos hasta 2038)
orange	20 MHz FDD	20 MHz FDD	20 MHz FDD	40 MHz FDD	30 MHz FDD 5 MHz TDD	40 MHz FDD 10 MHz TDD 10 MHz FDD excepto Castilla La Mancha, País Vasco, Asturias, Galicia, Madrid y Melilla	110 MHz T (40 MHz válidos hasta 2 (70 MHz válidos hasta 2
MÁSMÓVIL	-	-	-	30 MHz FDD	30 MHz FDD 5 MHz TDD	10 MHz TDD en Madrid, Cataluña, Castilla-La Mancha y Andalucía	80 MHz TD (validos hasta 2030)

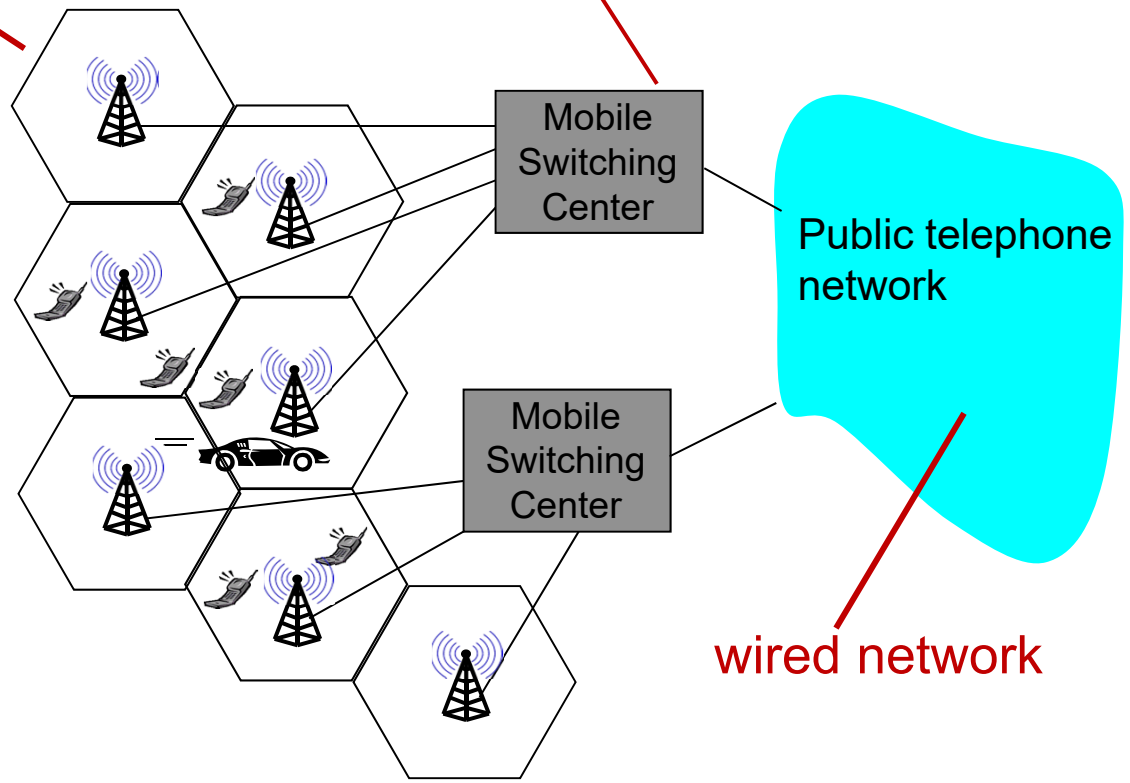
Principles of Cellular Networks

- 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

Components of cellular network architecture

MSC
- connects cells to wired tel. net.
- manages call setup (more later!)
- handles mobility (more later!)

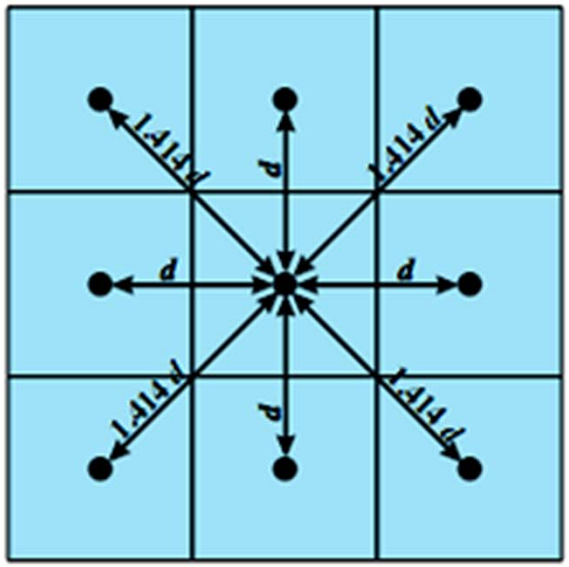
cell
- covers geographical region
- *base station* (BS) analogous to 802.11 AP
- *mobile users* attach to network through BS
- *air-interface:* physical and link layer protocol between mobile and BS



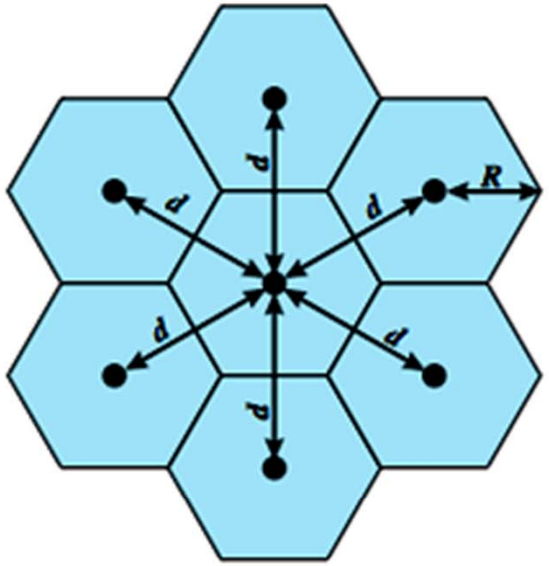
Cellular Network Organization

- 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

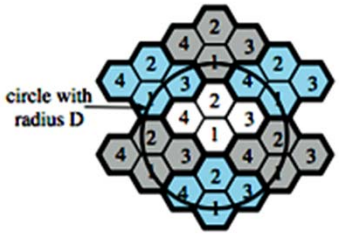
Object is to share nearby cell frequencies without interfering with each other

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

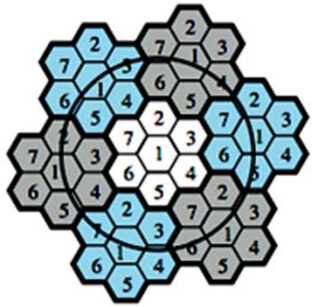
Power of base transceiver controlled

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

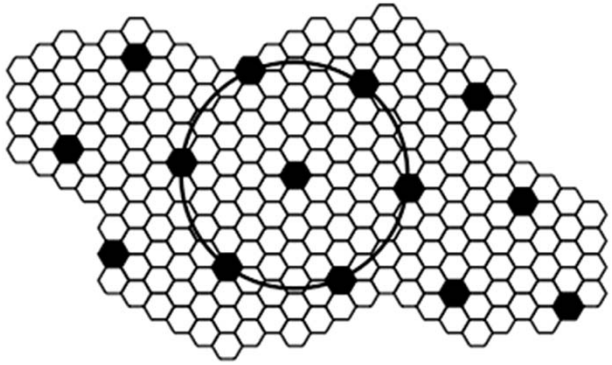
Frequency Reuse Patterns



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

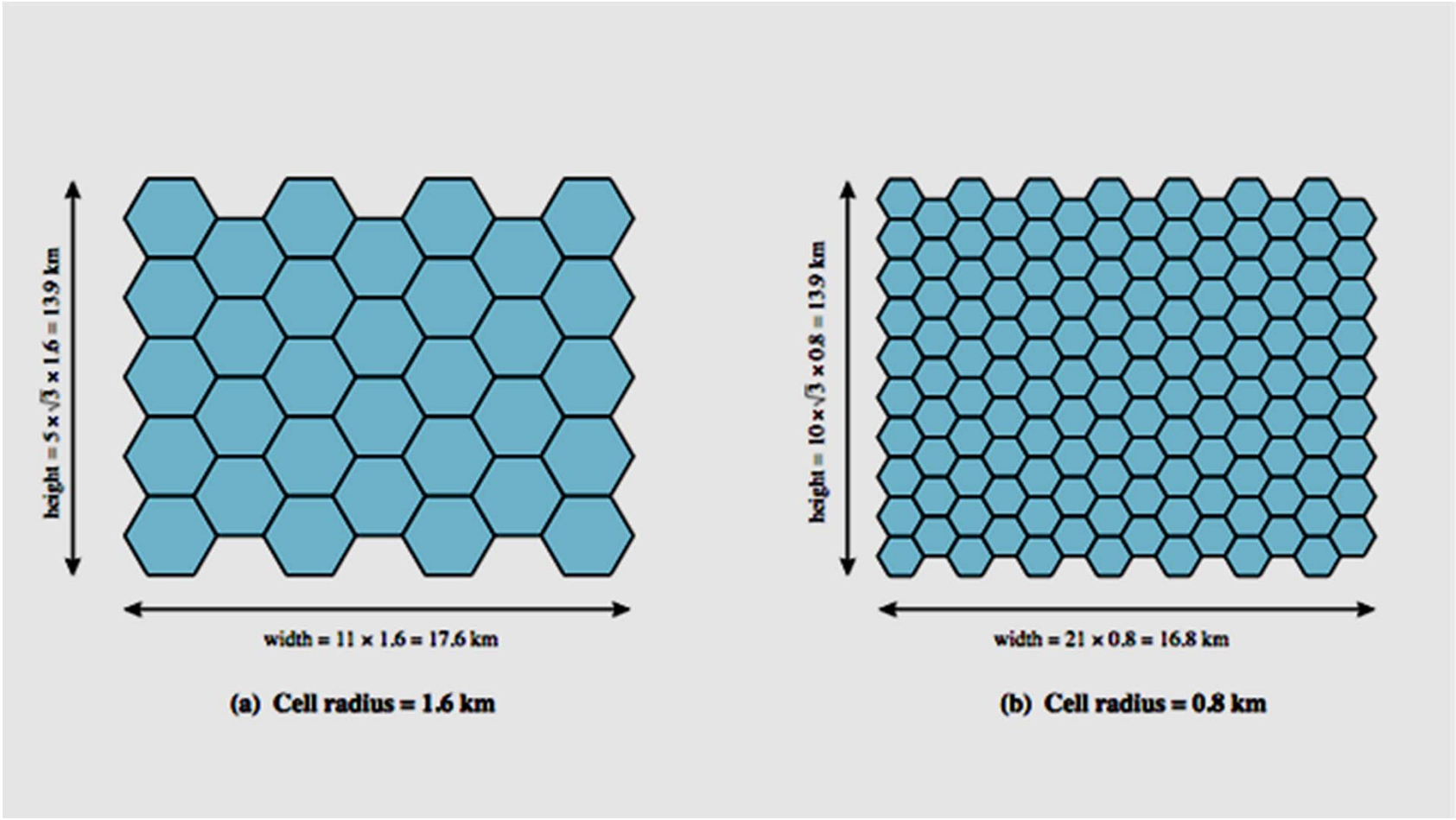


(b) Frequency reuse pattern for $N = 7$



(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

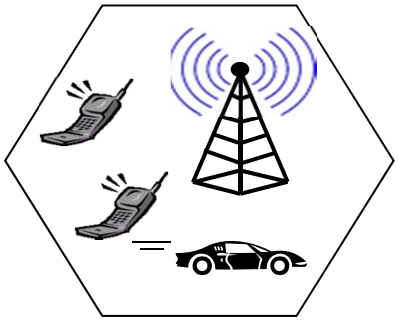
Wireless Network Generations

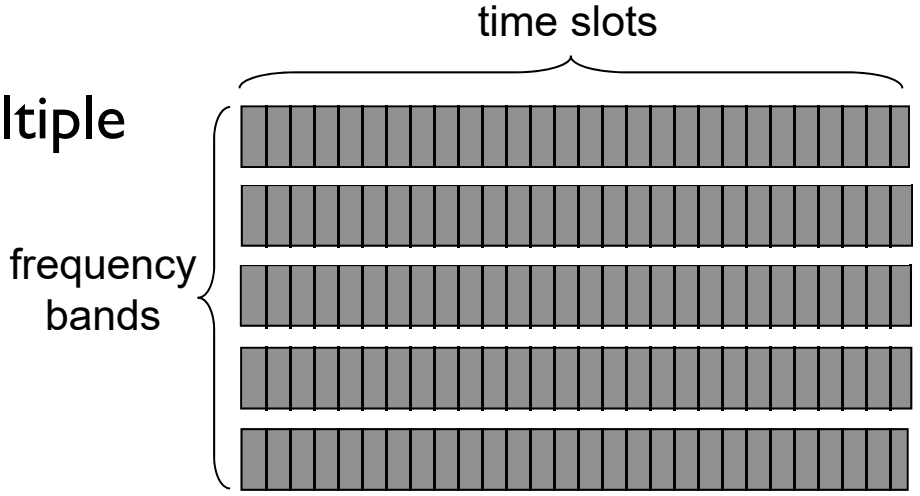
Technol ogy	1G	2G	2. 5G	3G	4G
Design began	1970	1980	1985	1990	2000
Implementation	1984	1991	1999	2002	2012
Services	Analog voice	Digital voice	Higher capacity packetized data	Higher capacity, broadband	Completely IP based
Data rate	1.9. kbps	14.4 kbps	384 kbps	2 Mbps	200 Mbps
Multiplexing	FDMA	TDMA,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

Cellular networks: the first hop

Two techniques for sharing mobile-to-BS radio spectrum

- combined FDMA/TDMA: divide spectrum in frequency channels, divide each channel into time slots
- CDMA: code division multiple access

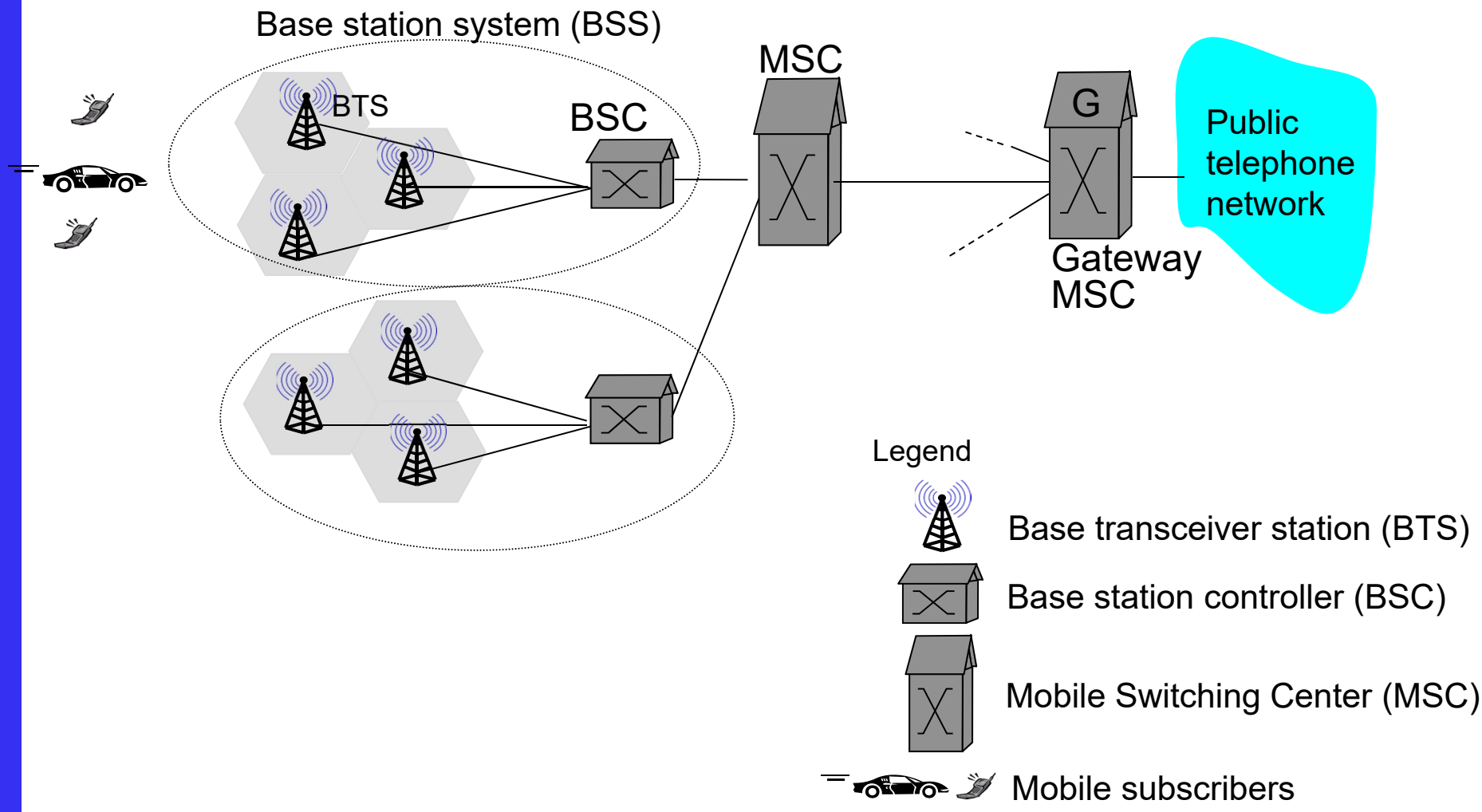




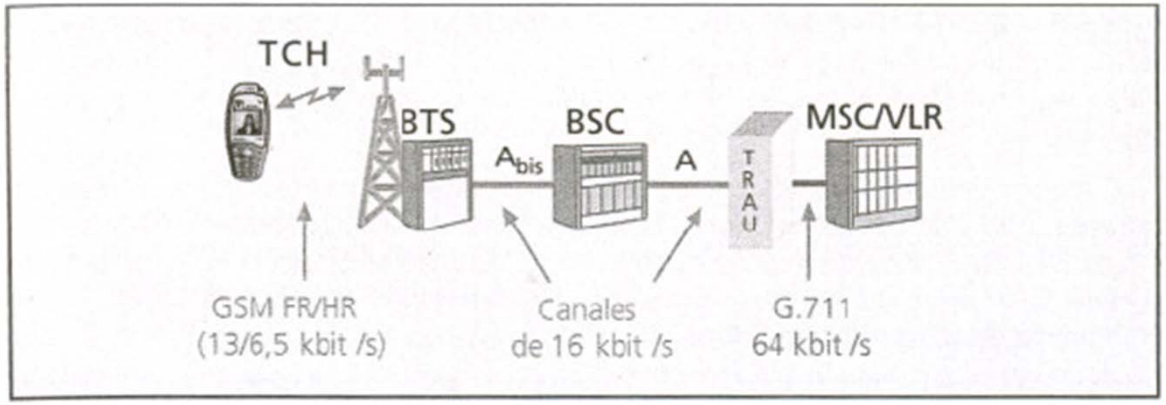
Second Generation (2G)

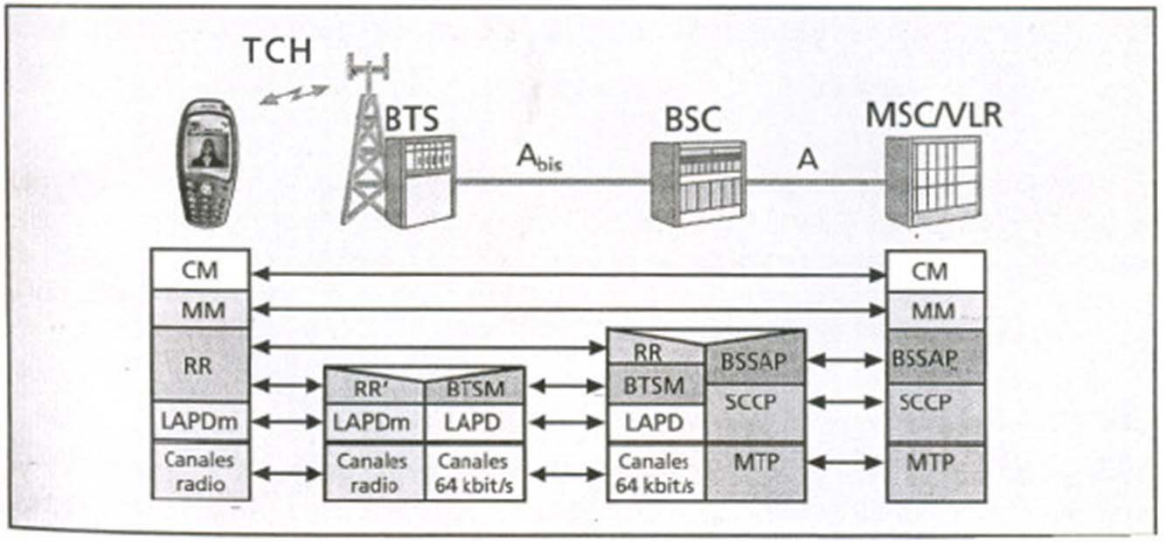
- Developed to provide higher quality signals, higher data rates for support of digital services, and greater capacity
- Key differences between 1G and 2G include:
  - Digital traffic channels
  - Encryption
  - Error detection and correction
  - Channel access
    - *Time division multiple access (TDMA)*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

2G (voice) network architecture

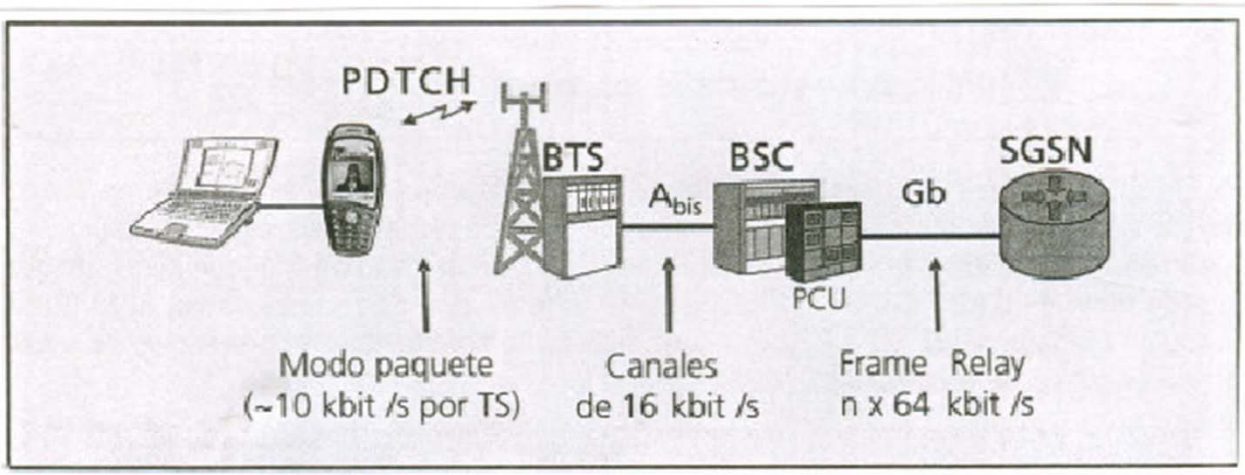


2G GSM

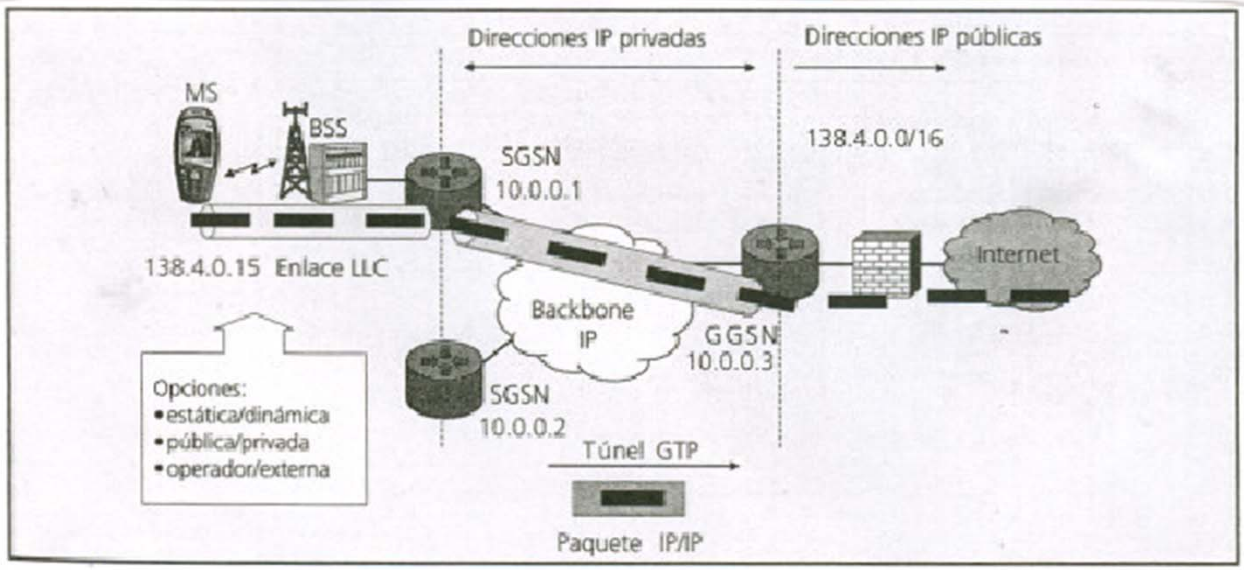

TCH
BTS
Abis
BSC
A
TRAU
MSC/VLR
GSM FR/HR
(13/6,5 kbit /s)
Canales
de 16 kbit /s
G.711
64 kbit /s


TCH
BTS
Abis
BSC
A
MSC/VLR
CM
MM
RR
LAPDm
Canales radio
RR'
BTSM
LAPD
Canales 64 kbit/s
RR
BTSM
LAPD
Canales 64 kbit/s
BSSAP
SCCP
MTP
CM
MM
BSSAP
SCCP
MTP

2.5G GPRS

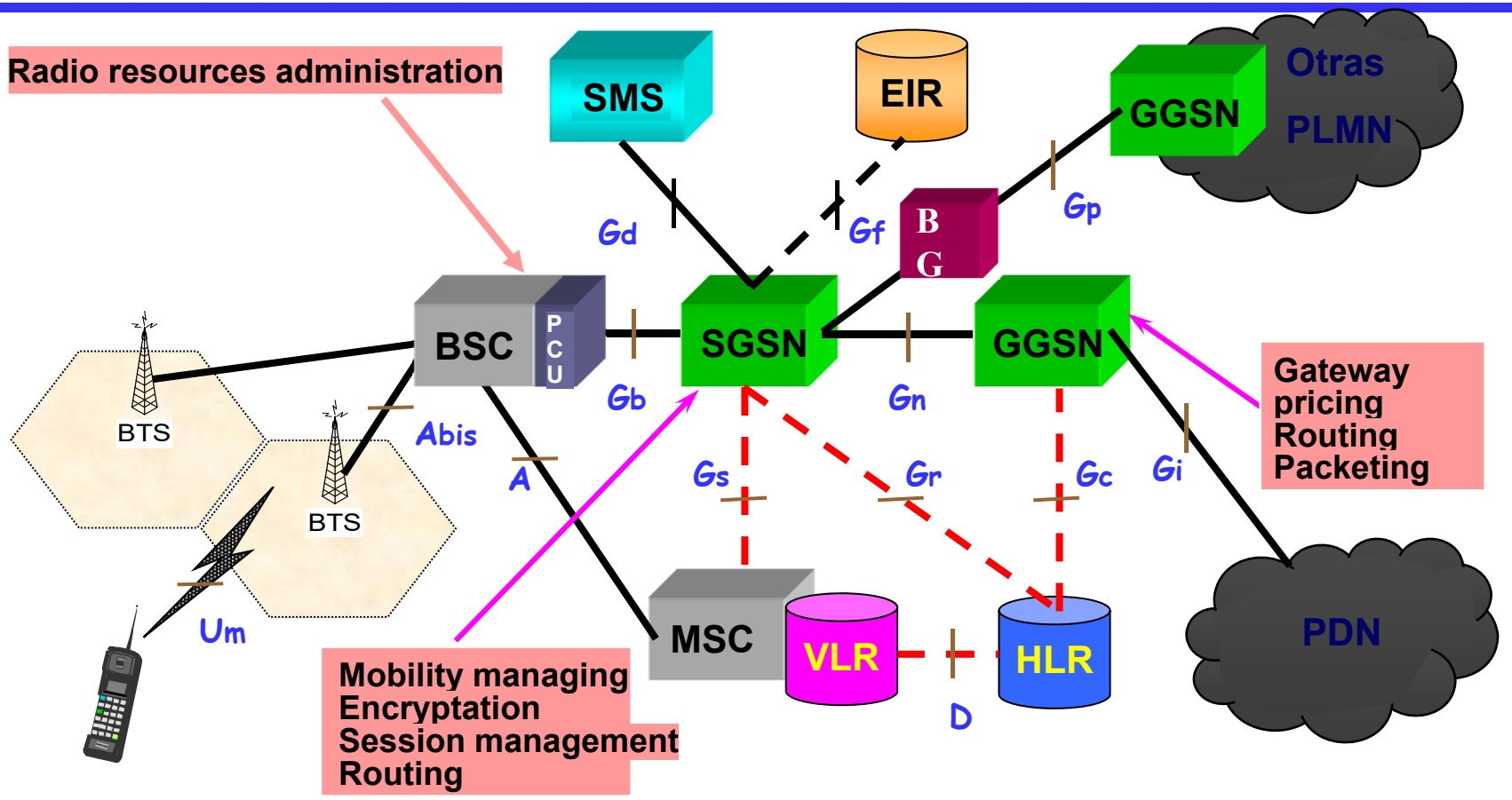


Data transport



Tunneling

2.5G GPRS system architecture



SGSN Serving GPRS Support Node

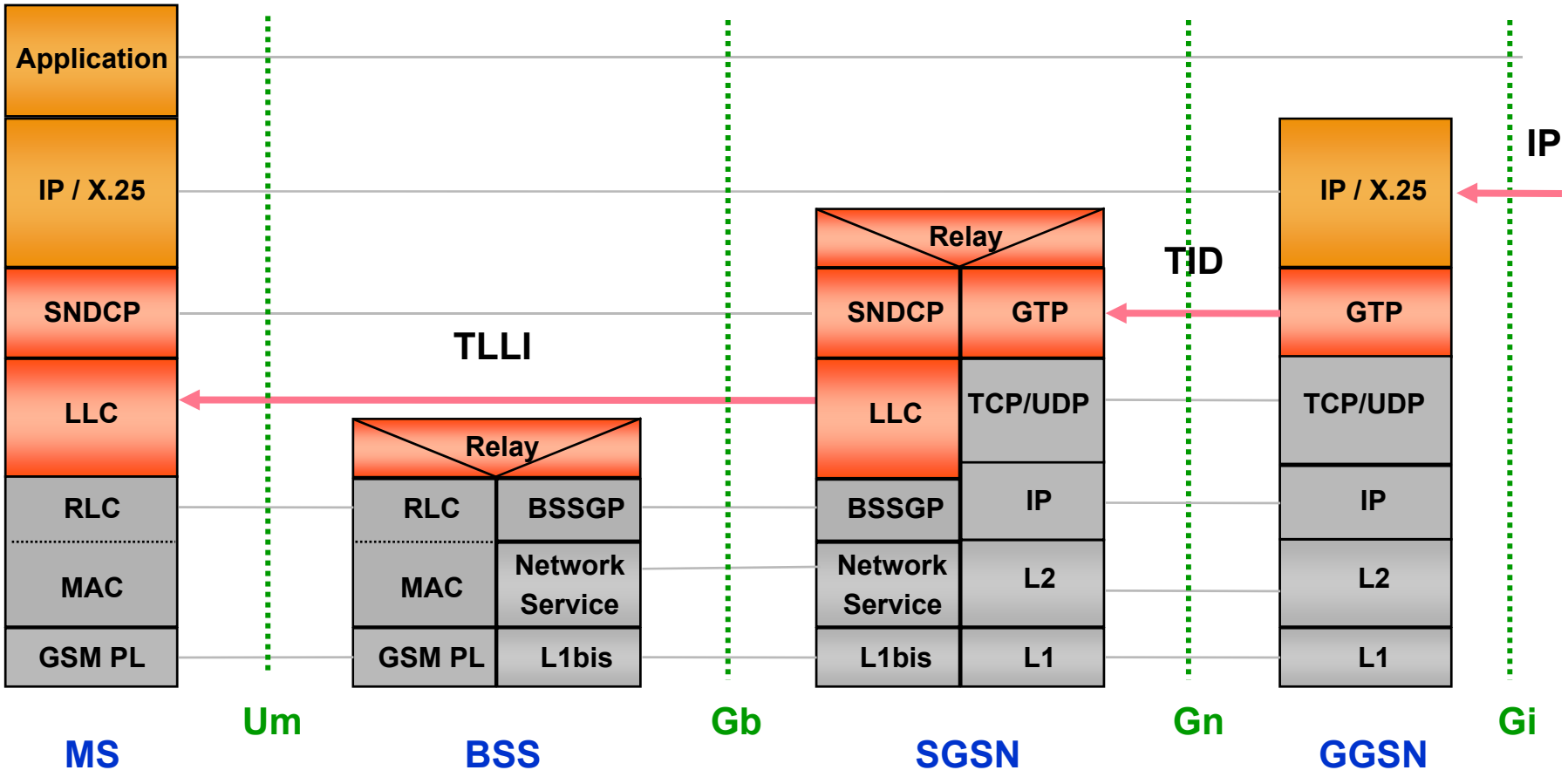
GGSN Gateway GPRS Support Node

PDN Packet Data Network

PCU Packet Control Unit

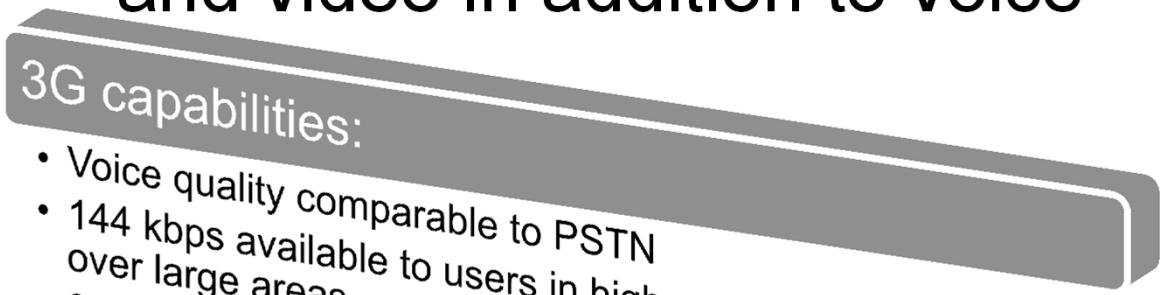
2.5G Protocol stack

- User plane



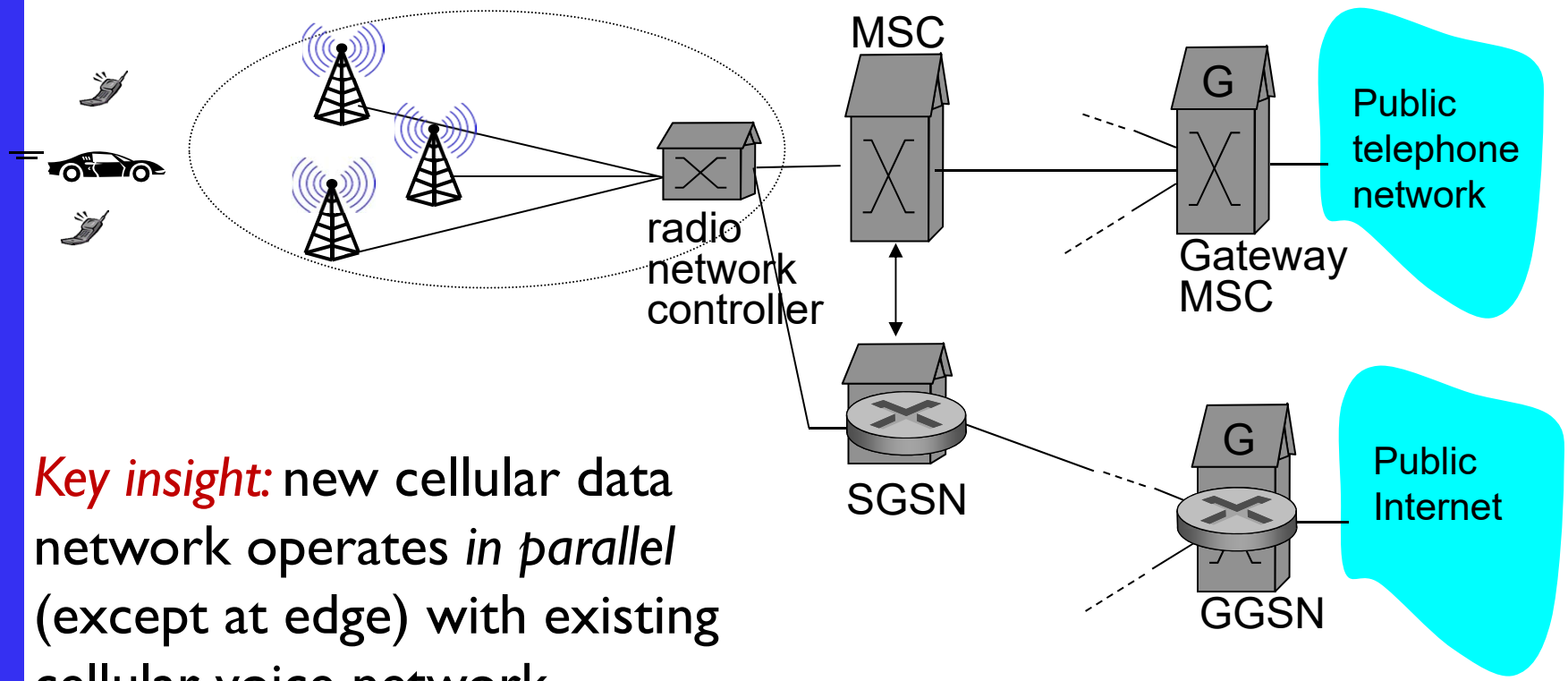
Third Generation (3G)

- 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

3G (voice+data) network architecture



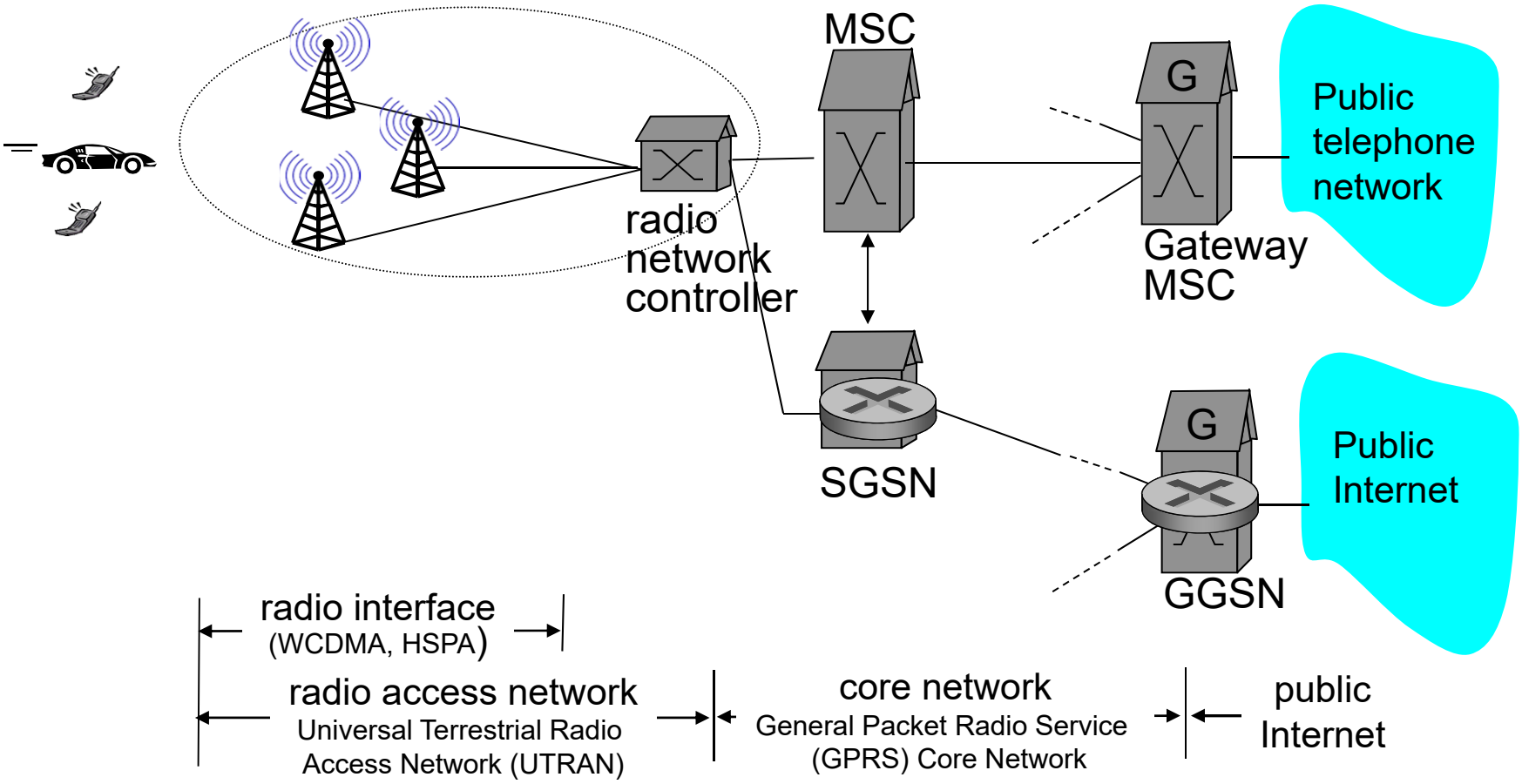
Key insight: new cellular data network operates *in parallel* (except at edge) with existing cellular voice network

- voice network *unchanged* in core
- data network operates in parallel

Serving GPRS Support Node (SGSN)

Gateway GPRS Support Node (GGSN)

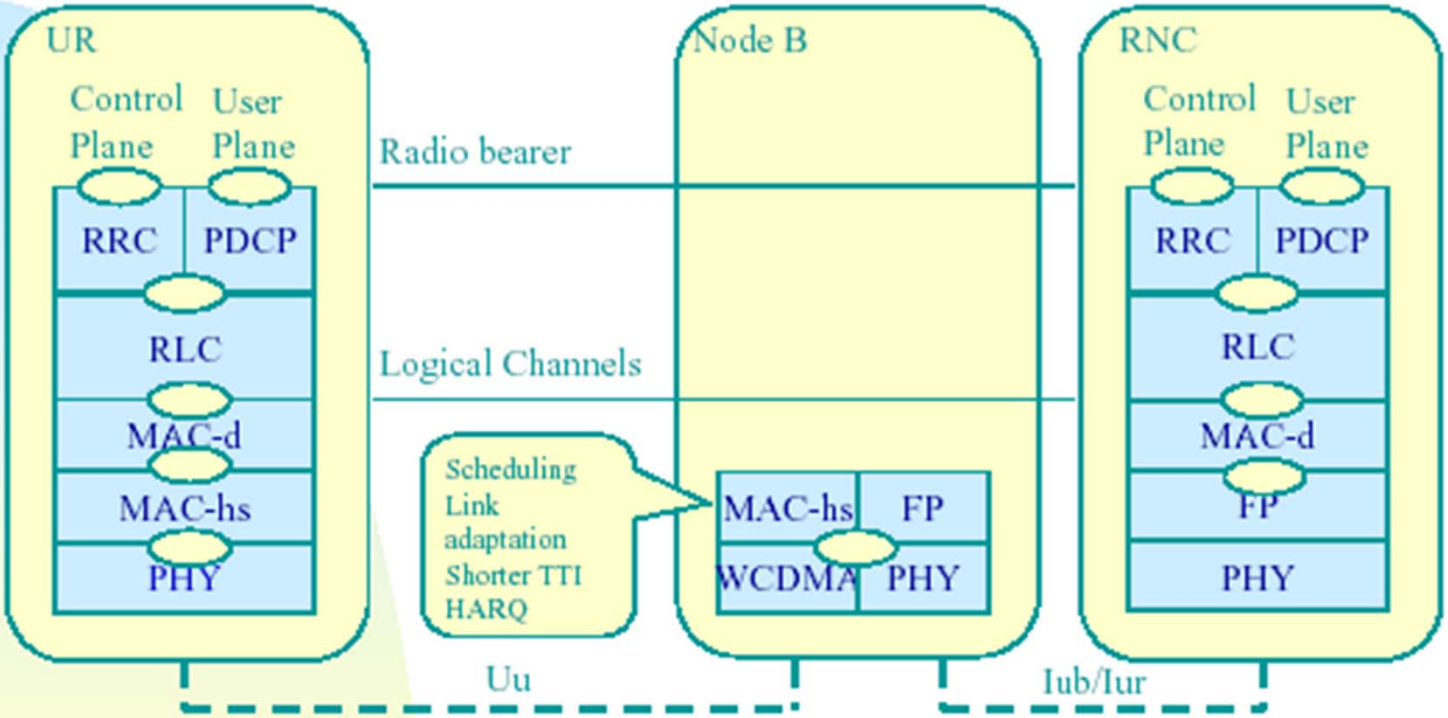
3G (voice+data) network architecture



3.5G HSPA (High Speed Packet Access)

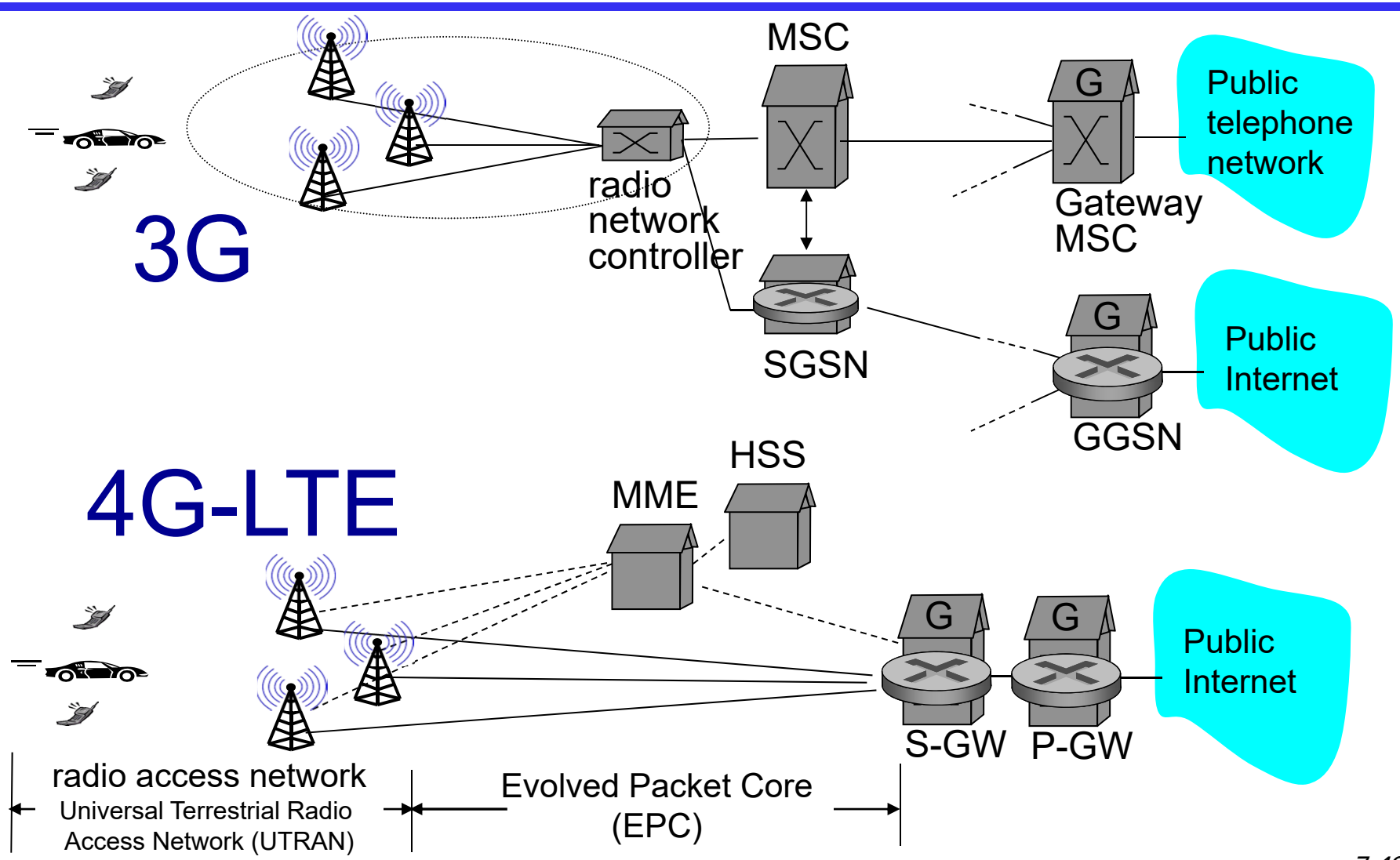
- In order to improve the packet data performance, the UMTS systems have been enhanced with HSPA.
- HSPA consists of two components, HSDPA and HSUPA:
- In the DL a new shared transport channel, the HS-DSCH
  - It allows to assign all available resource to one or more users in an efficient manner.
  -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

HSPA: 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.

3G versus 4G LTE network architecture



Fourth Generation (4G)

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

Minimum requirements:

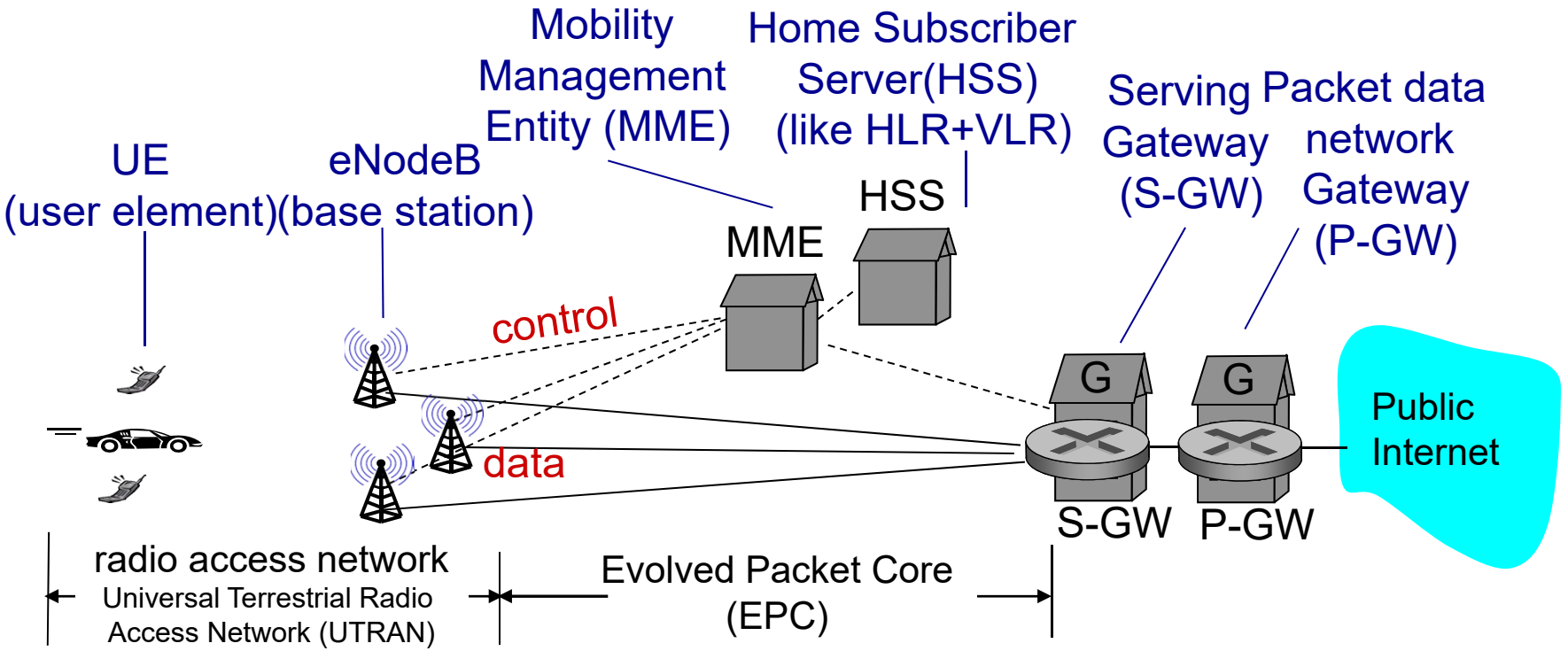
- Be based on an all-IP packet switched network
- Support peak data rates of up to approximately 100 Mbps for high-mobility mobile access and up to approximately 1 Gbps for low-mobility access such as local wireless access
- Dynamically share and use the network resources to support more simultaneous 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

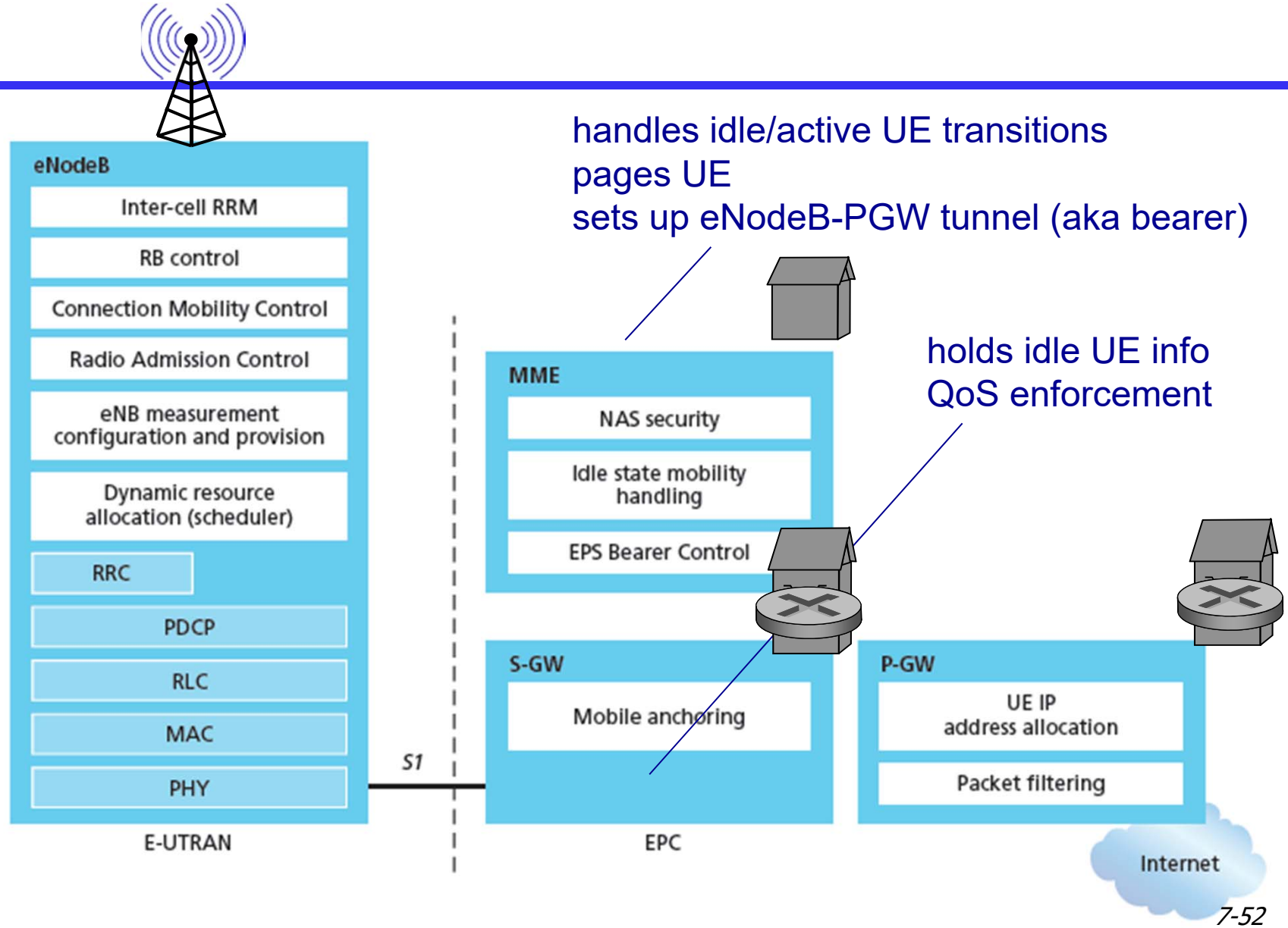
Designed to maximize bandwidth and throughput while also maximizing spectral efficiency

4G: differences from 3G

- all IP core: IP packets tunneled (through core IP network) from base station to gateway
- no separation between voice and data – all traffic carried over IP core to gateway



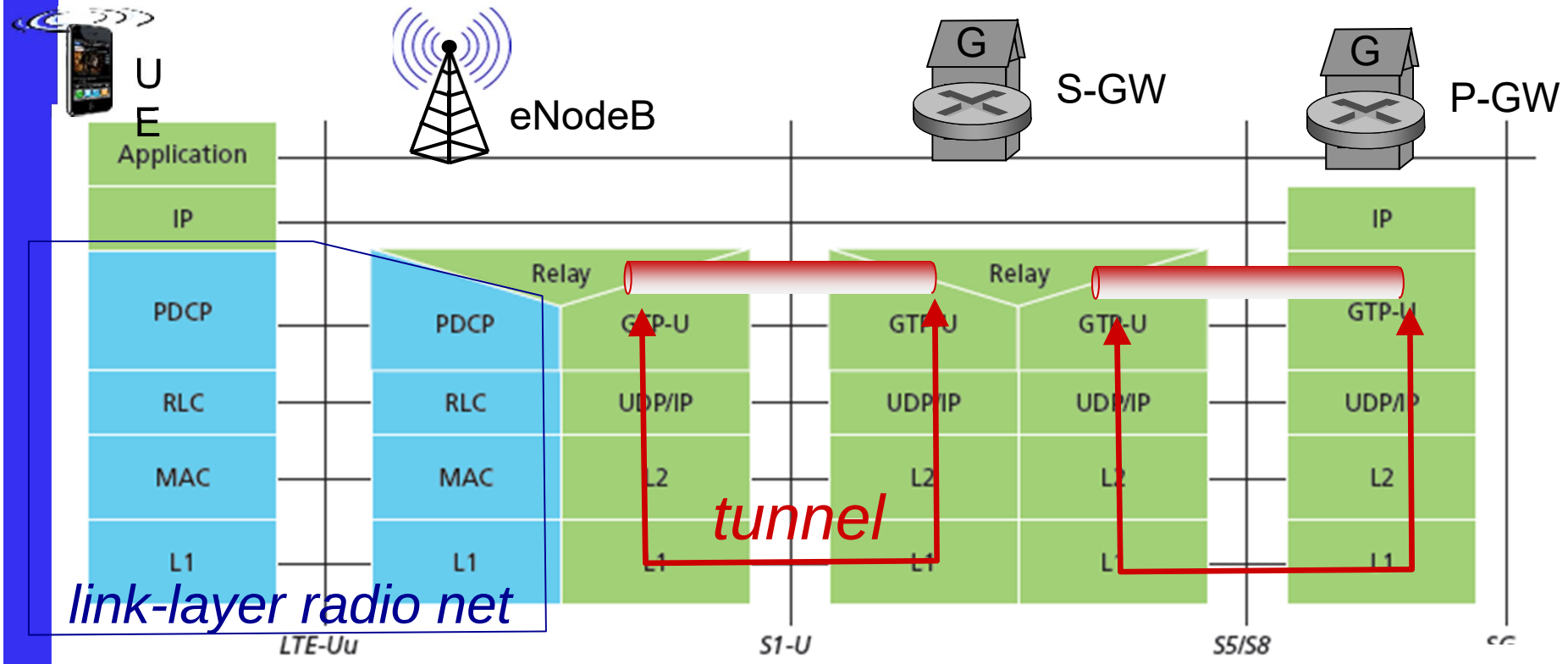
Functional split of major LTE components



Radio+Tunneling: UE – eNodeB – PGW

IP packet from UE encapsulated in GPRS Tunneling Protocol (GTP) message at ENodeB

GTP message encapsulated in UDP, then encapsulated in IP. large IP packet addressed to SGW



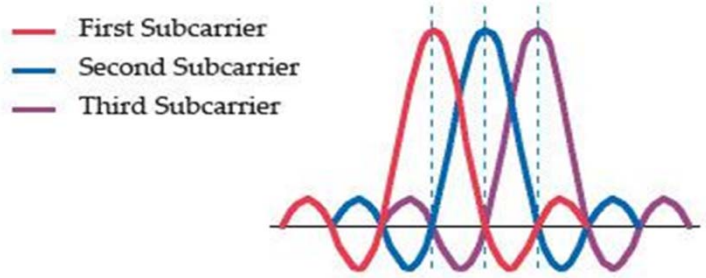
Quality of Service in LTE

- QoS from eNodeB to SGW: min and max guaranteed bit rate
- QoS in radio access network: one of 12 QCI values

QCI	RESOURCE TYPE	PRIORITY	PACKET DELAY BUDGET (MS)	PACKET ERROR LOSS RATE	EXAMPLE SERVICES
1	GBR	2	100	10^{-2}	Conversational voice
2	GBR	4	150	10^{-3}	Conversational video (live streaming)
3	GBR	5	300	10^{-6}	Non-conversational video (buffered streaming)
4	GBR	3	50	10^{-3}	Real-time gaming
5	Non-GBR	1	100	10^{-6}	IMS signaling
6	Non-GBR	7	100	10^{-3}	Voice, video (live streaming), interactive gaming
7	Non-GBR	6	300	10^{-6}	Video (buffered streaming)
8	Non-GBR	8	300	10^{-6}	TCP-based (for example, WWW, e-mail), chat, FTP, p2p file sharing, progressive video and others
9	Non-GBR	9	300	10^{-6}	

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

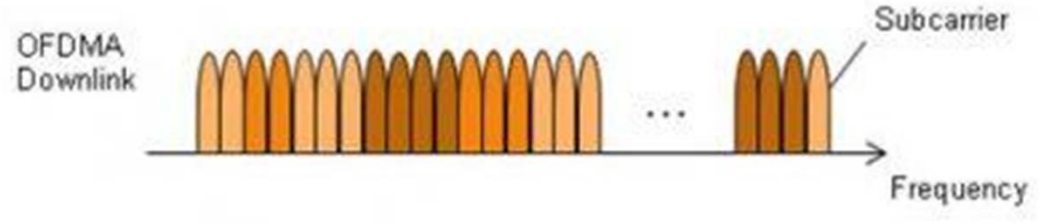
(from the IEEE 802.16 committee)

Comparison of Performance Requirements for LTE and LTE-Advanced

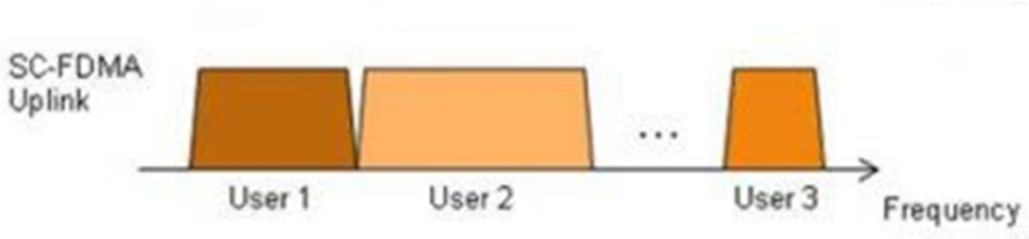
System Performance		LTE	LTE-Advanced
Peak rate	Downlink	100 Mbps @20 MHz	1 Gbps @100 MHz
	Uplink	50 Mbps @20 MHz	500 Mbps @100 MHz
Control plane delay	Idle to connected	<100 ms	< 50 ms
	Dormant to active	<50 ms	< 10 ms
User plane delay		< 5ms	Lower than LTE
Spectral efficiency (peak)	Downlink	5 bps/Hz @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

4G OFDMA, SC-FDMA

Downlink: Orthogonal Frecuency Division Multiple Access

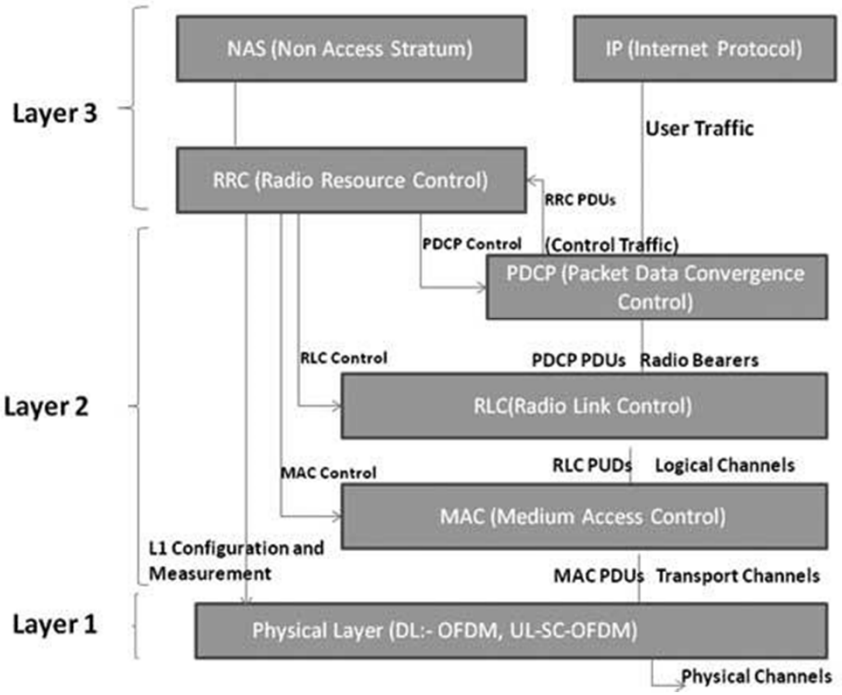


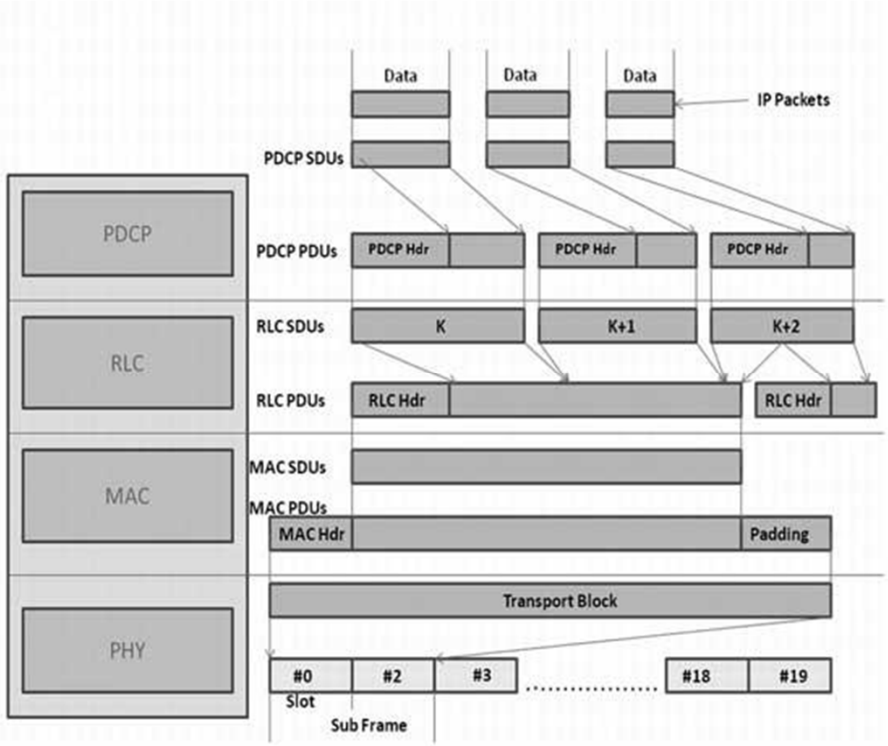
Uplink: Single-carrier Frecuency Division Multiple Access



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

4G Protocols





Resum Arquitectura 4G LTE

https://www.youtube.com/watch?v=-nDjkV-NulM