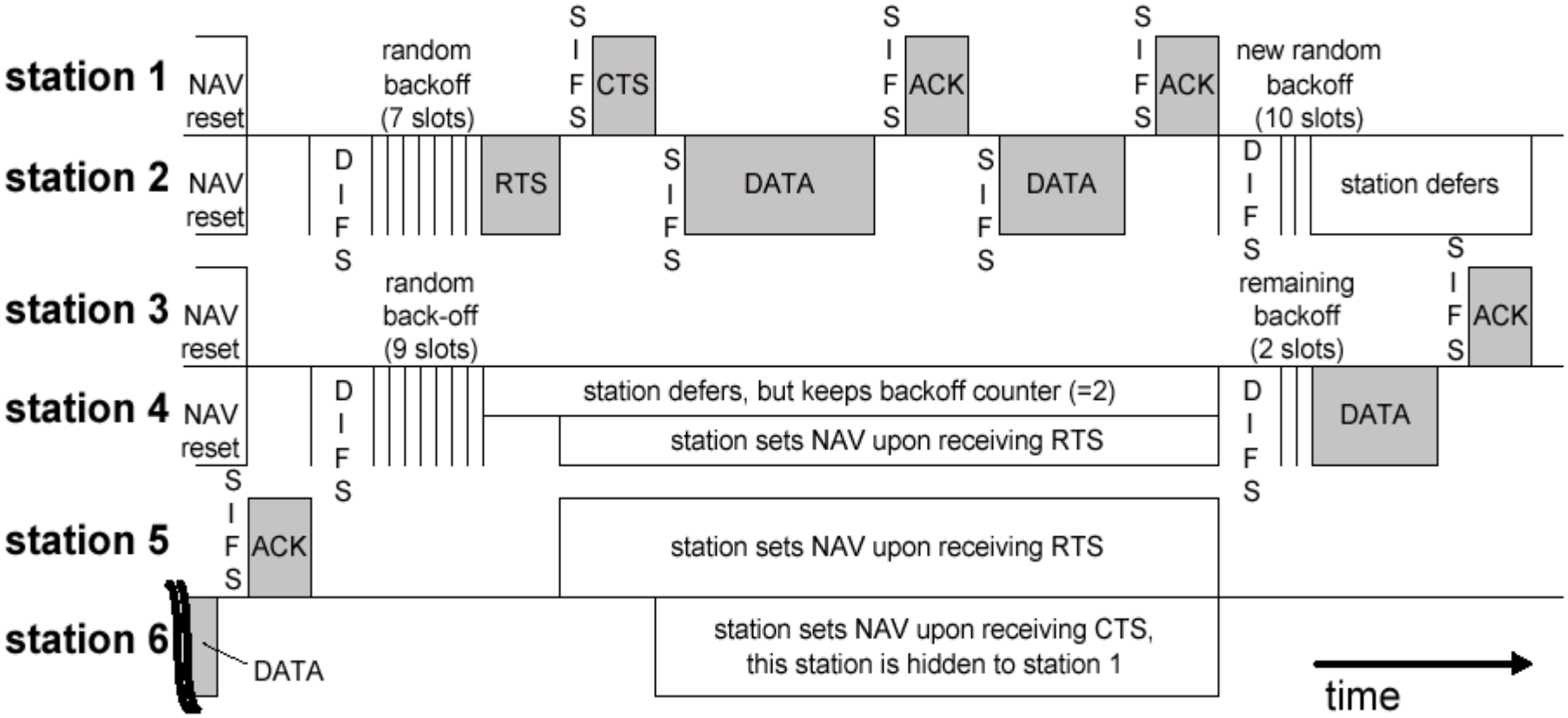
Mobile and Wireless Networks

QoS provisions in IEEE 802.11e

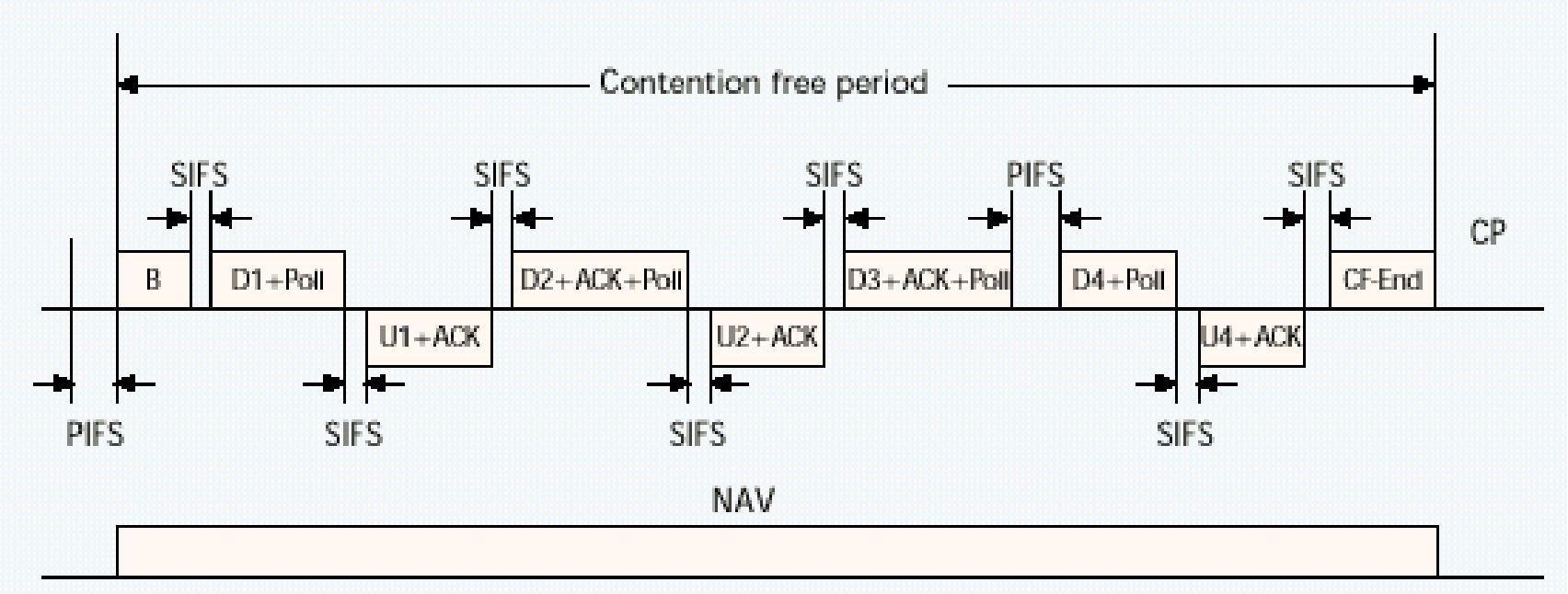
QoS restrictions in standard 802.11

• DCF is based on contention so it cannot differentiate traffic and provide guaranteed delays and packet losses



QoS restrictions in standard 802.11

- In PCF there is no knowledge of requirements per terminal to give the channel to the most demanding ones
- In PCF polling time is unspecified, giving the channel for unknown time



Extensions introduced by 802.11e

- AP is called Hybrid Coordinator (HC) implementing Hybrid Coordination Function (HCF) that includes two modes of operation:

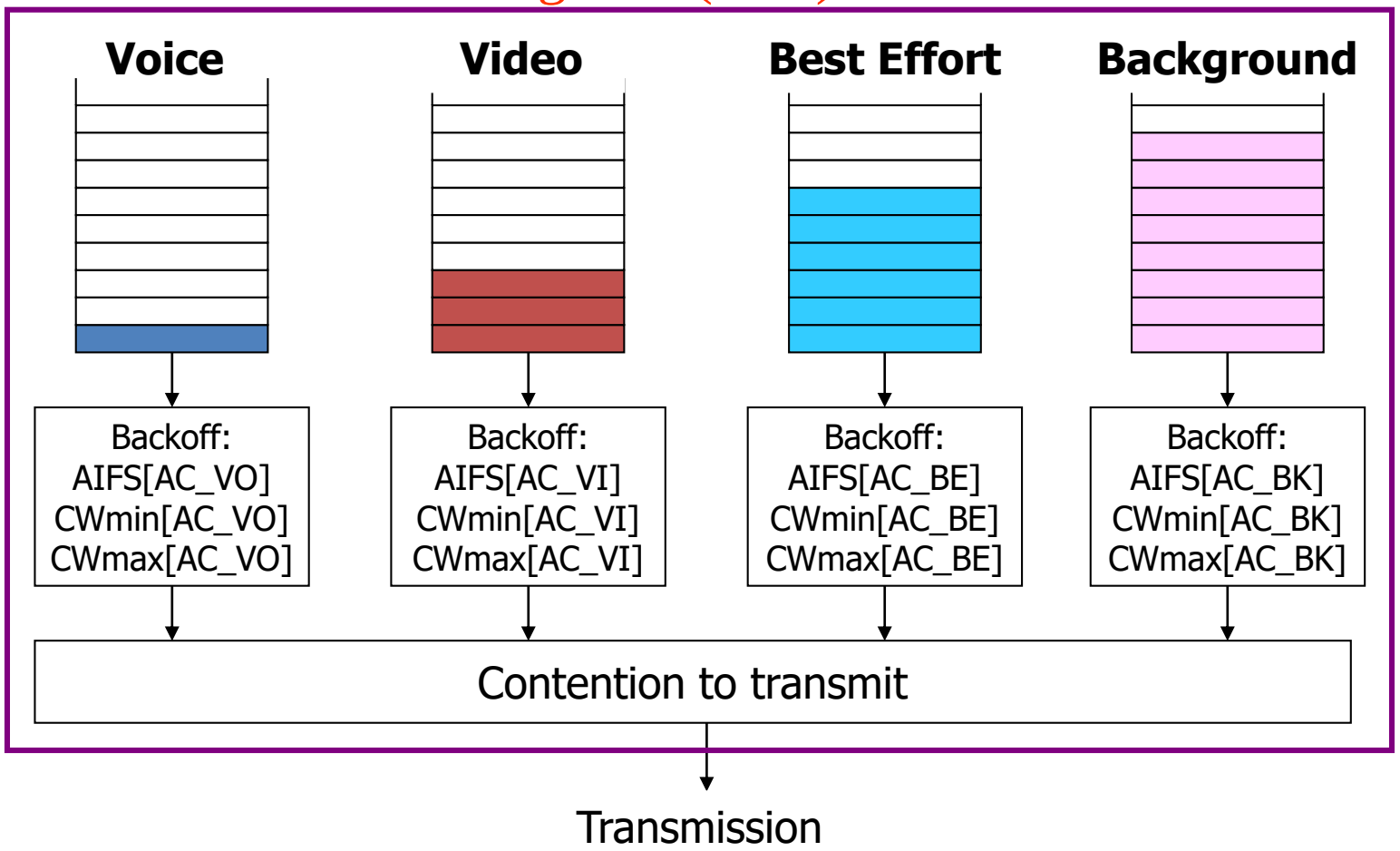
- EDCA (Enhanced Distributed Coordination Access): Different traffic classes in DCF with different behavior and medium access probabilities

- HCCA (HCF Control Channel Access): Improving weaknesses of PCF (beacon transmission, controlled reservation time, queue size information)

EDCA

(Enhanced Distributed Coordination Access)

- CSMA/CA and Exponential Backoff
- Four Access Categories (ACs) within one station



EDCA
(Enhanced Distributed Coordination Access)

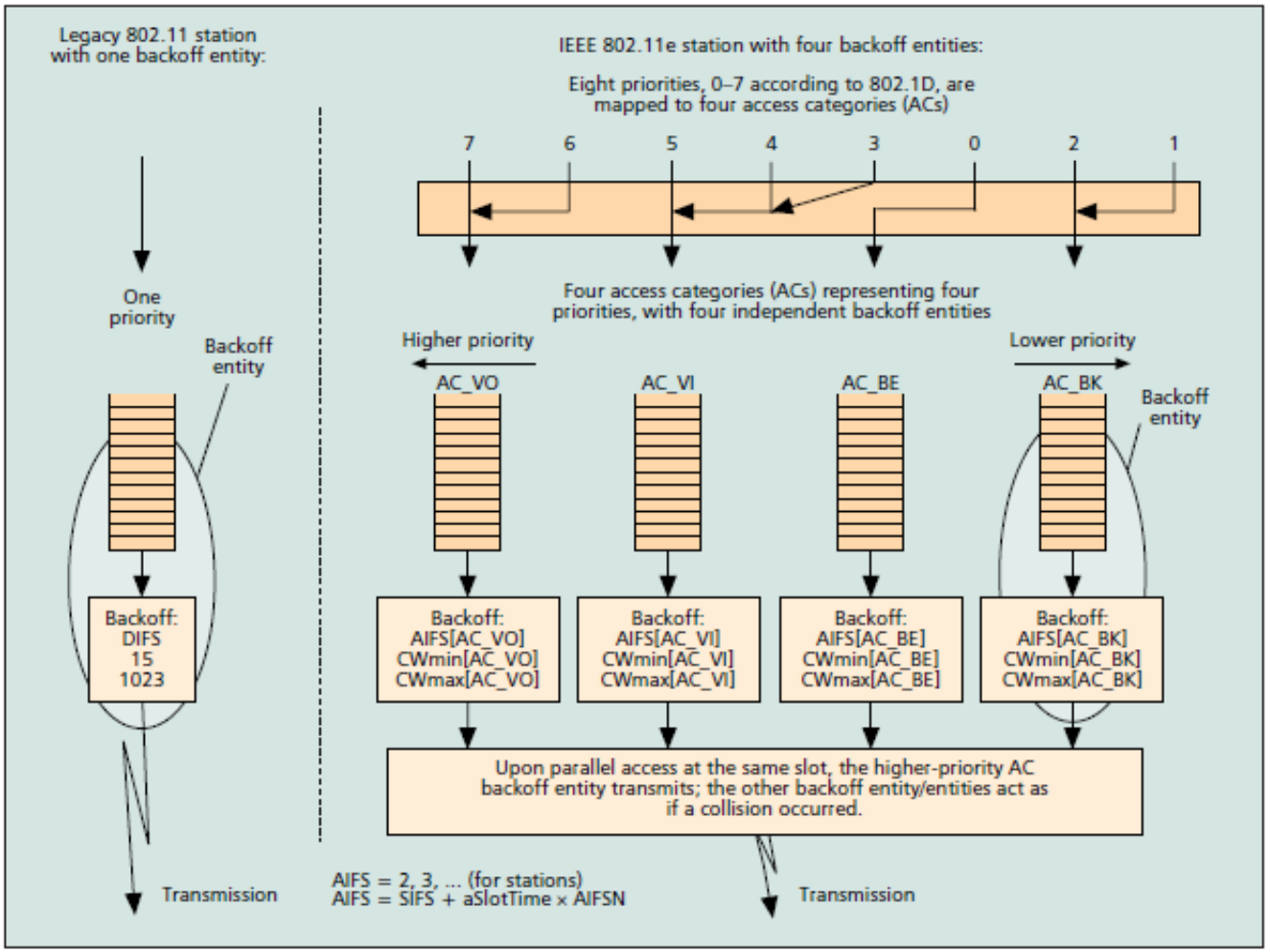
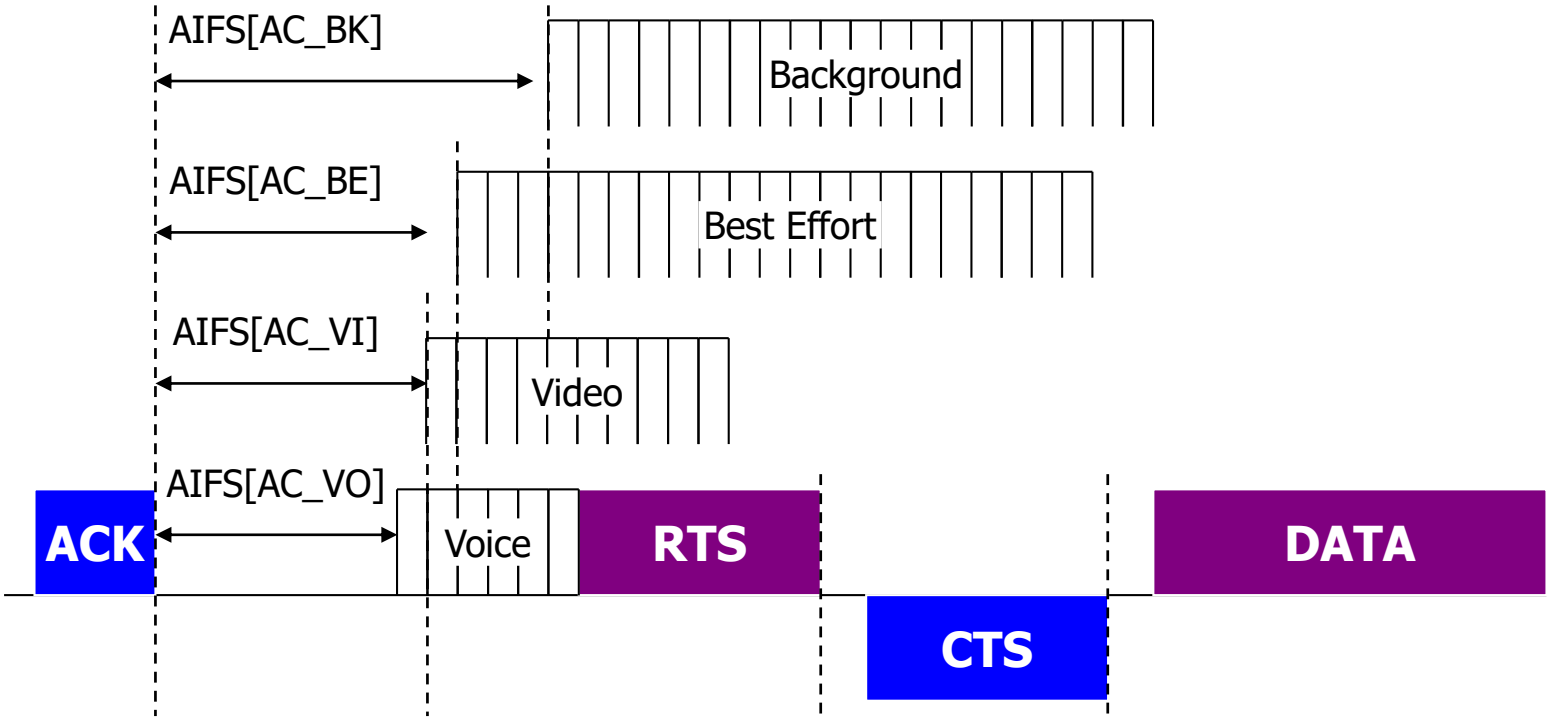
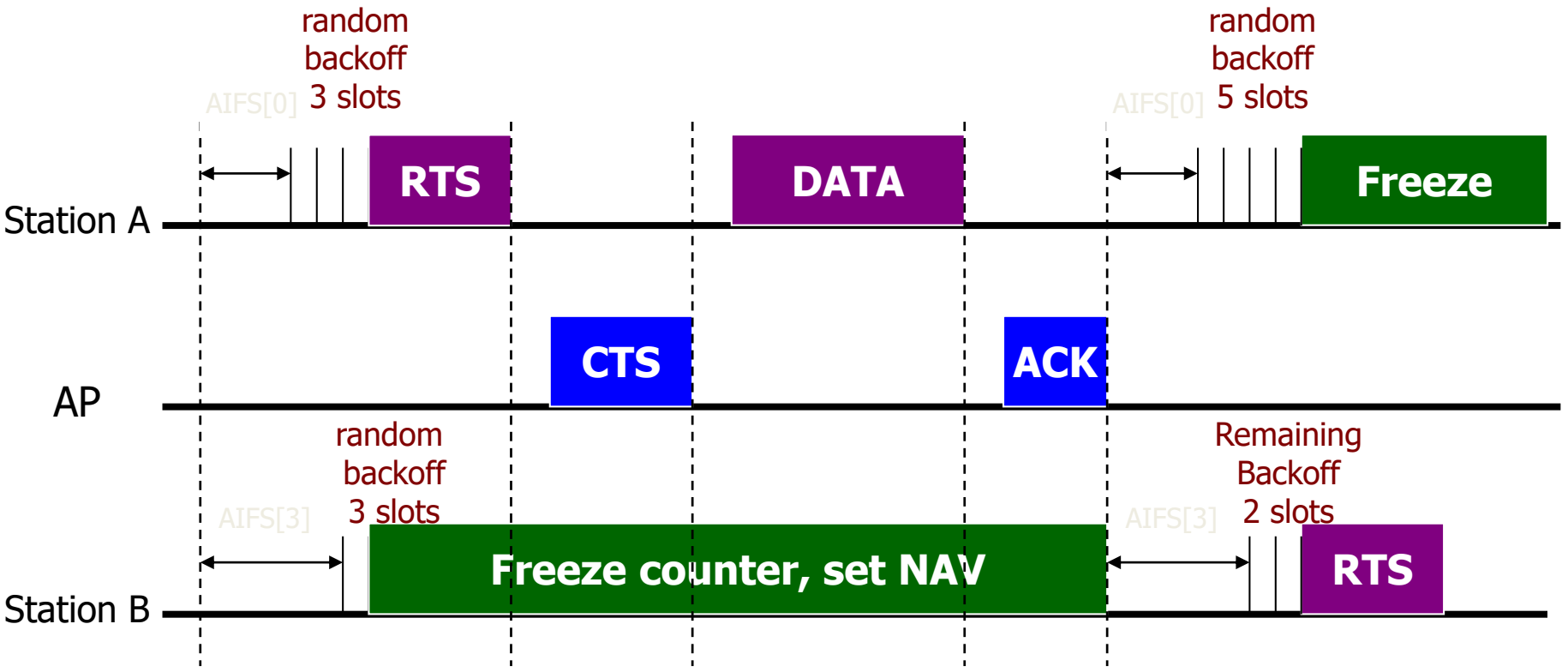


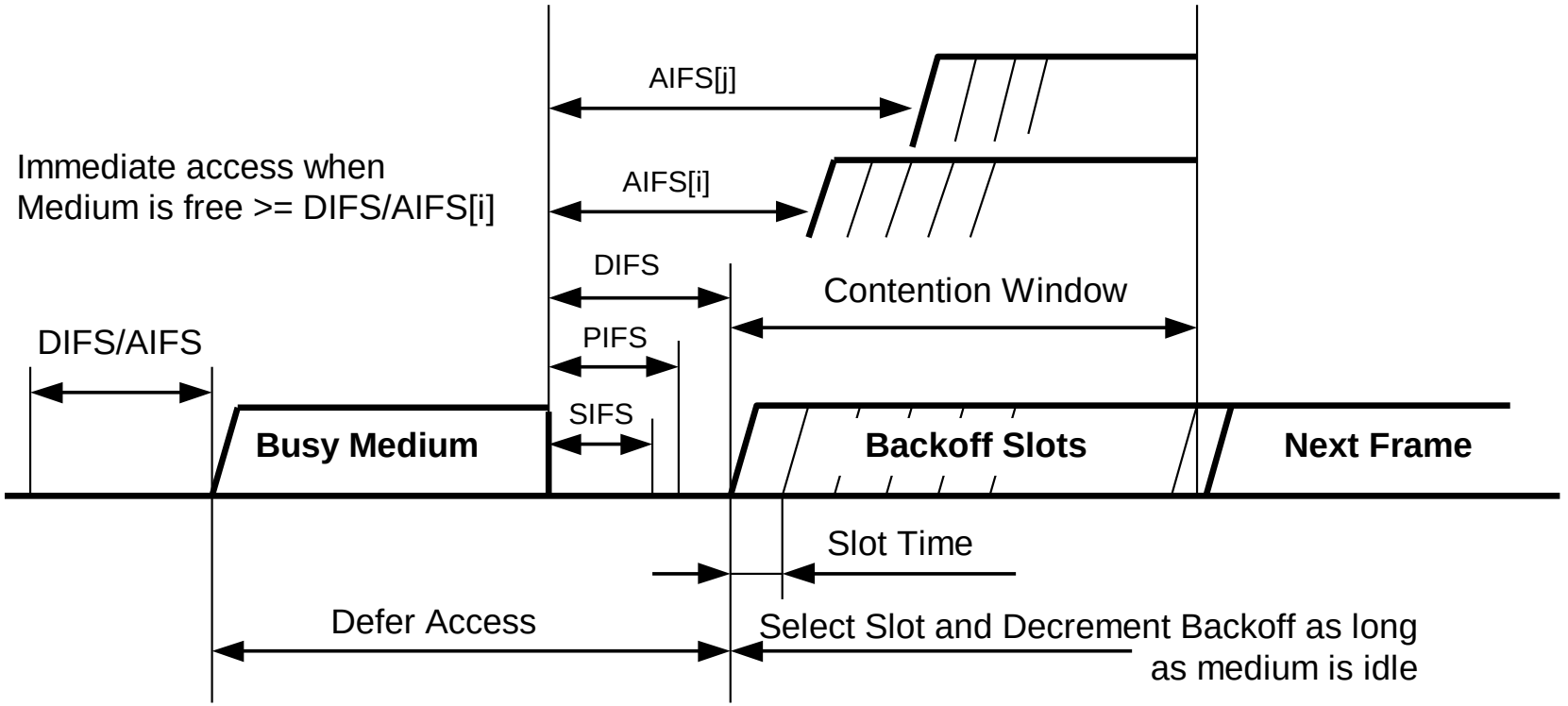
Figure 4. *[3] Legacy 802.11 station and 802.11e station with four ACs within one station.*

Inter Frame Space και Contention Window

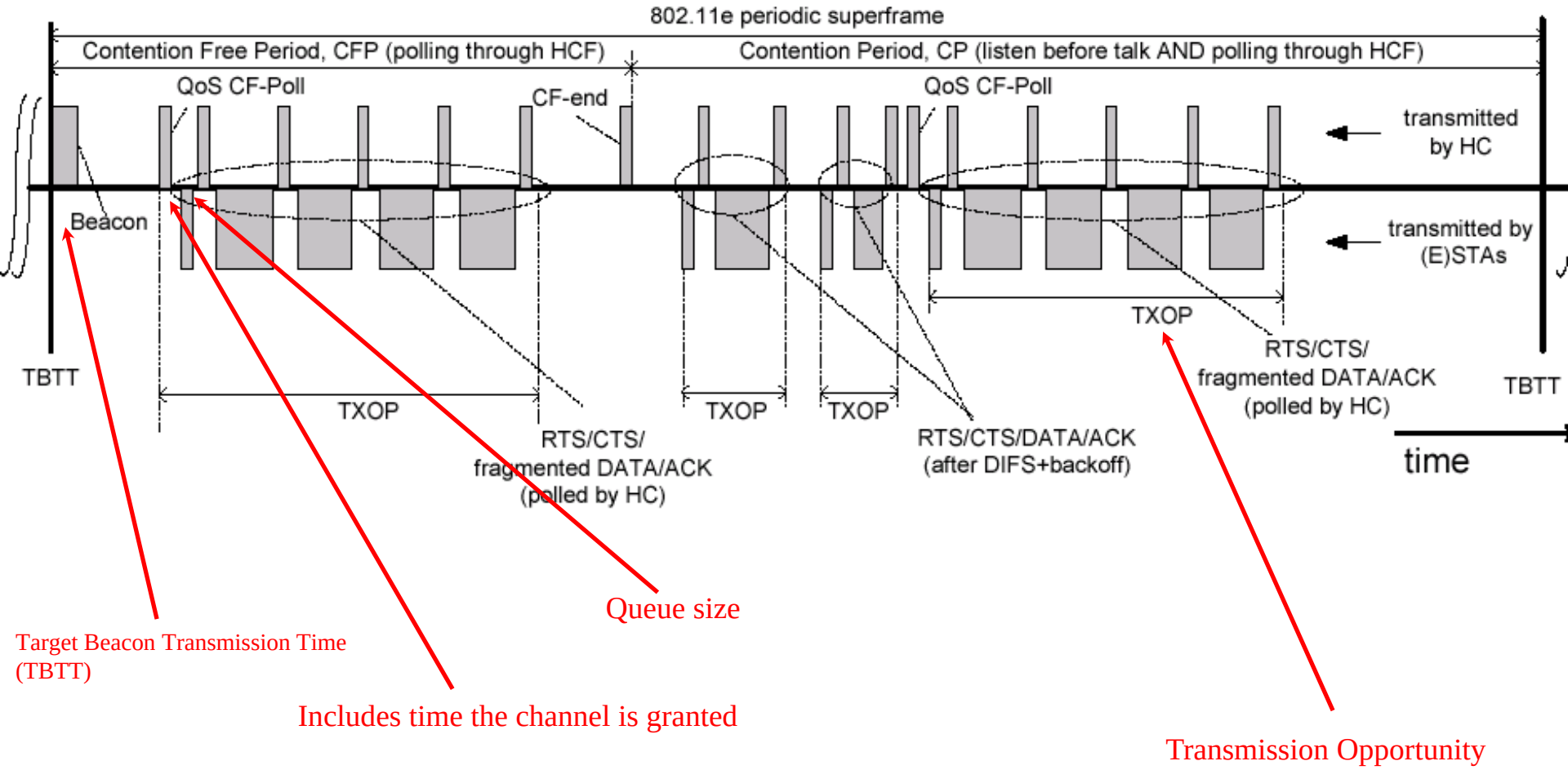


Contention in EDCA




AIFS[j]
Immediate access when
Medium is free >= DIFS/AIFS[i]
AIFS[i]
DIFS
Contention Window
DIFS/AIFS
PIFS
SIFS
Busy Medium
Backoff Slots
Next Frame
Slot Time
Defer Access
Select Slot and Decrement Backoff as long
as medium is idle

HCCA
(HCF Control Channel Access)



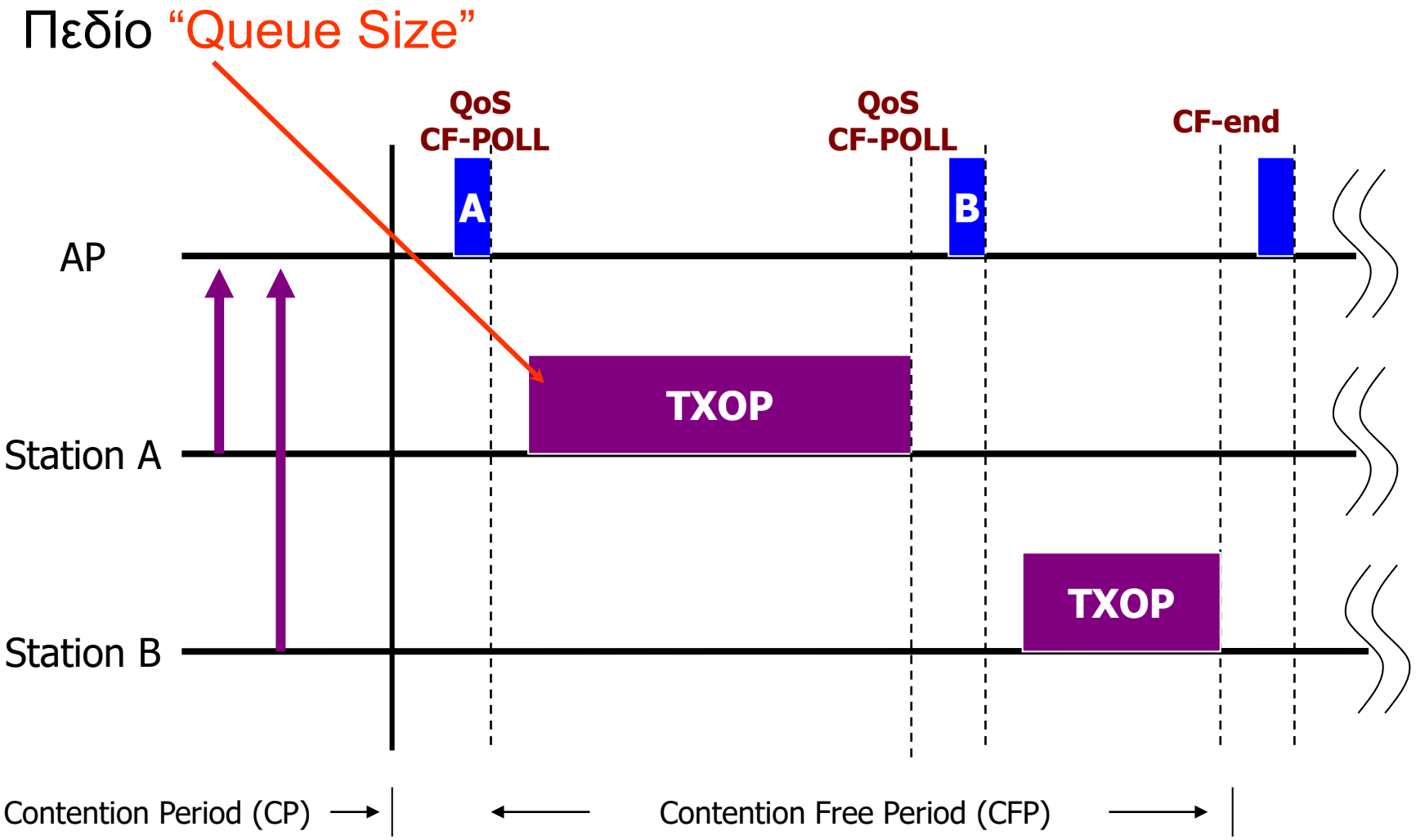
Target Beacon Transmission Time (TBTT)

Queue size

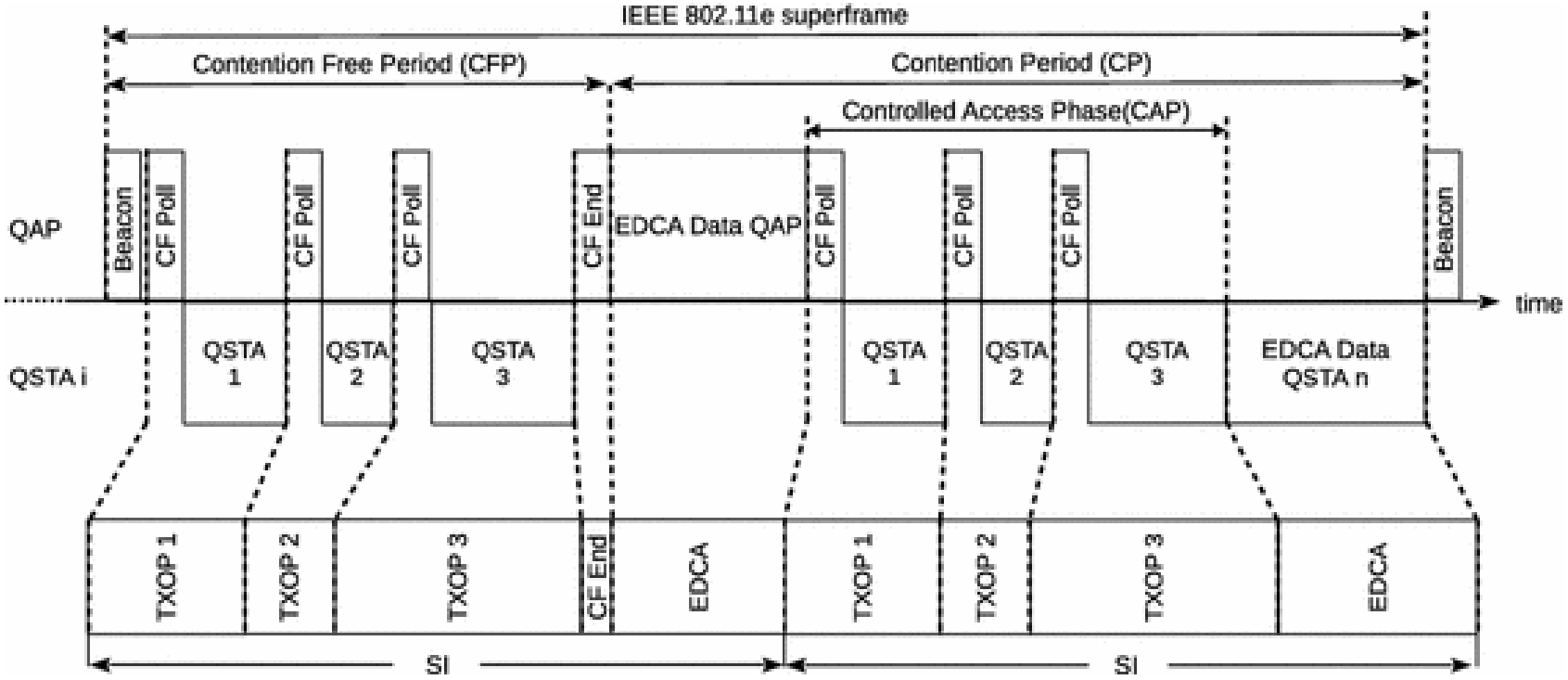
Includes time the channel is granted

Transmission Opportunity

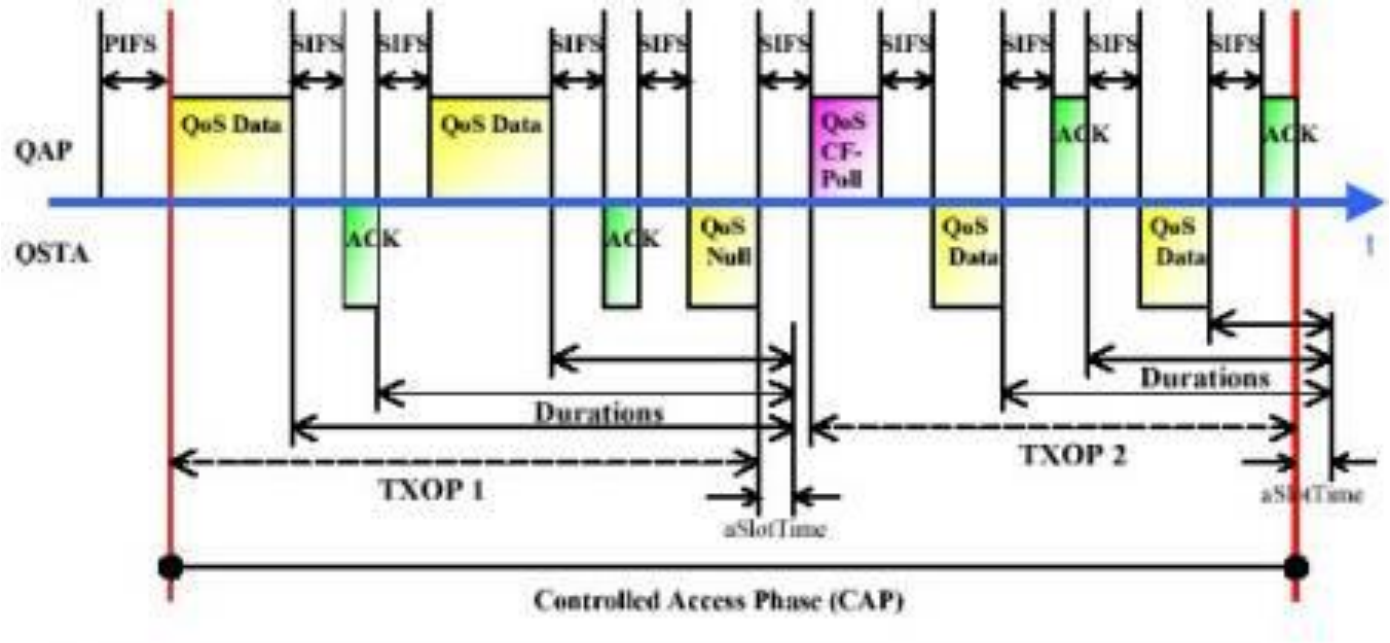
Reservation with HCCA



Reservation with HCCA

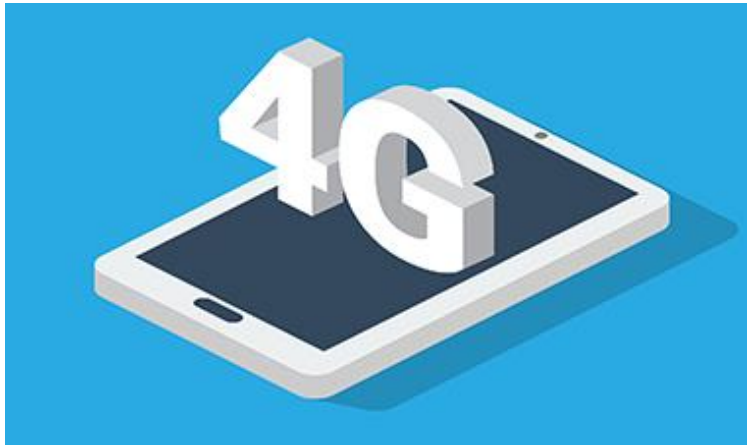


Reservation with HCCA

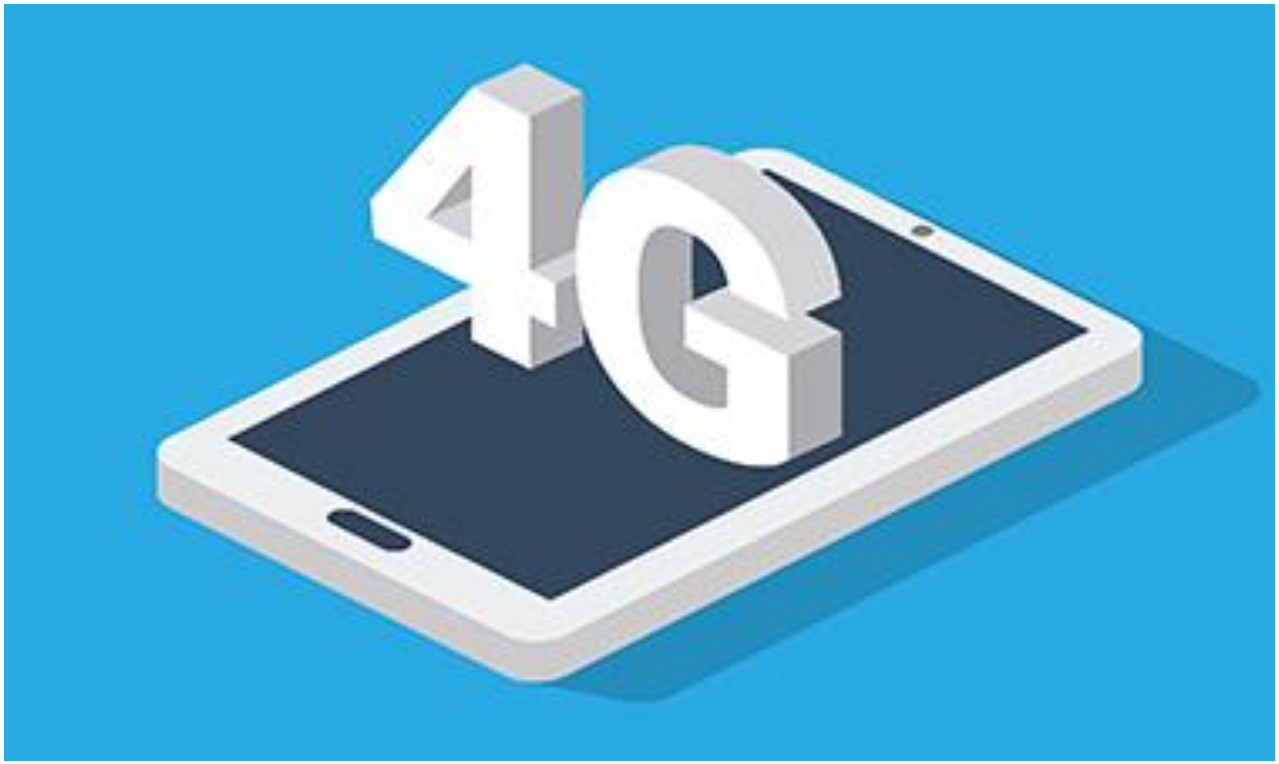


QoS CF-Poll	Transmitted by QAP to grant a HCCA-TXOP, no data.
QoS-Data+CF-Poll	Transmitted by QAP to grant a HCCA-TXOP, with data.
QoS-Null	Transmitted by QSTA when it has no more data, or it is the last frame of the TXOP.
QoS-Data	QoS data transfer between QAP and QSTA. Used by EDCA as well as HCCA.
QoS CF-Ack	Transmitted by QAP in response to QoS-Null requesting a TXOP, no data.
QoS-Data+CF-Ack	Transmitted by QAP in response to QoS-Null requesting a TXOP, with data.
QoS CF-Ack+CF-Poll, QoS-Data+CF-Ack+CF-Poll	Generally not used.

Mobile and Wireless Networks



Long Term Evolution (LTE)
Long Term Evolution – Advanced (LTE-A)



Long Term Evolution (LTE)
Long Term Evolution – Advanced (LTE-A)

What is LTE ?

- In Nov. 2004, 3GPP began a project to define the long-term evolution (LTE) of Universal Mobile Telecommunications System (UMTS) cellular technology
  - Higher performance
  - Backwards compatible
  - Wide application

Standards organizations and other related bodies have agreed to co-operate for the production of a complete set of globally applicable Technical Specifications for a 3rd Generation Mobile System based on the evolved GSM core networks and the radio access technologies supported by 3GPP partners (i.e., UTRA both FDD and TDD modes).

The Project is entitled the “Third Generation Partnership Project” and may be known by the acronym “3GPP”.

3GPP has been established for the preparation and maintenance of the above mentioned Technical Specifications, and is not a legal entity.

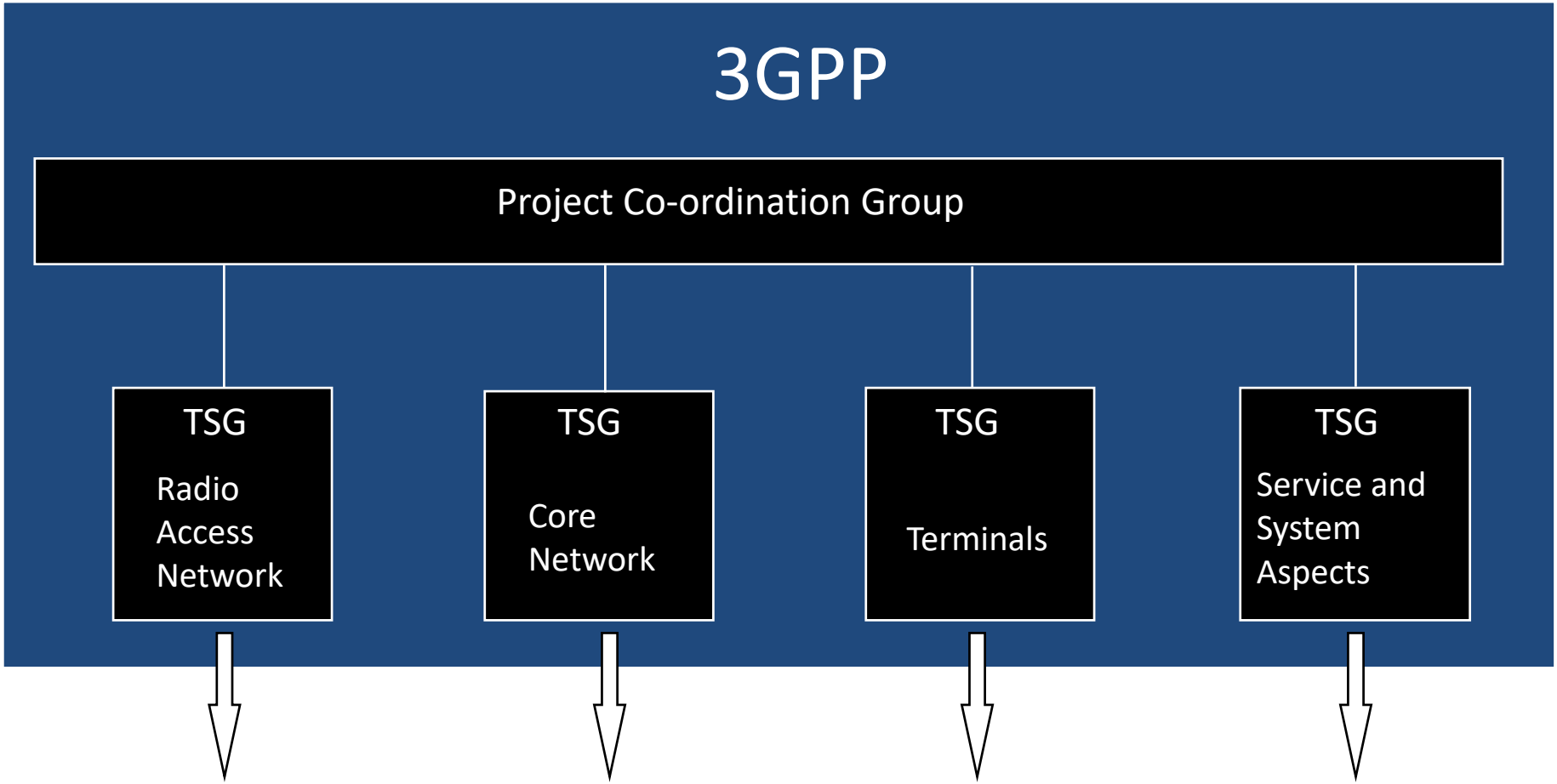
3GPP comprises of:

- Partners:
  - Organizational Partners
    - 3GPP is open to all standards organizations irrespective of the geographical location.
  - Market Representation Partners
- Individual Members

3GPP is characterized by the following attributes:

- Minimum production time for Technical Specifications from conception to approval
- Fast, electronic based approval process
- Maximum use of modern (electronic) working methods
- Minimum number of hierarchical levels with decision making taking place at the lowest appropriate levels

Internal structure of 3GPP



Technical Specifications

3GPP meetings

- **ARIB**

The Association of Radio Industries and Businesses, Japan

- **ATIS**

The Alliance for Telecommunications Industry Solutions, USA

- **CCSA**

China Communications Standards Association

- **ETSI**

The European Telecommunications Standards Institute

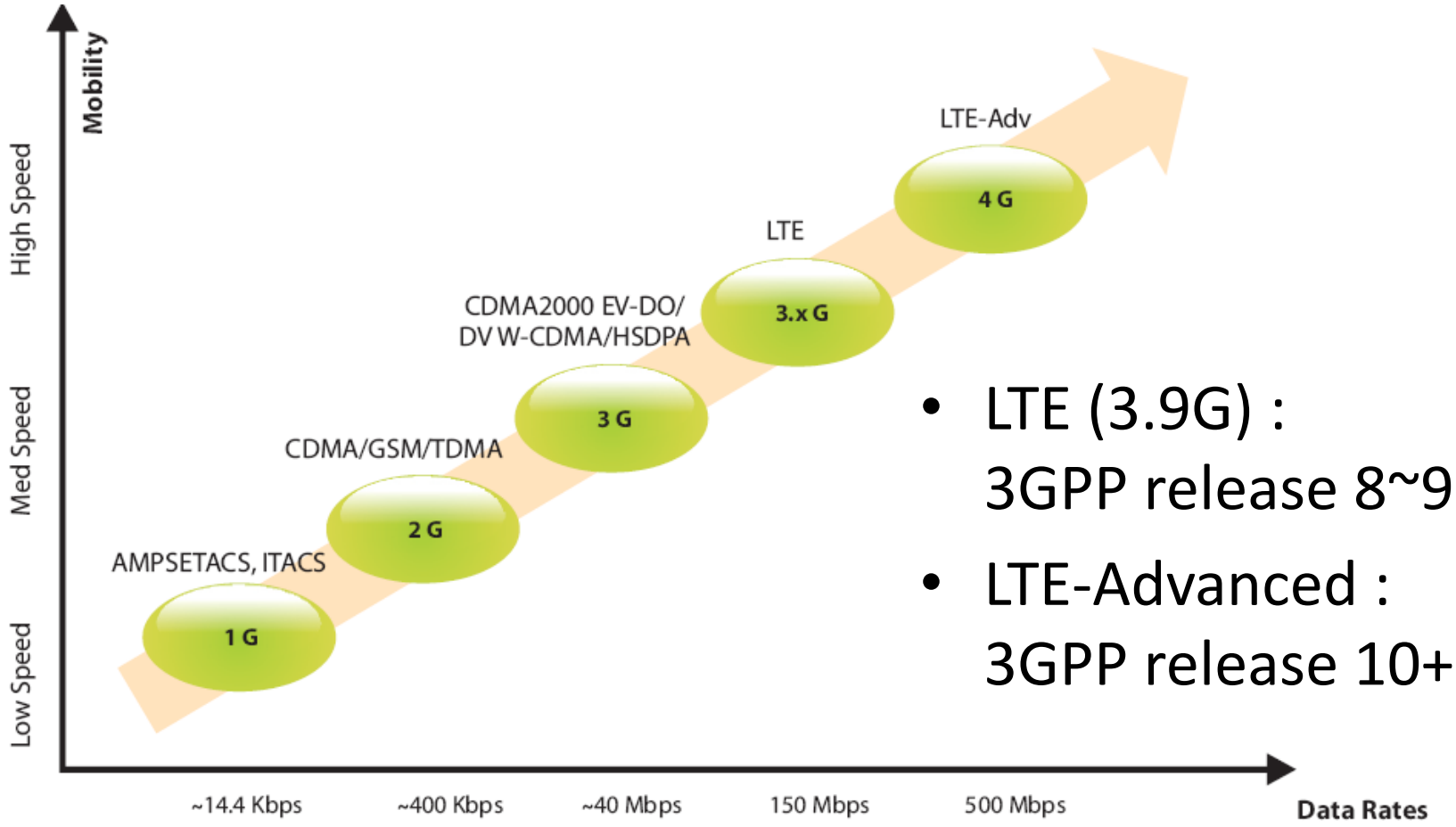
- **TTA**

Telecommunications Technology Association, Korea

- **TTC**

Telecommunication Technology Committee, Japan

Evolution of Radio Access Technologies



- LTE (3.9G) : 3GPP release 8~9
- LTE-Advanced : 3GPP release 10+

2G (GSM)

GSM

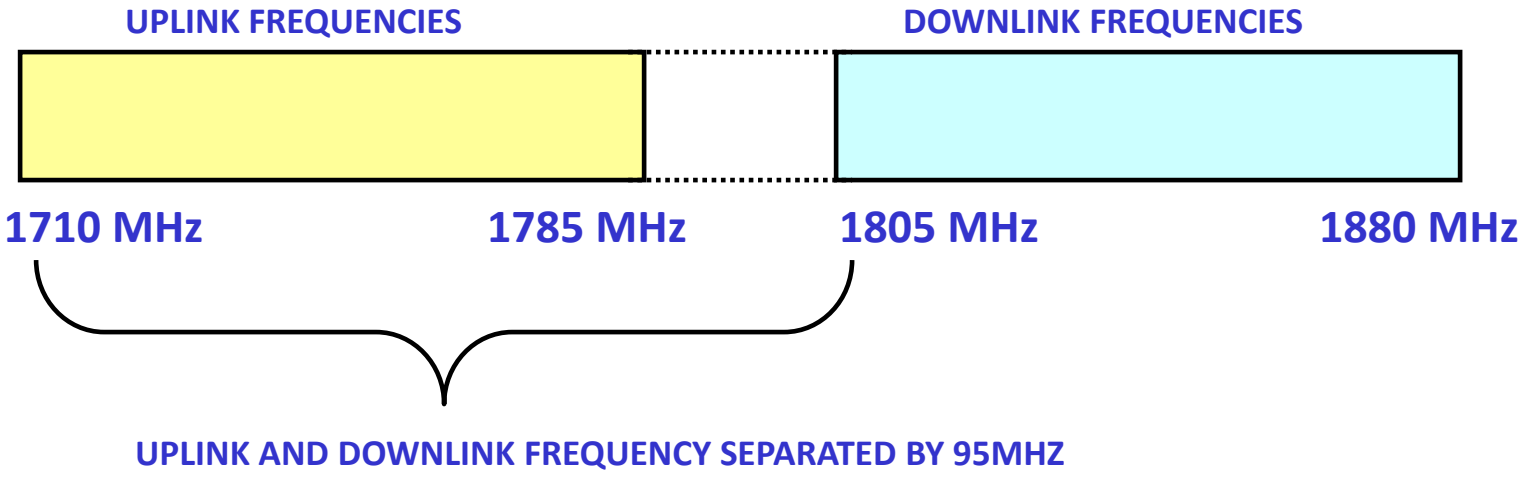
- Abbreviation for Global System for Mobile Communications
- In the mid 1980's, most of Europe didn't have a cellular network
  - They weren't committed to analog
- After many years of research, GSM was proposed around 1990
  - Covered Germany, France, England, and Scandinavia
  - In Greece GSM started in 1993
- Goals:
  - Roaming throughout all of Europe
  - Low power and inexpensive devices
  - All digital to offer 64kbps throughput
    - Never achieved

GSM Services

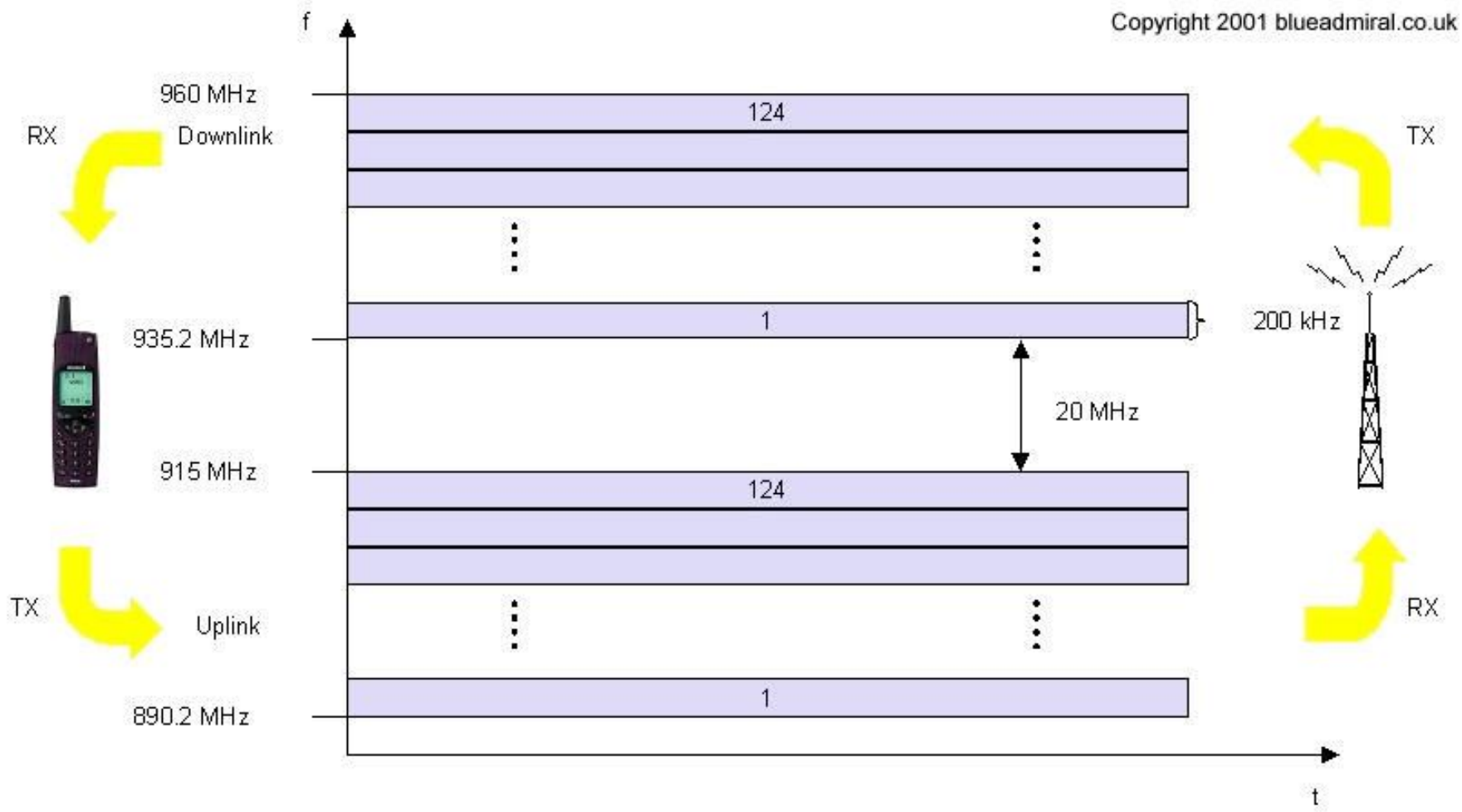
- Voice, 3.1 kHz
- Some data transmission is possible with very low speeds (originally 9.6kbps) – e.g. fax.
- Short Message Service (SMS)
  - 1985 GSM standard that allows messages of at most 160 chars (incl. spaces) to be sent between handsets and other stations
  - SMS was until recently the most widely used data application in the world, with 3.6 billion active users, or 78% of all mobile phone subscribers (2011).

GSM Frequencies

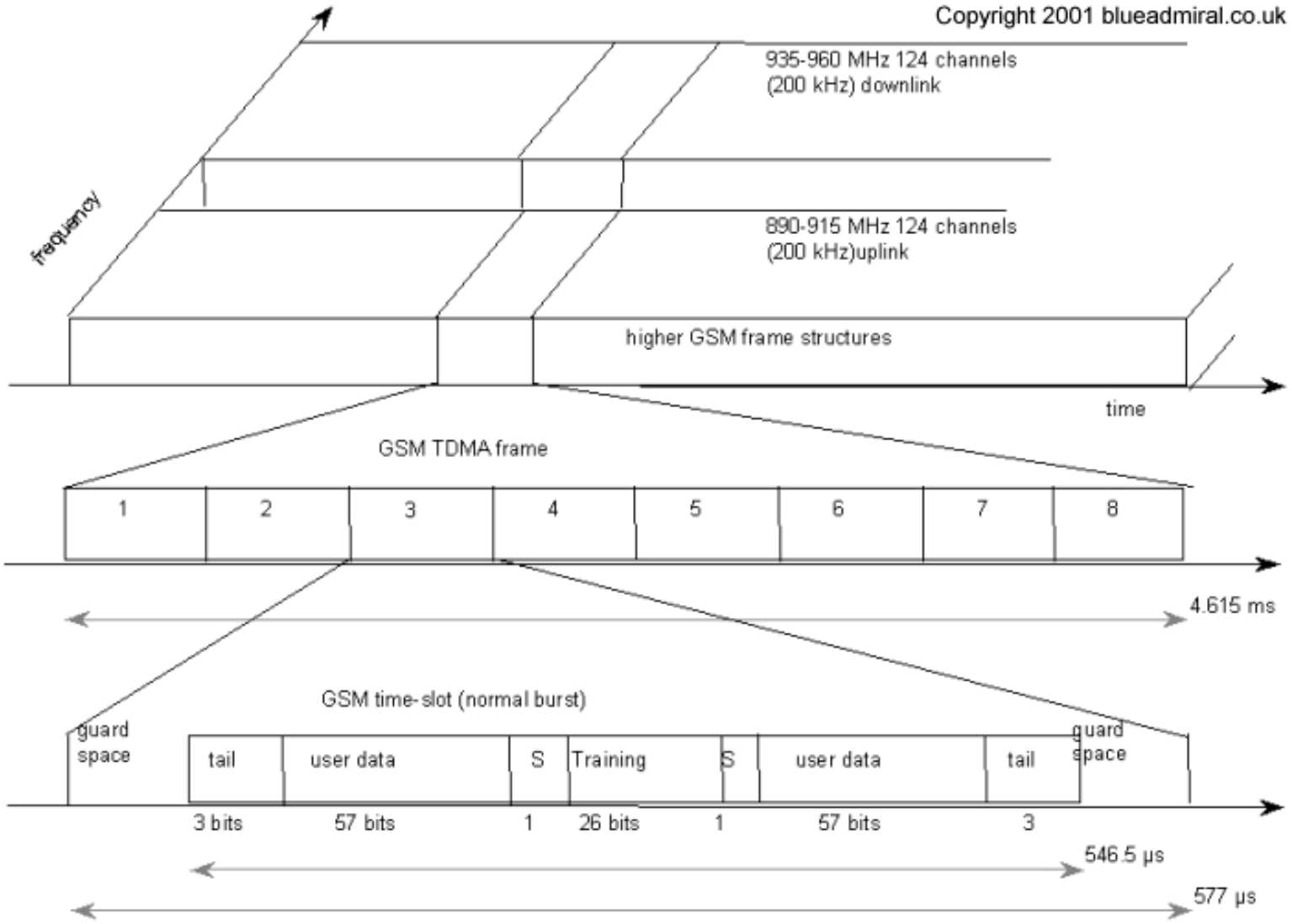
- Originally designed on 900MHz range, later available on 800MHz, 1800MHz and 1900 MHz ranges.
- Separate Uplink and Downlink frequencies
  - One example channel on the 1800 MHz frequency band, where RF carriers are spaced every 200 kHz



Uplink/Downlink frequency channels



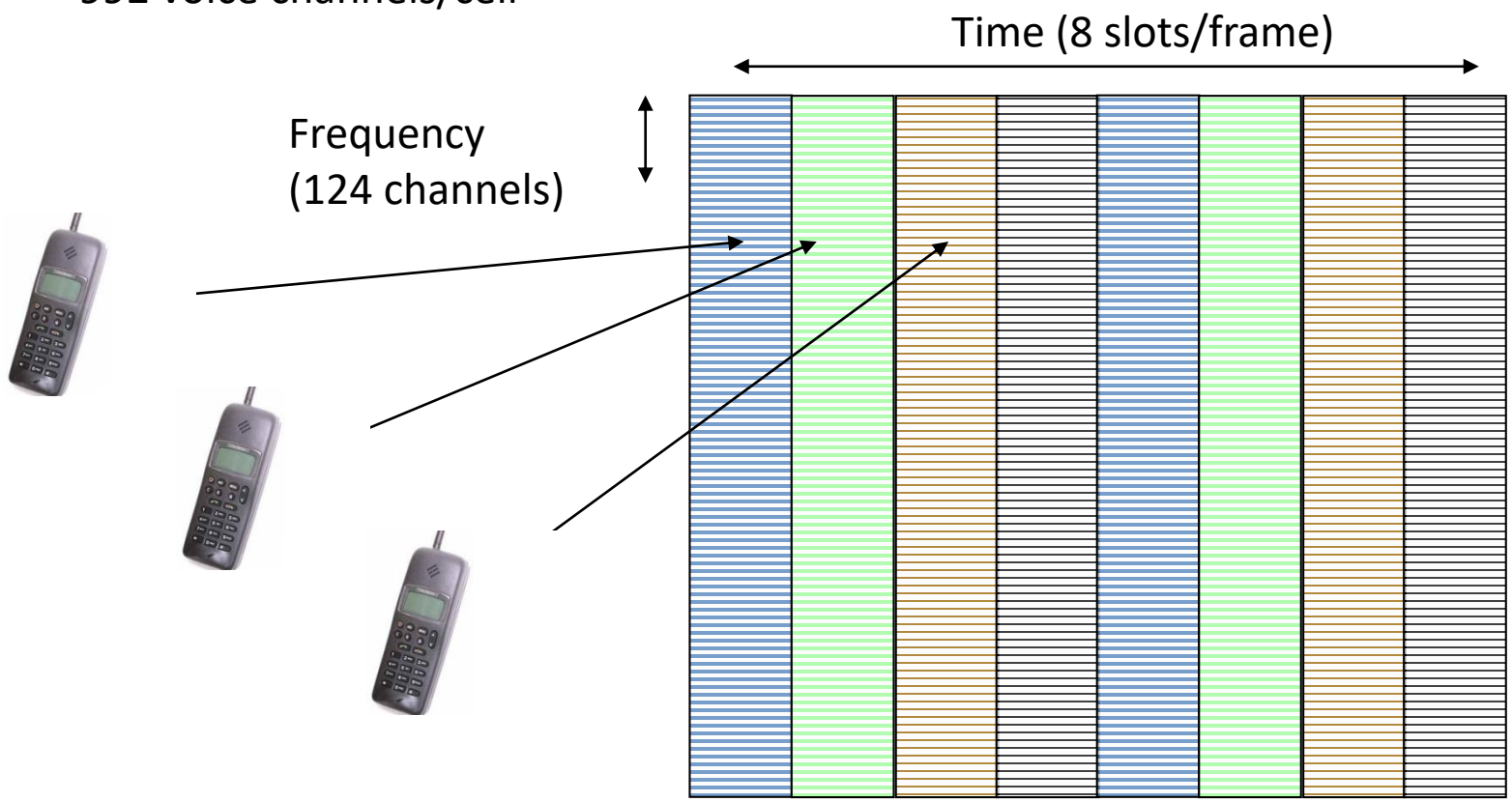
GSM resource allocation



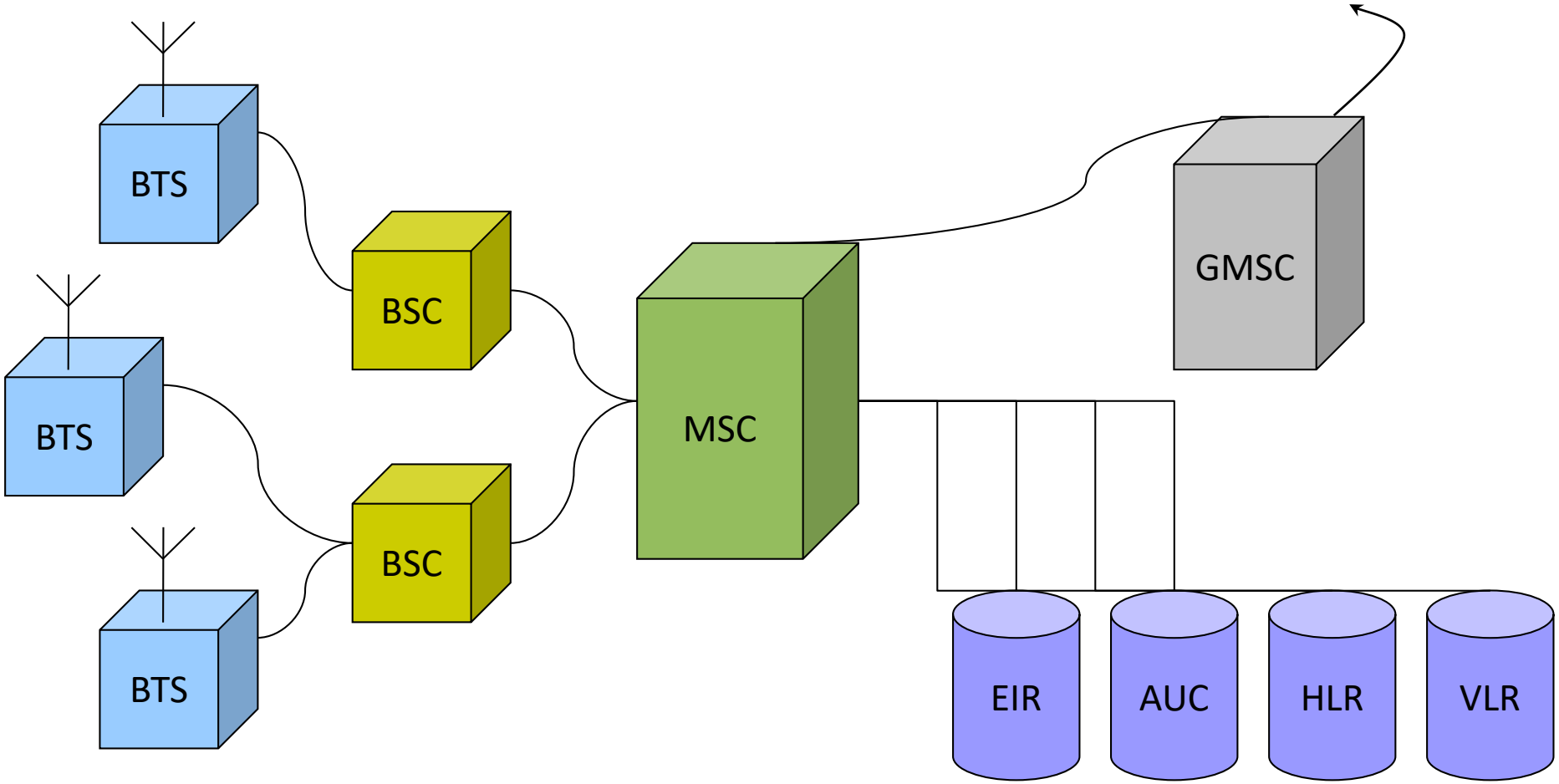
GSM System – Multiple Access

Time Division Multiple Access (TDMA)

992 voice channels/cell



GSM architecture



GSM main components

Base Transceiver Station (BTS): Encodes, encrypts, multiplexes, modulates and feeds the RF signals to the antenna.

Base Station Controller (BSC): Manages Radio resources for BTSs, assigns frequency and time slots for all mobile terminals in its area.

Mobile Switching Center (MSC): Heart of the network, call setup function and basic switching, call routing , billing information and collection, mobility management.

Home/Visiting Location Registers (HLR/VLR): permanent/temporary database about mobile subscribers in a large service area.

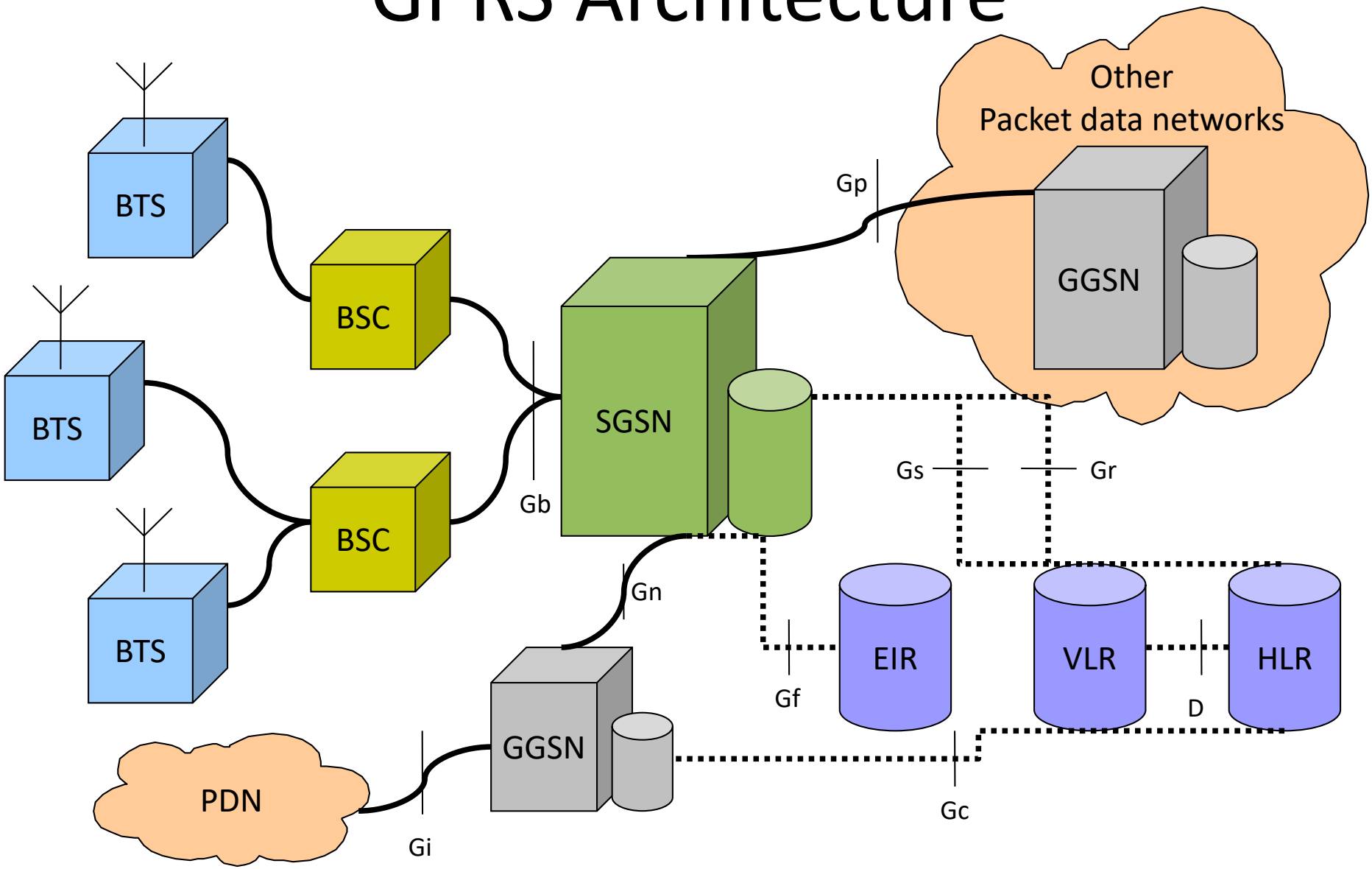
Authentication Center (AUC): Protects against intruders in air interface, maintains authentication keys and algorithms.

Equipment Identity Register (EIR): Database that is used to track handsets using the IMEI (International Mobile Equipment Identity).

GPRS (General Packet Radio Service)

- GSM upgrade that provides IP-based packet data transmission up to 171 kbps (never allowed)
- Users can “simultaneously” make calls and send data
- GPRS provides “always on” Internet access and the Multimedia Messaging Service (MMS)
- Performance degrades as number of users increase
- GPRS is an example of 2.5G telephony

GPRS Architecture

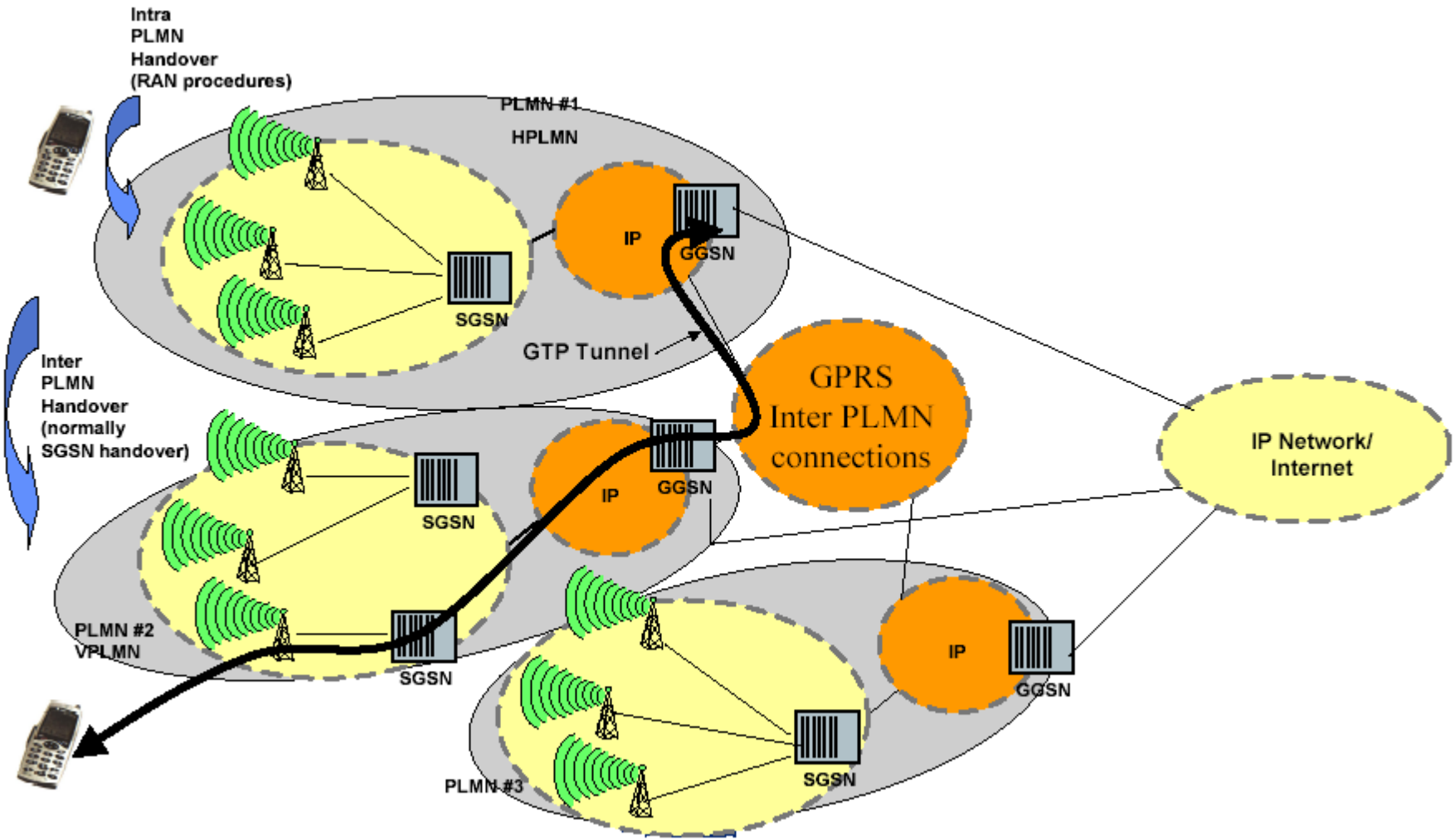


Main difference with GSM

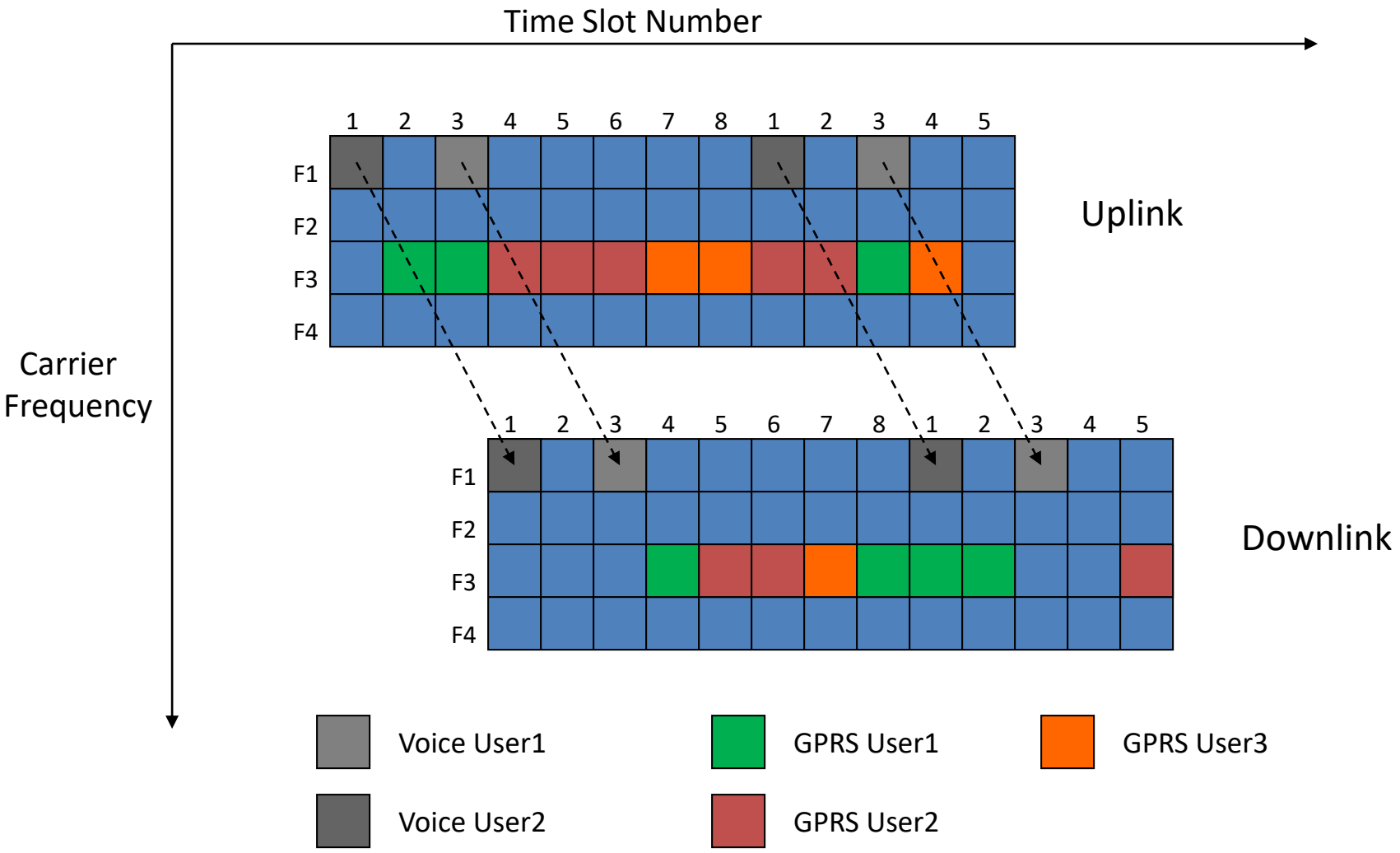
SGSN (Serving GPRS Support Node): Packet switching with mobility management capabilities. Responsible for the delivery of data packets from and to the mobile stations within its geographical service area.

GGSN (Gateway GPRS Support Node): Packet switch interworking with other data networks (Internet). Converts the GPRS packets coming from the SGSN into the appropriate packet data protocol format (e.g., IP)

Routing in GPRS



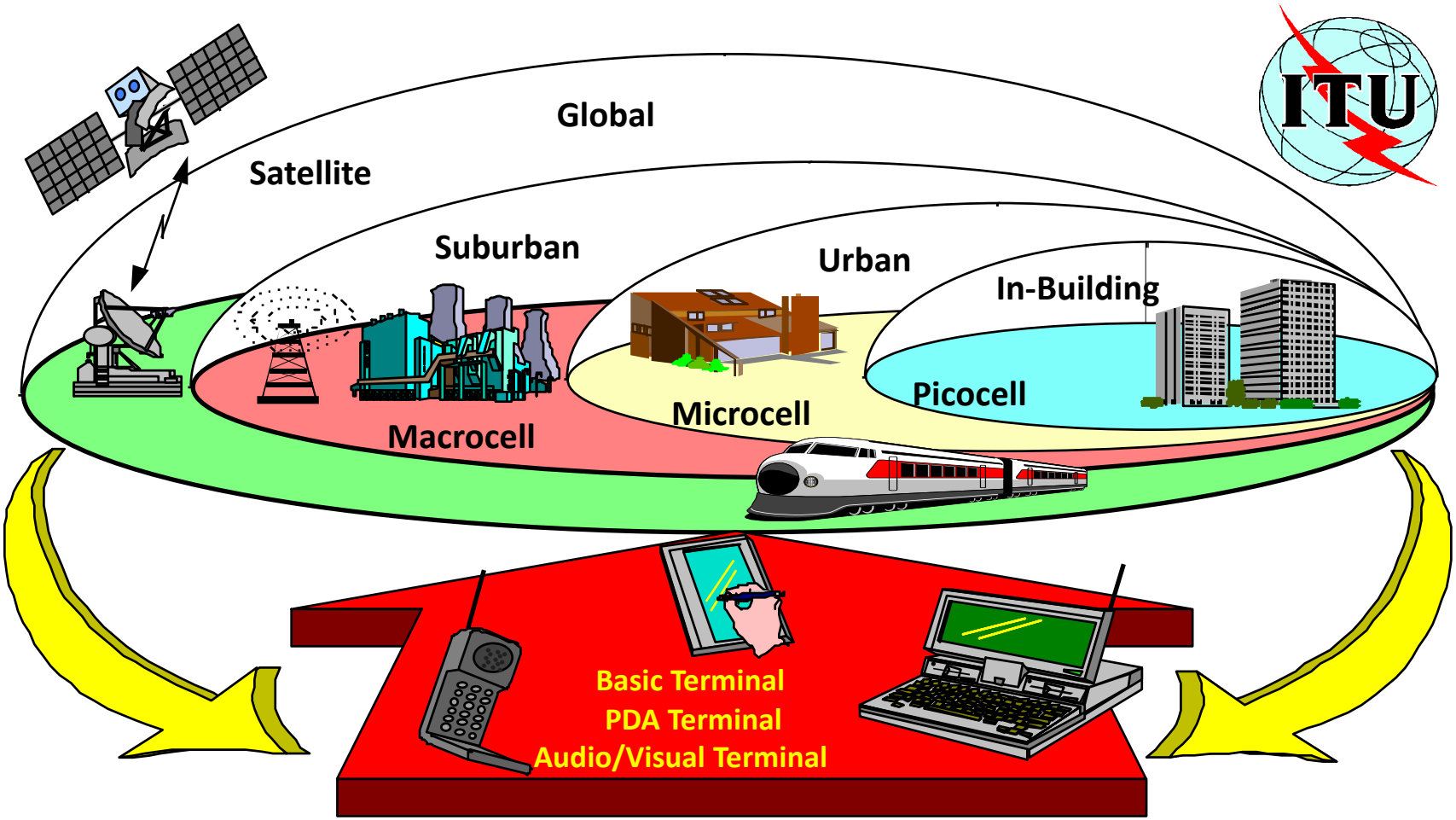
GPRS System – Multiple Access



3G

- 3G refers to a set of standards that comply to IMT-2000 specifications by ITU
- The following standards are typically branded 3G:
  - the UMTS system, first offered in 2001, standardized by 3GPP, used primarily in Europe
  - the CDMA2000 system, first offered in 2002, standardized by 3GPP2, used especially in North America

IMT-2000 Vision Includes LAN, WAN and Satellite Services

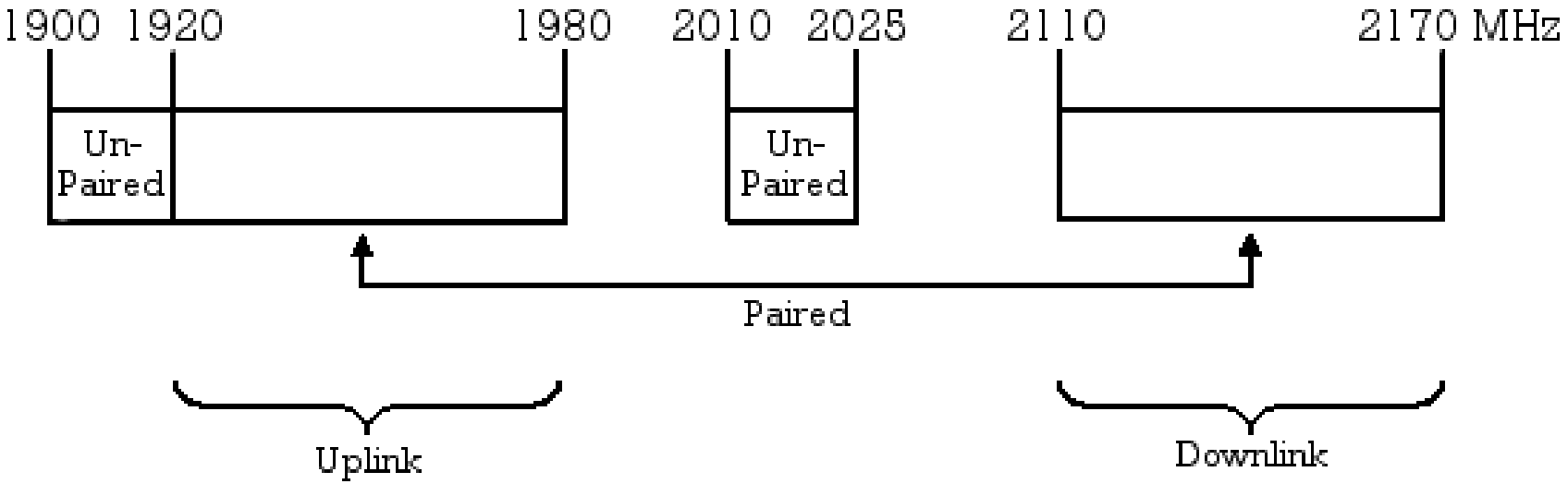


UMTS (Universal Mobile Telecommunications System)

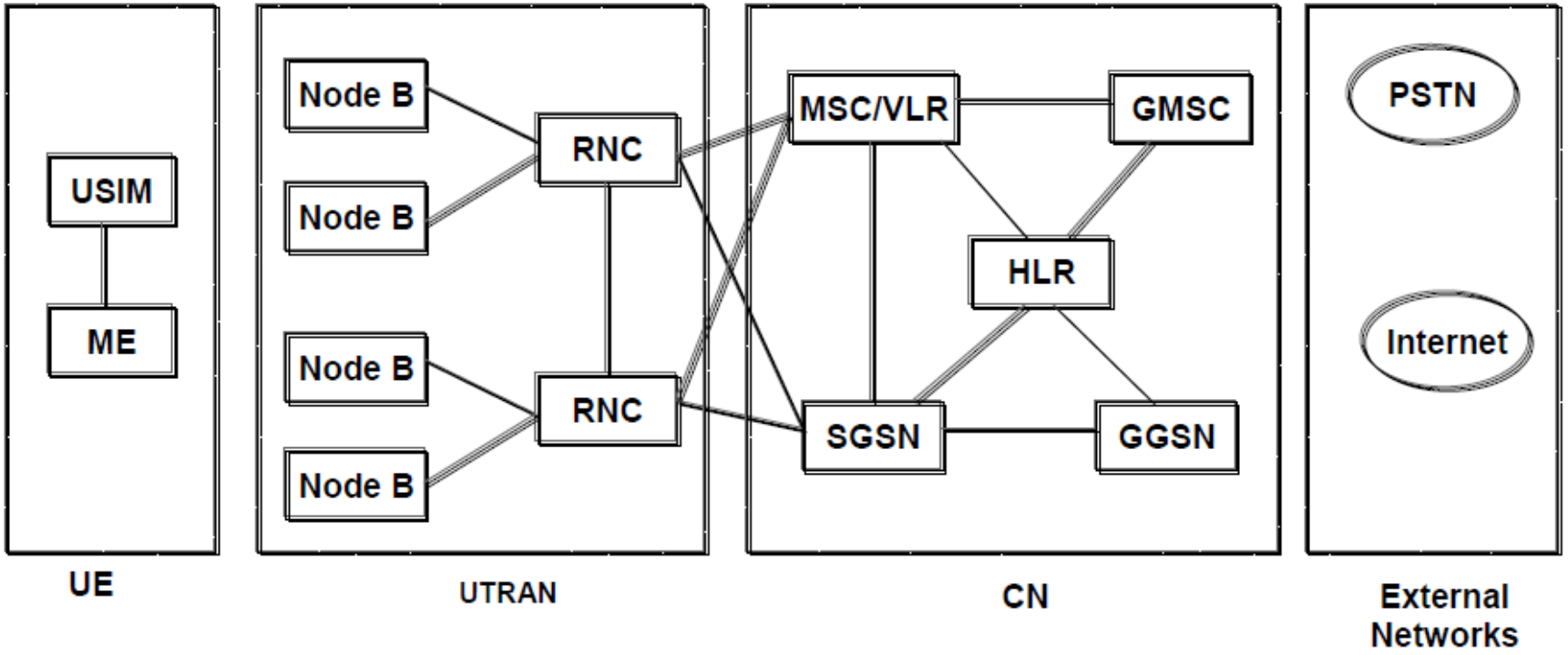
- Voice quality comparable to the public switched telephone network
- 144 Kbps/user in high-speed motor vehicles
- 384 Kbps/pedestrian standing or moving slowly over small areas
- Up to 2 Mbps for fixed applications like office use
- Symmetrical/asymmetrical data transmission rates
- Support for both packet switched and circuit switched data services like Internet Protocol (IP) traffic and real time video

UMTS Frequency Spectrum

- UMTS Band
  - 1900-2025 MHz and 2110-2200 MHz for 3G transmission
  - In the US, 1710–1755 MHz and 2110–2155 Mhz is used instead, as the 1900 MHz band was already used.



UMTS Architecture



- UE (User Equipment) that interfaces with the user
- UTRAN (UMTS Terrestrial Radio Access Network) handles all radio related functionality – WCDMA is radio interface standard here.
- CN (Core Network) is responsible for transport functions such as switching and routing calls and data, tracking users

UMTS Network Architecture

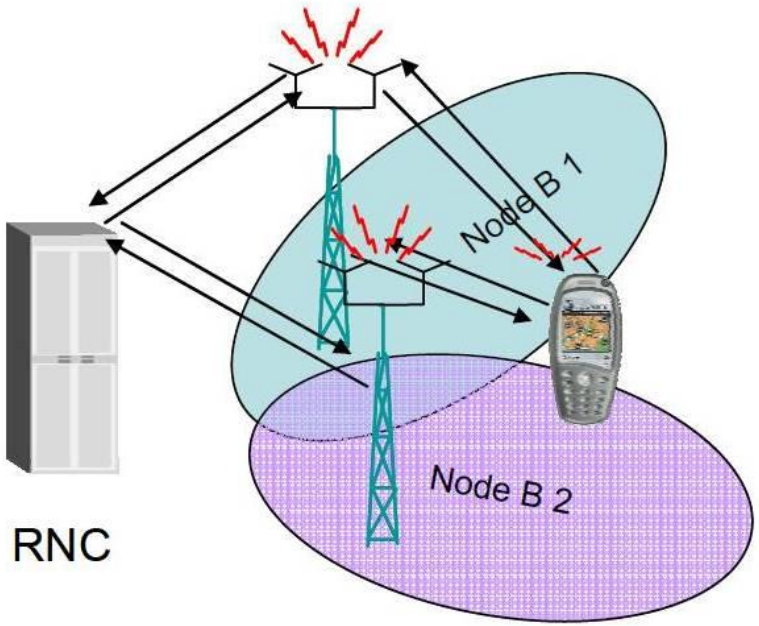
- UMTS network architecture consists of three domains
  - **Core Network (CN):** Provide switching, routing and transit for user traffic
  - **UMTS Terrestrial Radio Access Network (UTRAN):** Provides the air interface access method for user equipment.
  - **User Equipment (UE):** Terminals work as air interface counterpart for base stations.

UMTS QoS Classes

Traffic class	**Conversational class**	**Streaming class**	**Interactive class**	**Background**
Fundamental characteristics	Preserve time relation between information entities of the stream Conversational pattern (stringent and low delay)	Preserve time relation between information entities of the stream	Request response pattern Preserve data integrity	Destination is not expecting the data within a certain time Preserve data integrity
Example of the application	Voice, videotelephony, video games	Streaming multimedia	Web browsing, network games	Background download of emails

UTRAN

- Wide band CDMA technology is selected for UTRAN air interface (instead of FDMA/TDMA in GSM and GPRS)
- Advanced mobility support (e.g., **soft handover**)



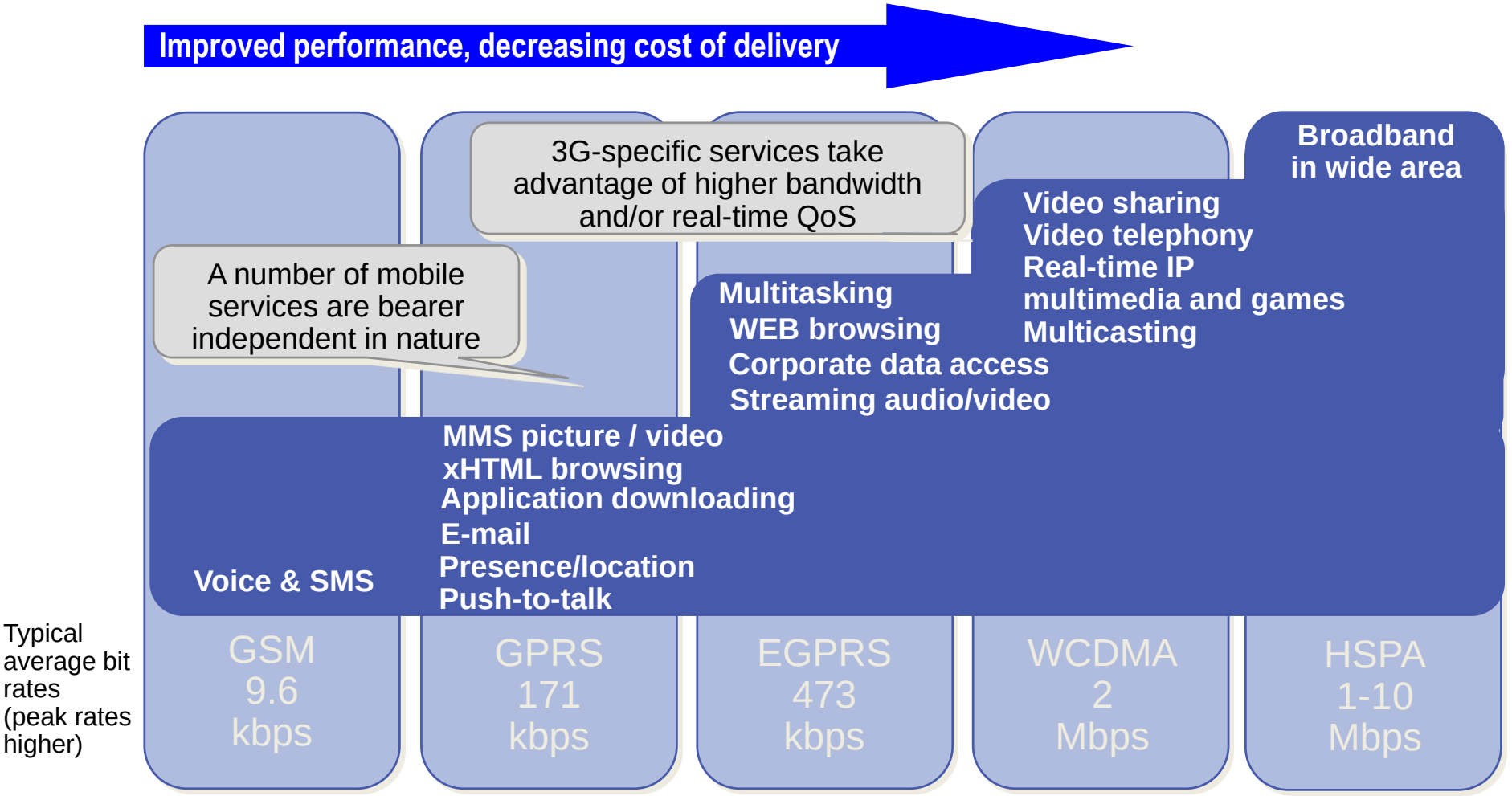
3.5G (HSPA)

High Speed Packet Access (HSPA) is an amalgamation of two mobile telephony protocols, High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA), that extends and improves the performance of existing WCDMA protocols

3.5G introduces many new features that enhance the UMTS technology. These include:

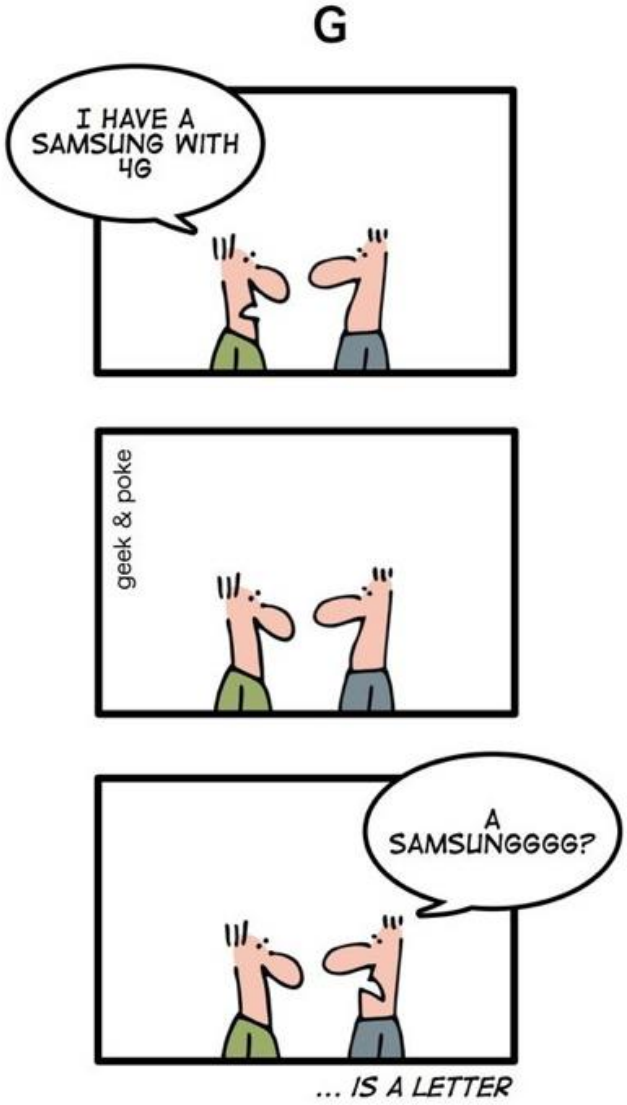
- Adaptive Modulation and Coding
- Fast Scheduling
- Backward compatibility with 3G
- Enhanced Air Interface

Service Roadmap



LTE - Towards 4G

- LTE stands for Long Term Evolution
  (… of UMTS)
- Next Generation mobile broadband technology
- Promises data transfer rates of 100 Mbps
- Based on UMTS 3G technology
- Optimized for All-IP traffic



Motivation for LTE

- Need for higher data rates and greater spectral efficiency
  - Can be achieved with HSDPA/HSUPA
  - and/or new air interface defined by 3GPP LTE
- Need for Packet Switched optimized system
  - Evolve UMTS towards packet only system
- Need for high quality of services
  - Use of licensed frequencies to guarantee quality of services
  - Always-on experience (reduce control plane latency significantly)
  - Reduce round trip delay
- Need for cheaper infrastructure
  - Simplify architecture, reduce number of network elements

Advantages of LTE

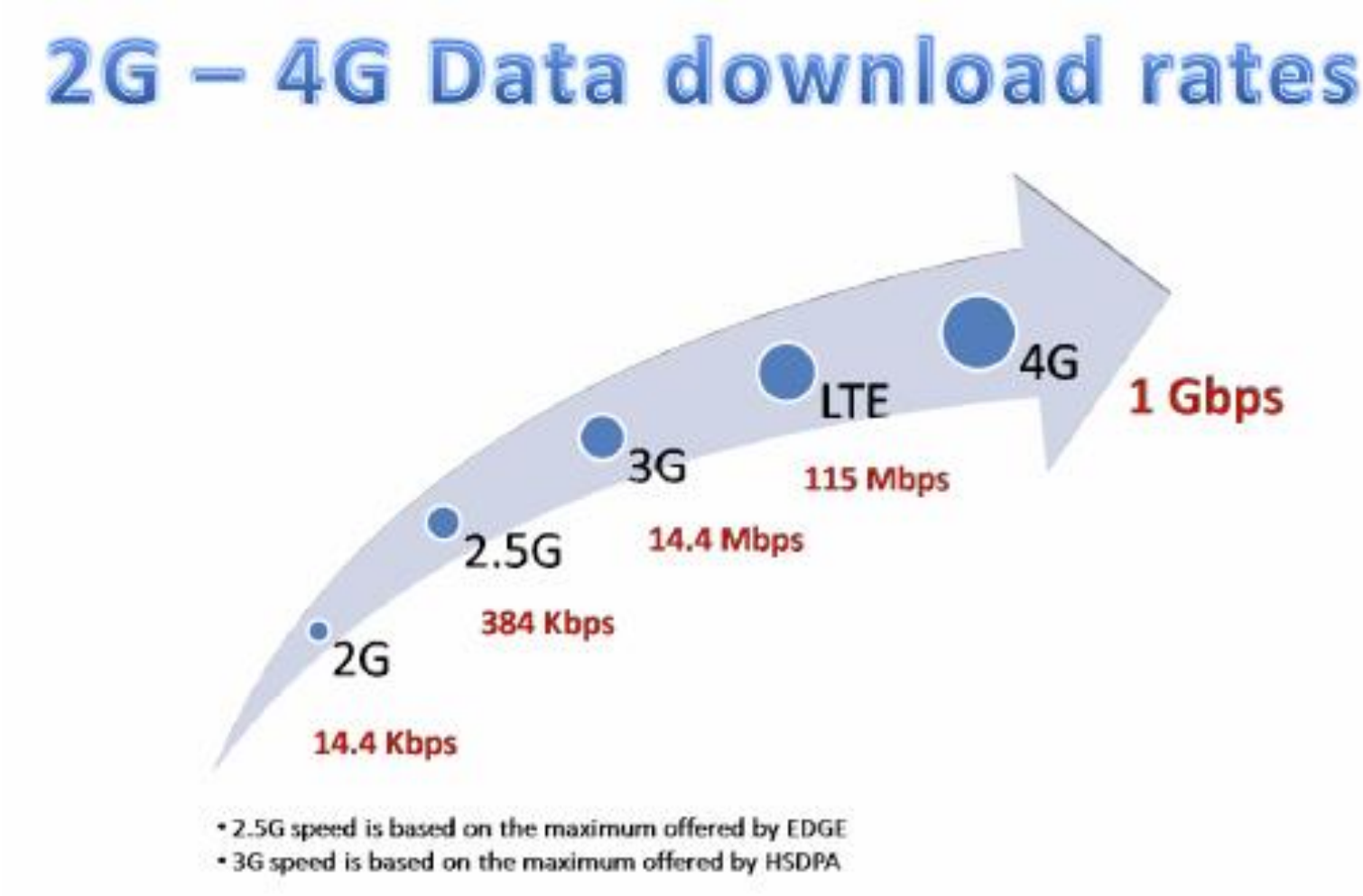
- High network throughput
- Low latency
- Plug & Play architecture
- Low Operating Costs
- All-IP network
- Simplified upgrade path from 3G networks

for Network Operators

- Faster data downloads/uploads
- Improved response for applications
- Improved end-user experience

for End Users

Comparison of LTE Speed



LTE Evolution

- Specification managed by 3GPP organization
  - 3rd Generation Partnership Project
  - UMTS (Universal Mobile Telephone System) Rel 99
  - HSDPA (High Speed Downlink Packet Access) Rel 5
  - HSUPA (High Speed Uplink Packet Access) Rel 6
  - HSPA+ Rel 7, enhancements in Rel 8-10
- New LTE specification in Release 8-9
- LTE-A in Release 10

	WCDMA (UMTS)	HSPA HSDPA / HSUPA	HSPA+	LTE	LTE ADVANCED (IMT ADVANCED)
Max downlink speed (bps)	384k	14 M	28 M	100 M	1 G
Max uplink speed (bps)	128 k	5.7 M	11 M	50 M	500 M
Latency round trip time (approx.)	150 ms	100 ms	50 ms (max)	~10 ms	Less than 5 ms
3GPP releases	Rel 99/4	Rel 5/6	Rel 7	Rel 8/9	Rel 10
Approx years of initial roll out	2003/4	2005/6 HSDPA 2007/8 HSUPA	2008/9	2009/10	
Access methodology	CDMA	CDMA	CDMA	OFDMA/SC-FDMA	OFDMA/SC-FDMA

LTE performance requirements

- Data Rate:
  - Instantaneous downlink peak data rate of 100Mbit/s in a 20MHz downlink spectrum (i.e. 5 bit/s/Hz)
  - Instantaneous uplink peak data rate of 50Mbit/s in a 20MHz uplink spectrum (i.e. 2.5 bit/s/Hz)
- Cell range
  - 5 km - optimal size
  - 30km sizes with reasonable performance
  - up to 100 km cell sizes supported with acceptable performance
- Cell capacity
  - up to 200 active users per cell(5 MHz) (i.e., 200 active data clients)

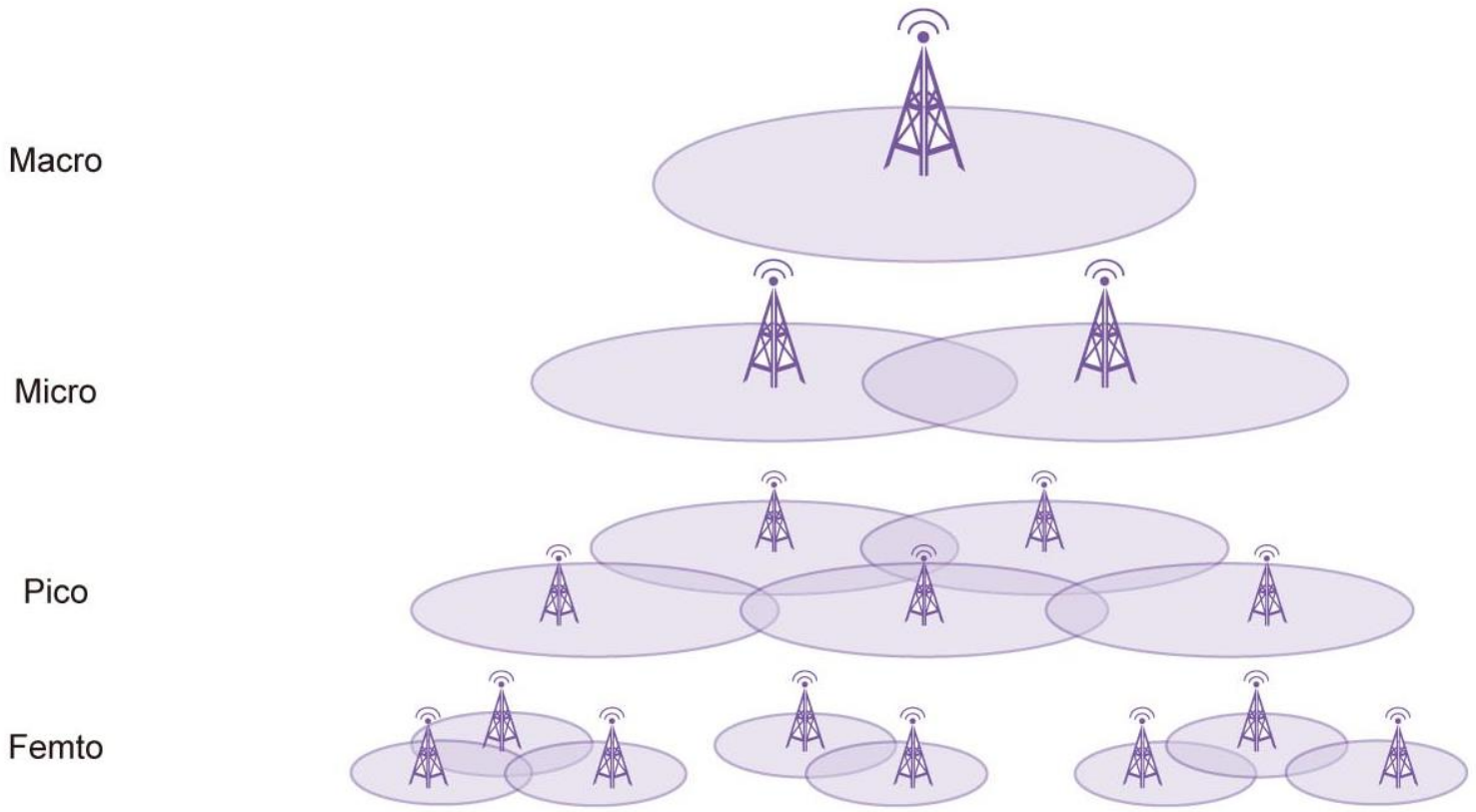
LTE performance requirements

- Mobility
  - Optimized for low mobility(0-15km/h) but supports high speed
- Latency
  - user plane < 5ms
  - control plane < 50 ms
- Improved spectrum efficiency
- Improved broadcasting
- IP-optimized
- Scalable bandwidth of 20, 15, 10, 5, 3 and 1.4MHz
- Co-existence with legacy standards

Key parameters of LTE

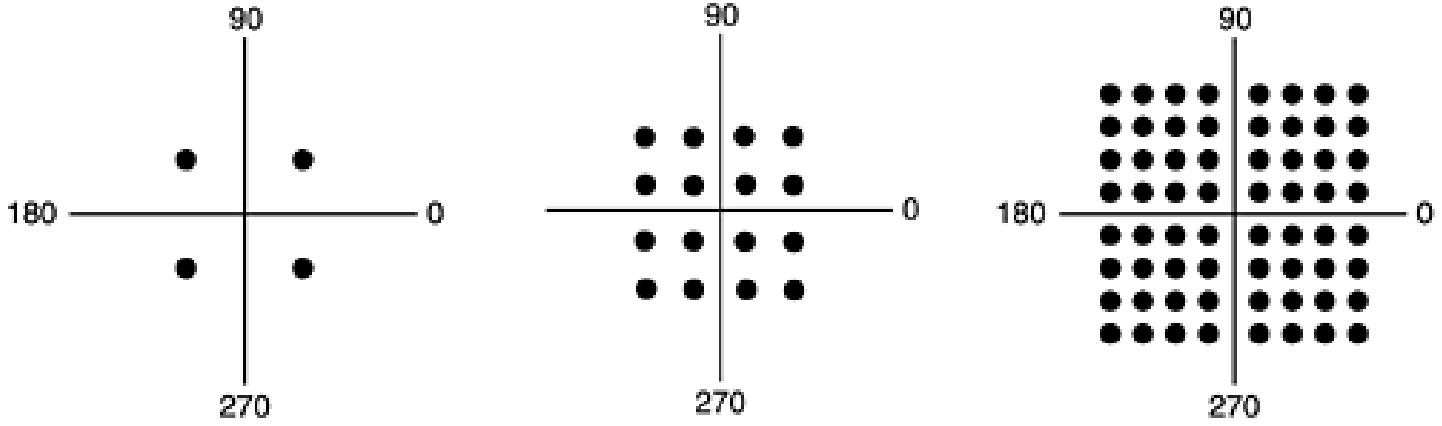
Frequency Range	**UMTS FDD bands and UMTS TDD bands**					
Channel bandwidth 1 Resource Block (RB) =180 kHz	**1.4 MHz**	**3 MHz**	**5 MHz**	**10 MHz**	**15 MHz**	**20 MHz**
	6 RB	15 RB	25 RB	50 RB	75 RB	100 RB
Modulation Schemes	**Downlink**	QPSK, 16QAM, 64QAM				
	Uplink	QPSK, 16QAM, 64QAM (⇨ optional for handset)				
Multiple Access	**Downlink**	OFDMA (Orthogonal Frequency Division Multiple Access)				
	Uplink	SC-FDMA (Single Carrier Frequency Division Multiple Access)				
MIMO technology	**Downlink**	Wide choice of MIMO configuration options for transmit diversity, spatial multiplexing, and cyclic delay diversity (max. 4 antennas at base station and handset)				
	Uplink	Multi-user collaborative MIMO				
Peak Data Rate	**Downlink**	150 Mbps (UE category 4, 2x2 MIMO, 20 MHz) 300 Mbps (UE category 5, 4x4 MIMO, 20 MHz)				
	Uplink	75 Mbps (20 MHz)				

Multi-tier Architecture



Multiple modulations

- QPSK (Quadrature Phase Shift Keying) = 4 phase shifts, 1 amplitude level, 2 bits/symbol
- QAM-16 = 4 phase shifts, 4 amplitude levels, 4 bits/symbol
- QAM-64 = 4 phase shifts, 16 amplitude levels, 6 bits/symbol



QPSK QAM-16 QAM-64

Adaptive modulation