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Reti cellulari LTE

Reti Avanzate, a.a. 2012/2013

Un. of Rome "La Sapienza"

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Emerging needs

- Requirements for LTE (2005)
  - Increased user data rates
  - Uniformity of service provisioning
  - Improved spectral efficiency
  - Greater flexibility of spectrum usage
  - Reduced delays (connection establishment and transmission latency)
  - Low energy consumption at the mobile
  - Seamless mobility and simplified network architecture
- Cellular systems aggregated data rate:

Bandwidth * Spectral efficiency

Bandwidth: Regulation and licences — ITU-R, FCC, regional regulators

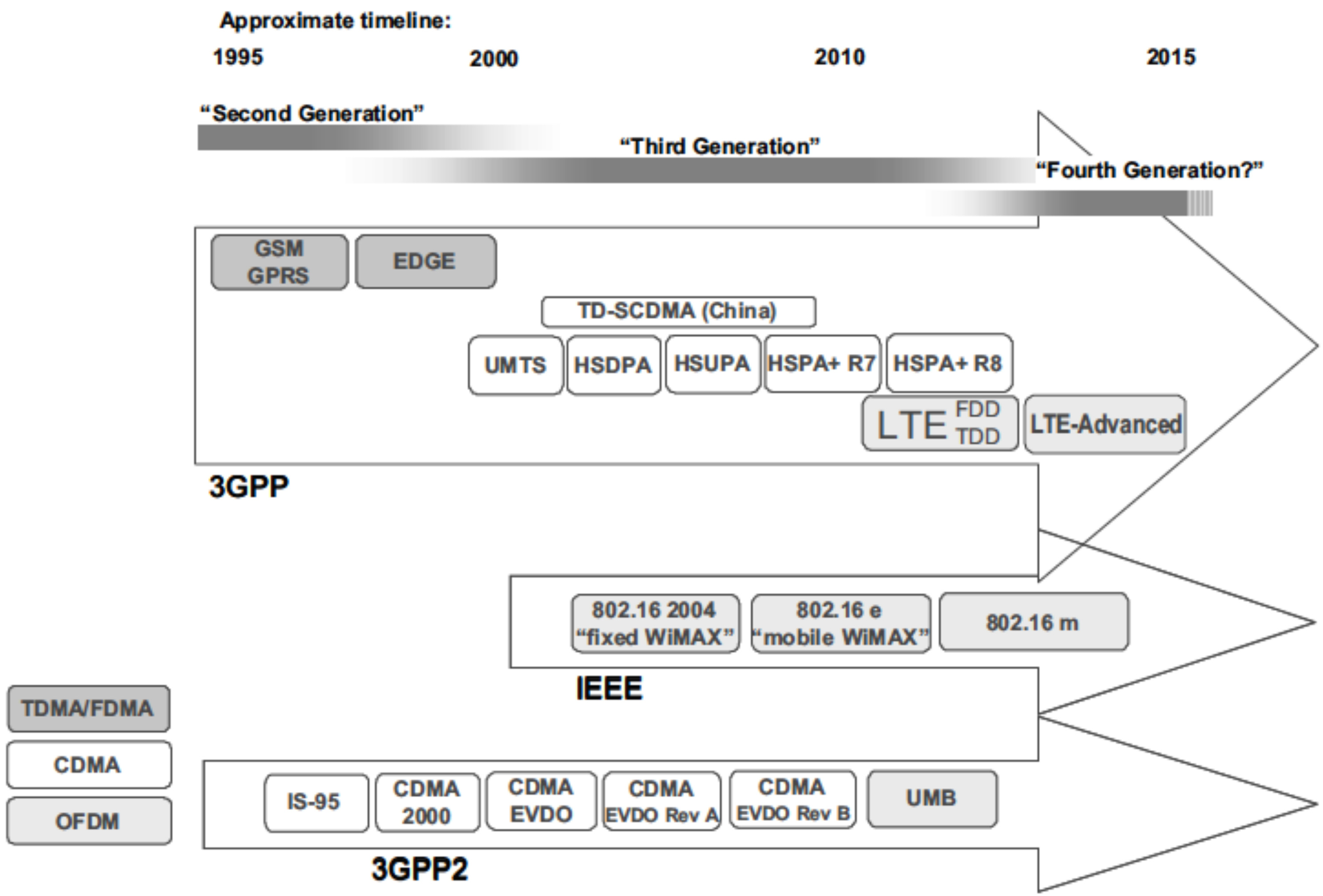
High cost of spectrum — Licences, spectrum almost completely allocated

Spectral efficiency: Technology and standards

		Absolute requirement	Comparison to Release 6	Comment
Downlink	Peak transmission rate	> 100 Mbps	7 × 14.4 Mbps	LTE in 20 MHz FDD, 2 × 2 spatial multiplexing. Reference: HSDPA in 5 MHz FDD, single antenna transmission
	Peak spectral efficiency	> 5 bps/Hz	3 bps/Hz	
	Average cell spectral efficiency	> 1.6 – 2.1 bps/Hz/cell	3 – 4 × 0.53 bps/Hz/cell	LTE: 2 × 2 spatial multiplexing, Interference Rejection Combining (IRC) receiver [3]. Reference: HSDPA, Rake receiver [4], 2 receive antennas
	Cell edge spectral efficiency	> 0.04 – 0.06 bps/Hz/user	2-3 × 0.02 bps/Hz	As above, 10 users assumed per cell
	Broadcast spectral efficiency	> 1 bps/Hz	N/A	Dedicated carrier for broadcast mode
Uplink	Peak transmission rate	> 50 Mbps	5 × 11 Mbps	LTE in 20 MHz FDD, single antenna transmission. Reference: HSUPA in 5 MHz FDD, single antenna transmission
	Peak spectral efficiency	> 2.5 bps/Hz	2 bps/Hz	
	Average cell spectral efficiency	> 0.66 – 1.0 bps/Hz/cell	2 – 3 × 0.33 bps/Hz	LTE: single antenna transmission, IRC receiver [3]. Reference: HSUPA, Rake receiver [4], 2 receive antennas
	Cell edge spectral efficiency	> 0.02 – 0.03 bps/Hz/user	2 – 3 × 0.01 bps/Hz	As above, 10 users assumed per cell
System	User plane latency (two way radio delay)	< 10 ms	One fifth	
	Connection set-up latency	< 100 ms		Idle state → active state
	Operating bandwidth	1.4 – 20 MHz	5 MHz	(initial requirement started at 1.25 MHz)
	VoIP capacity	NGMN preferred target expressed in [2] is > 60 sessions/MHz/cell		

Standard Evolution

- GSM/GPRS/EDGE ← TDMA/FDMA based, designed for voice, extended for data



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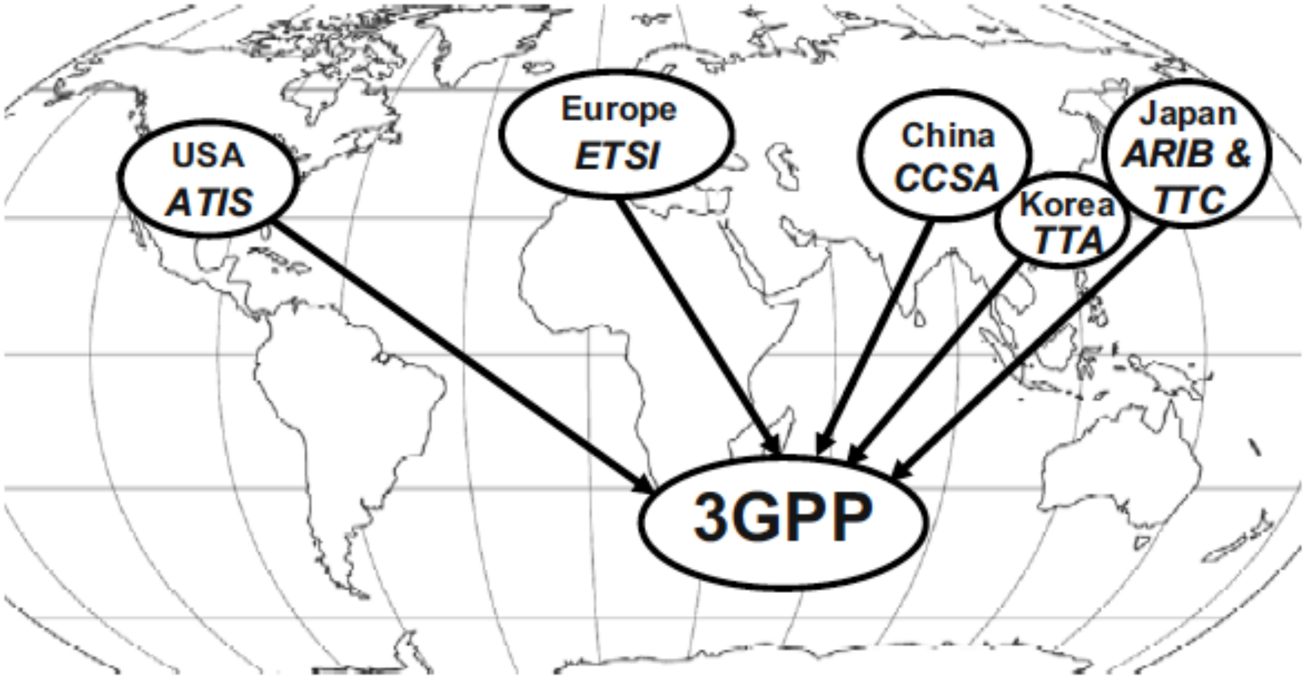

Specification through consensus in Working Groups part of

Technical Specification Groups ←accounting for performance, implementation cost, complexity, backward compatibility

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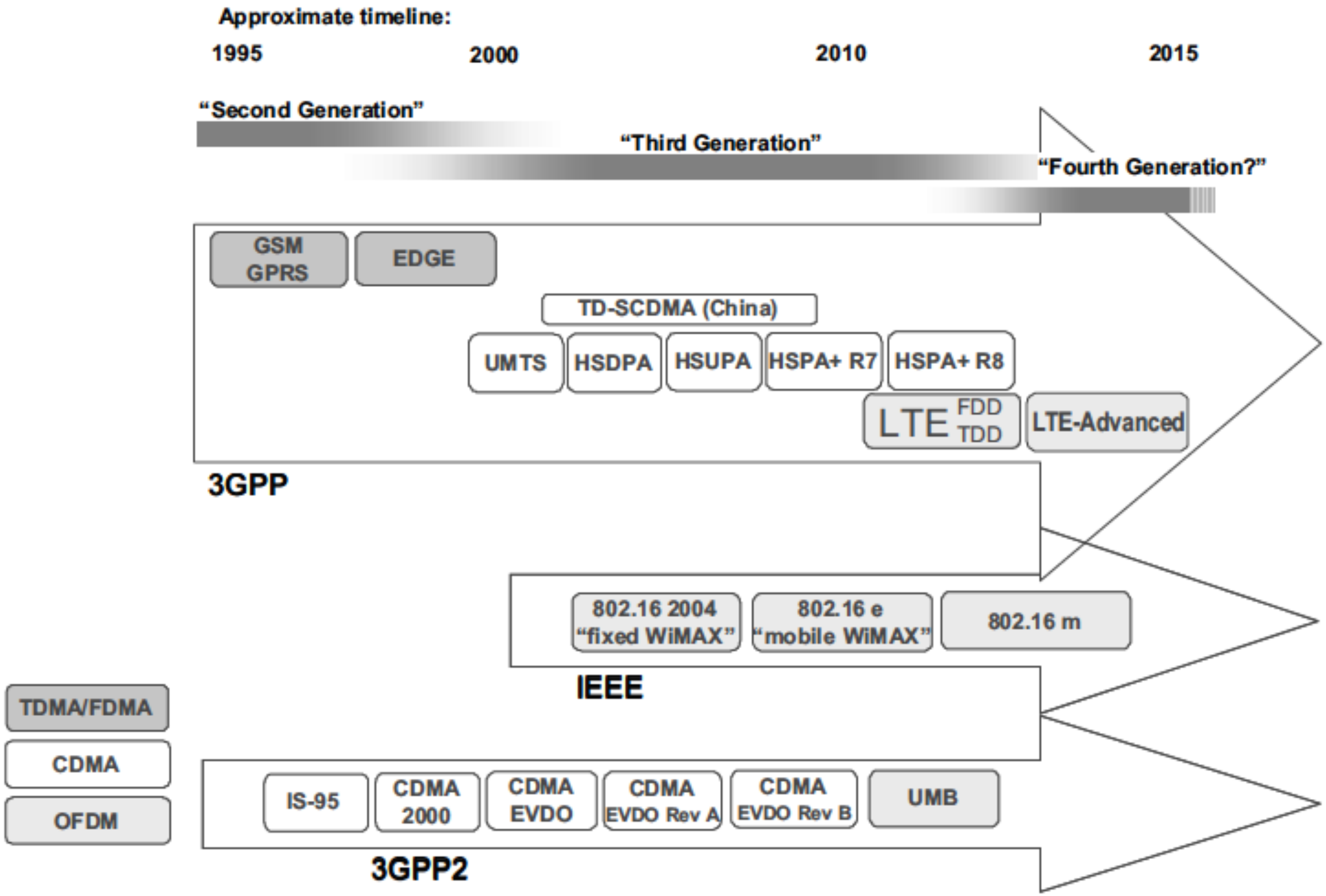
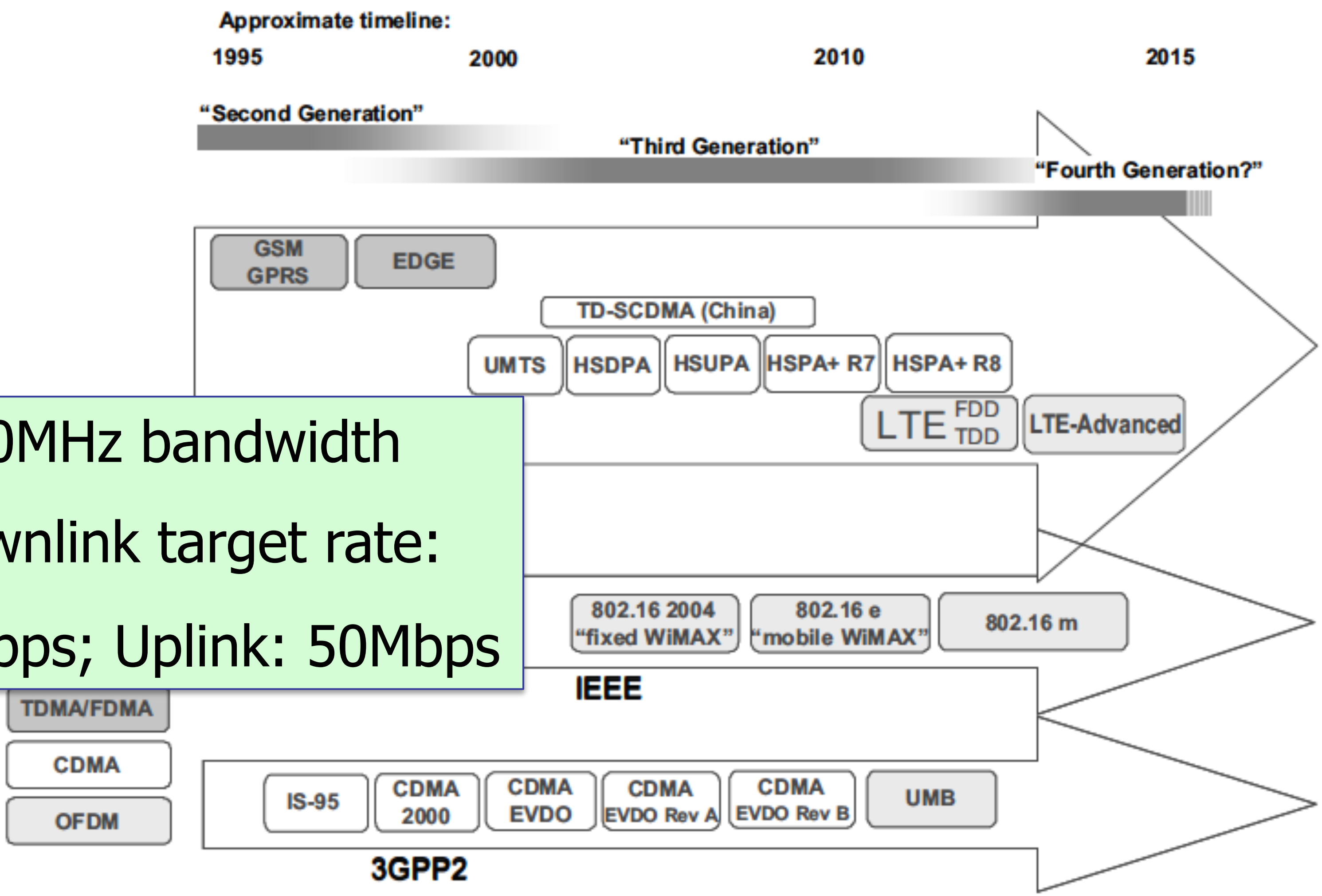
Standard Evolution

- UMTS ← CDMA based, up to high frequency, MIMO, multiservice support



Standard Evolution

- LTE←OFDM based, designed from the very beginning based on a packet switched model, complete realization of the multiservice model



20MHz bandwidth

Downlink target rate:

100Mbps; Uplink: 50Mbps

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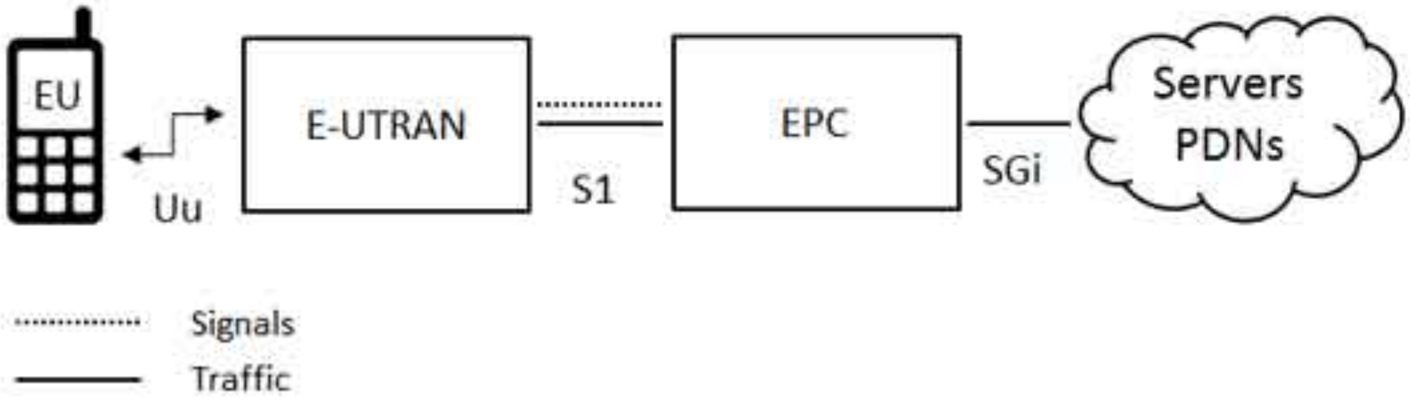
- Requirements for LTE
  - Able to operate in a wide range of frequency bands and sizes of spectrum allocations (from 1.4 up to 20MHz per carrier)
  - Fast connection time (less than 100ms), at least 200 active state users per cell supported by control signaling up to 5MHz and at least 400 users per cell for wider spectrum allocation, one way packet latency =5ms in light traffic.
  - Increased peak rate, uniform performance (requirements on cell edge performance as 5° percentile of performance)
  - Support of mobility up to 350-500Km/h, cells radius 5-100Km
  - Flexible interoperation with other radio access technologies (service continuity in the migration phase), in particular earlier 3GPP technologies, and non 3GPP technologies (WiFi, CDMA 2000, WiMax)
  - Low terminal complexity and power consumption
  - Cost effective deployment
    - ✓ One type of node, the BS, named eNodeB
    - ✓ Open interfaces, multivendor interoperability
    - ✓ Self optimization and easy management
    - ✓ Packet switched services
    - ✓ Easy deployment and configuration of home base station

Technologies for LTE

- Multicarrier technology
  - OFDMA for downlink+ SC-FDMA for uplink
    - ✓ Flexible, adaptable, robust
    - ✓ Low complexity receivers
- Multiantenna technology
- Packet switching
  - System architecture evolution
    - ✓ Concept of Evolved packet system bearer to route IP packets from a gateway of the Packet Data Network to the User Equipment
      - Internet traffic, VoIP traffic
    - ✓ Bearer = IP packet flow with a given QoS between the gateway and the UE (set up and released by the radio access and the evolved packet core together)
      - Multiple bearers can be established for an end user providing different QoS

Network architecture

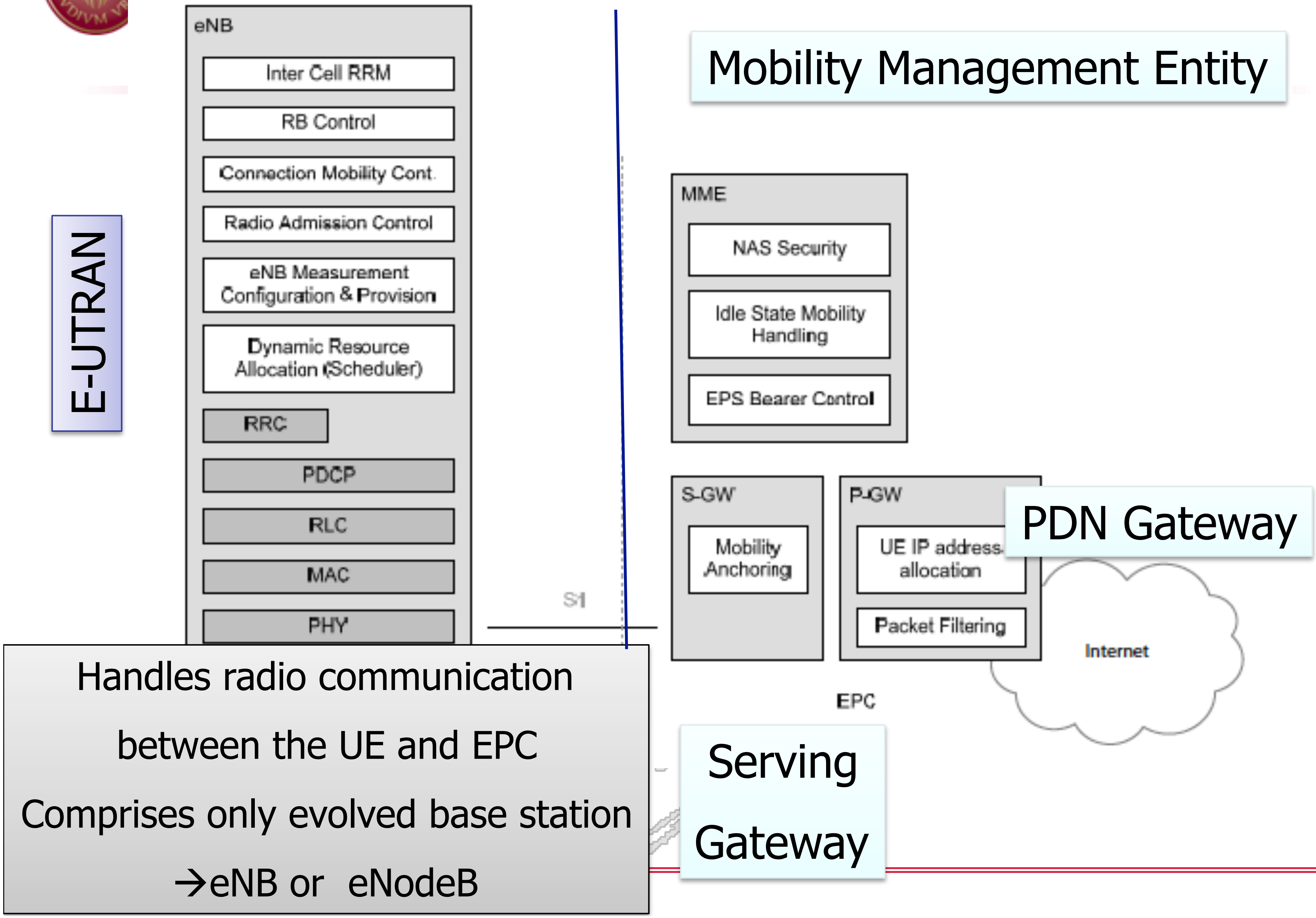
- The high-level network architecture of LTE is comprised of following three main components:
  - The User Equipment (UE).
  - The Evolved UMTS Terrestrial Radio Access Network (E-UTRAN).
  - The Evolved Packet Core (EPC).



Access Network

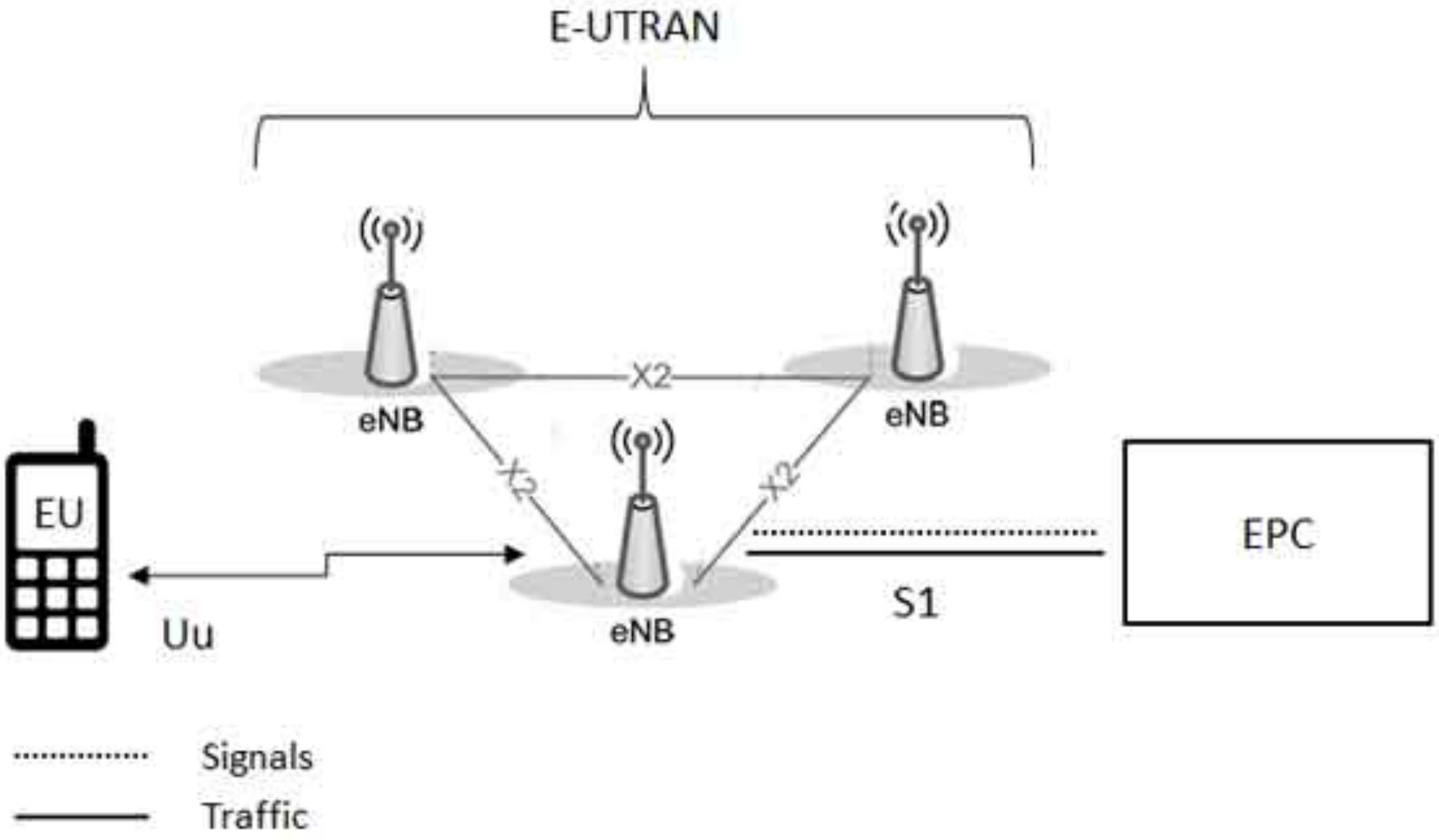
Core network

Network architecture



Network architecture

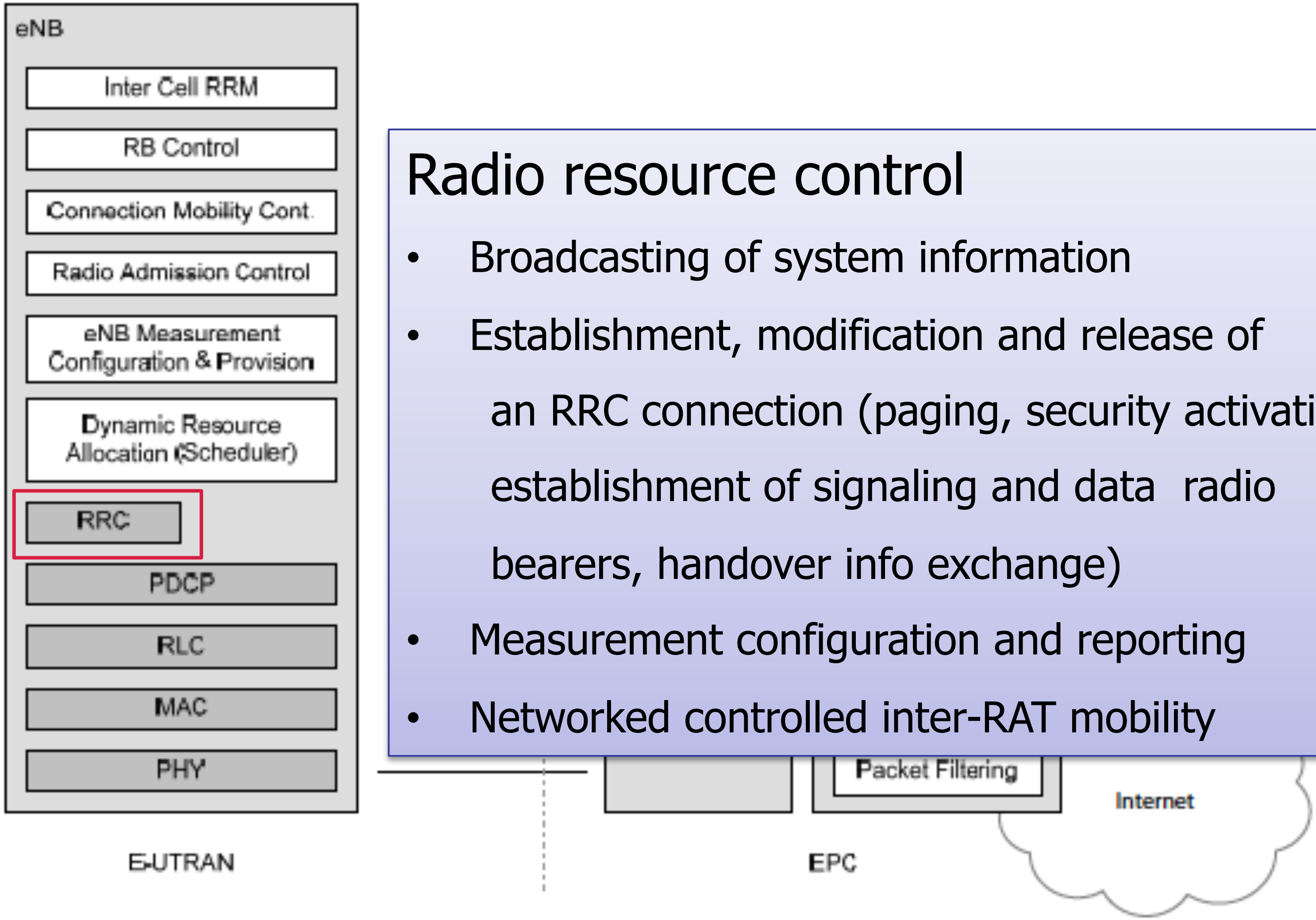
E-UTRAN



Handles radio communication between the UE and EPC

Comprises only evolved base station →eNB or eNodeB

Network architecture



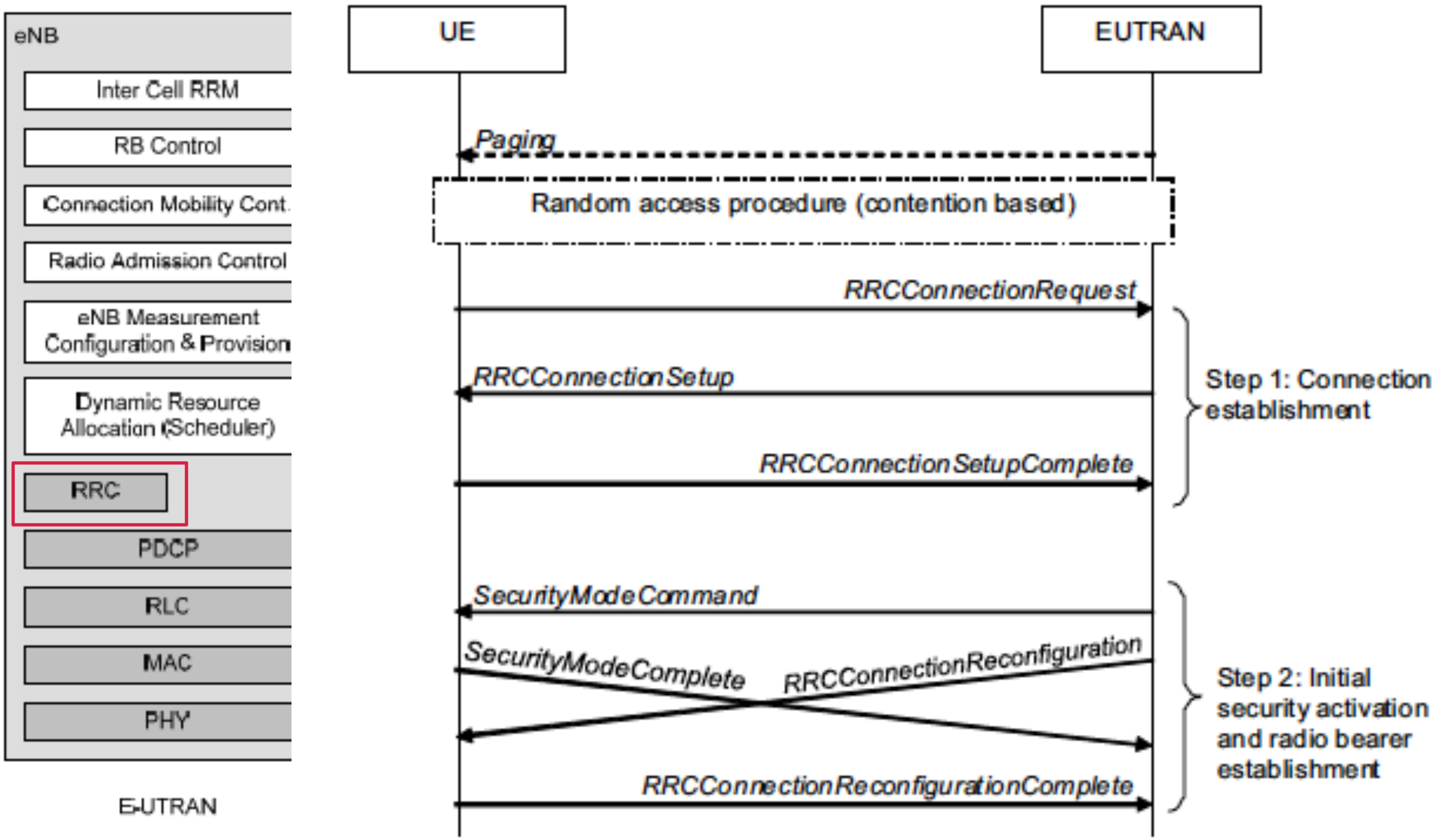
Radio resource control

- Broadcasting of system information
- Establishment, modification and release of an RRC connection (paging, security activation, establishment of signaling and data radio bearers, handover info exchange)
- Measurement configuration and reporting
- Networked controlled inter-RAT mobility

Access Network

Core network

Network architecture



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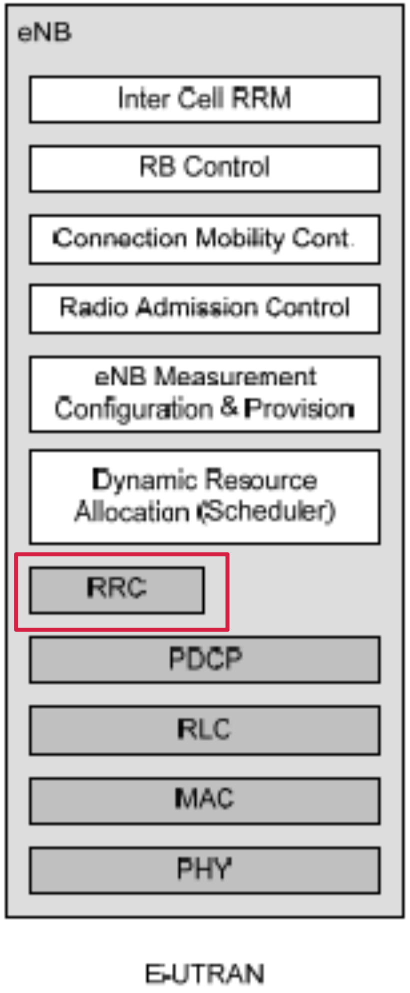
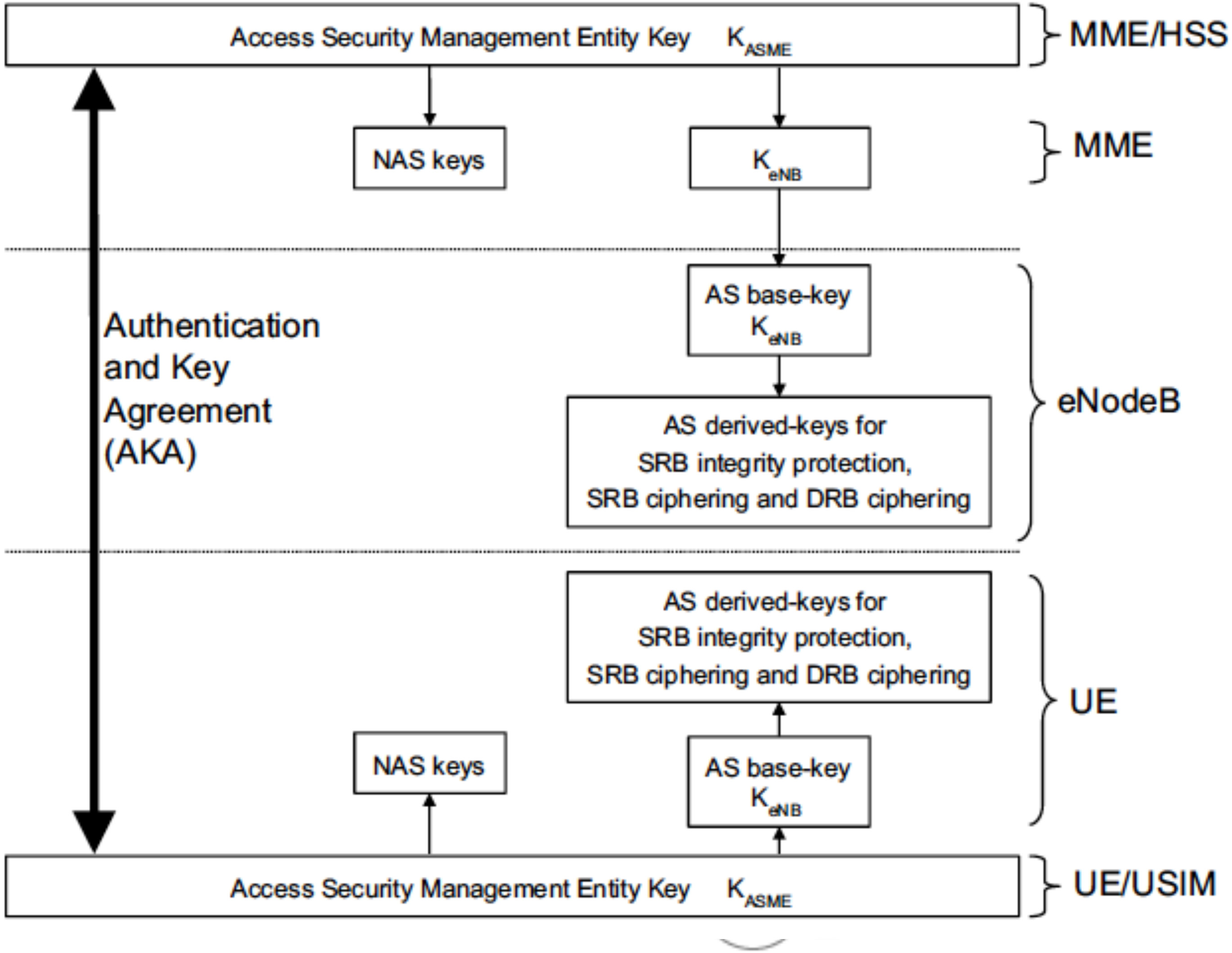
Network architecture





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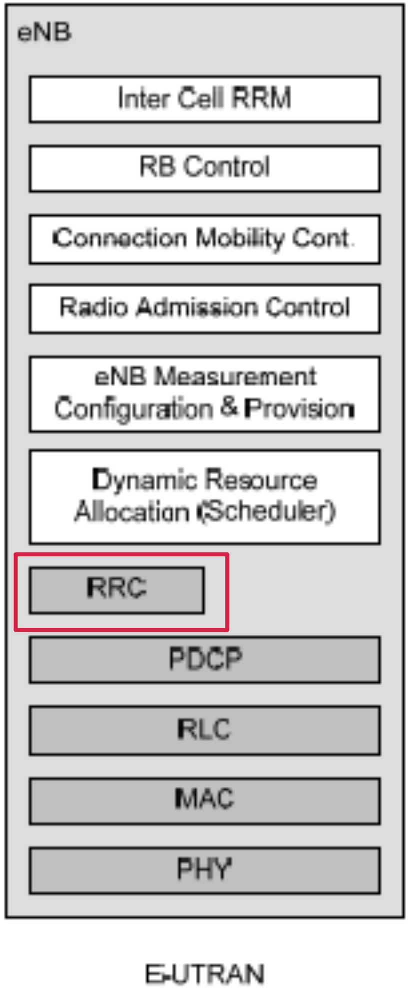

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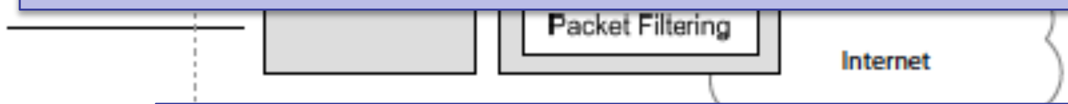
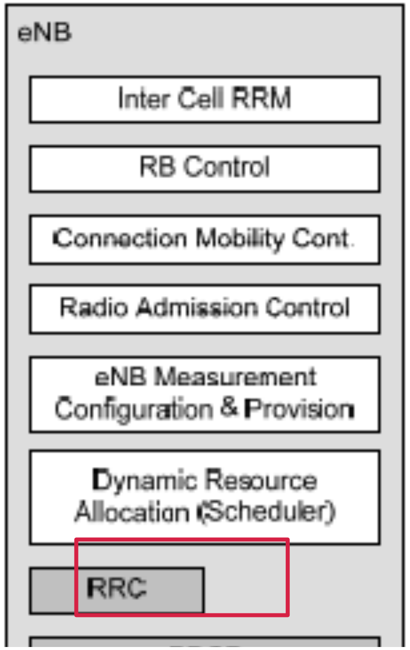


Cell selection based on cell priority

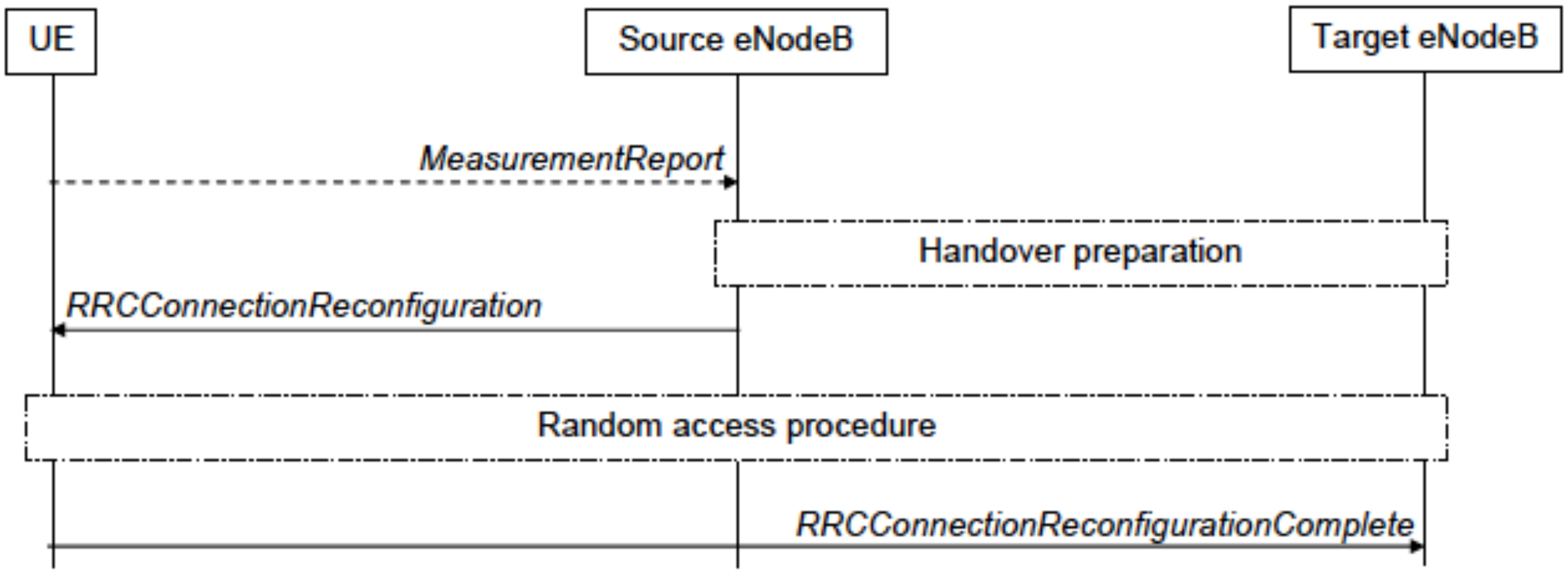
Second criterion: radio link quality

Access Network

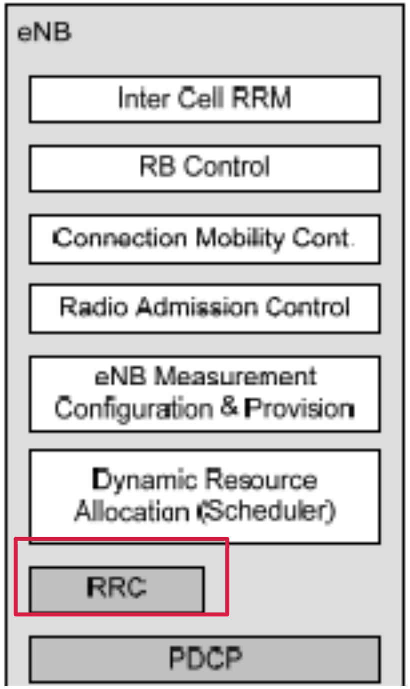
Network architecture



- Hard handover
- UE provides measurements
- eNodeN controlling the source cell requests one or more target eNodeB to prepare for handover (and provides UE radio resource information/context info)
- Target eNodeB generates RRC "message of handover which is forwarded by source eNodeB to the UE
- UE initiates a random access procedure to connect to the new cell



Network architecture



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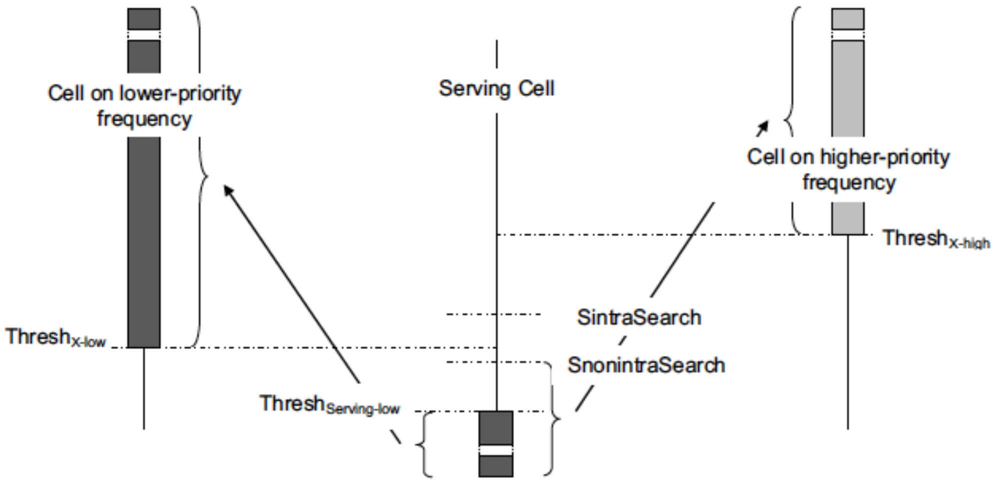
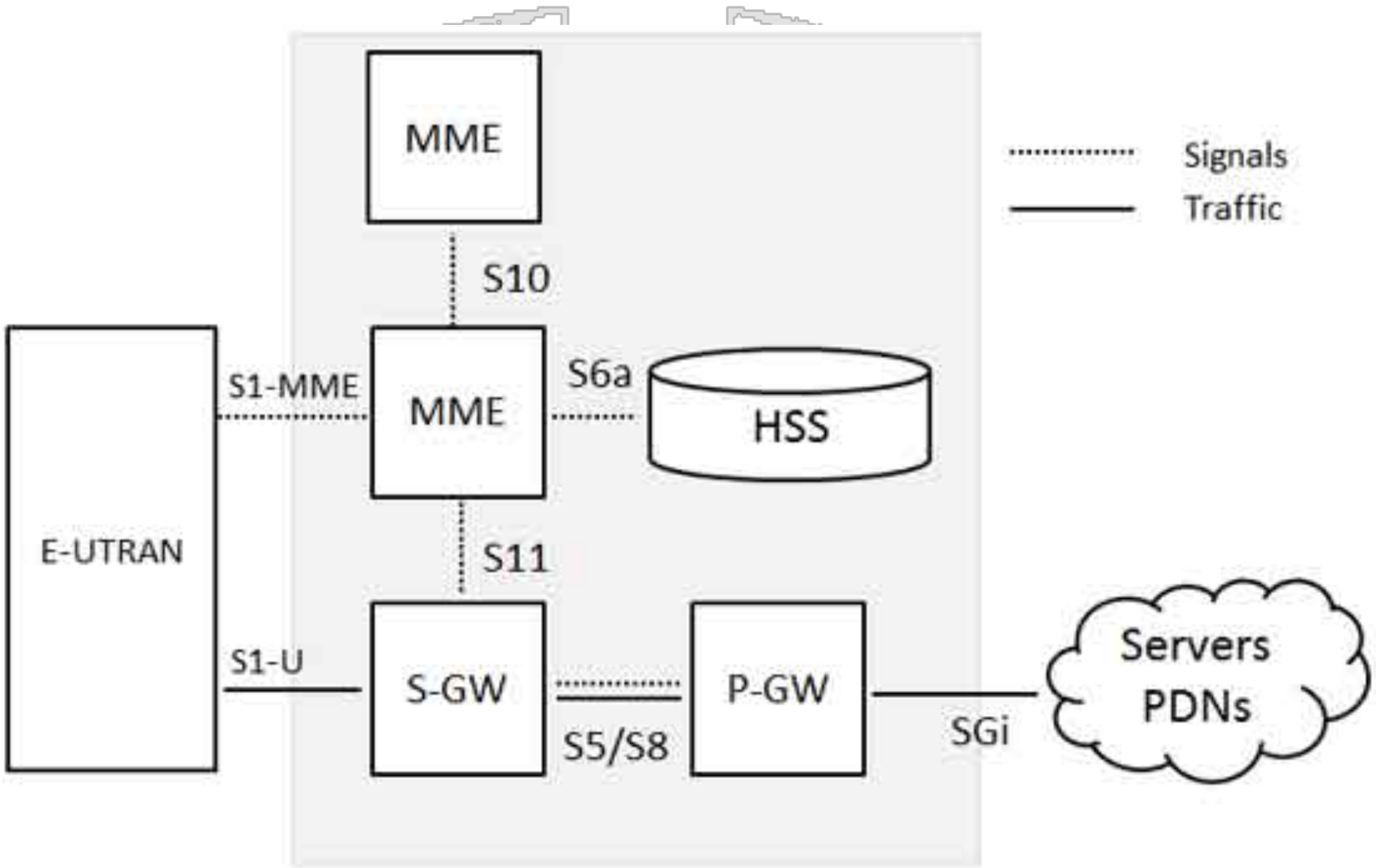


- Flexible measurements configuration
- Event based reporting
- Periodic reporting
- Optimized to save energy

Network architecture

- HSS (Home Subscriber Server)
  - User subscription data, PDNs to which the user can connect, identity of the MME the user is connected to, authentication center
  - HLR+AuC
- P-GW: IP address allocation to UE+ QoS enforcement in downlink+interworking with non 3GPP technologies
- S-GW:tranports the IP data traffic between the User Equipment and the external networks.
- MME: connection set up including paging within a tracking area; security

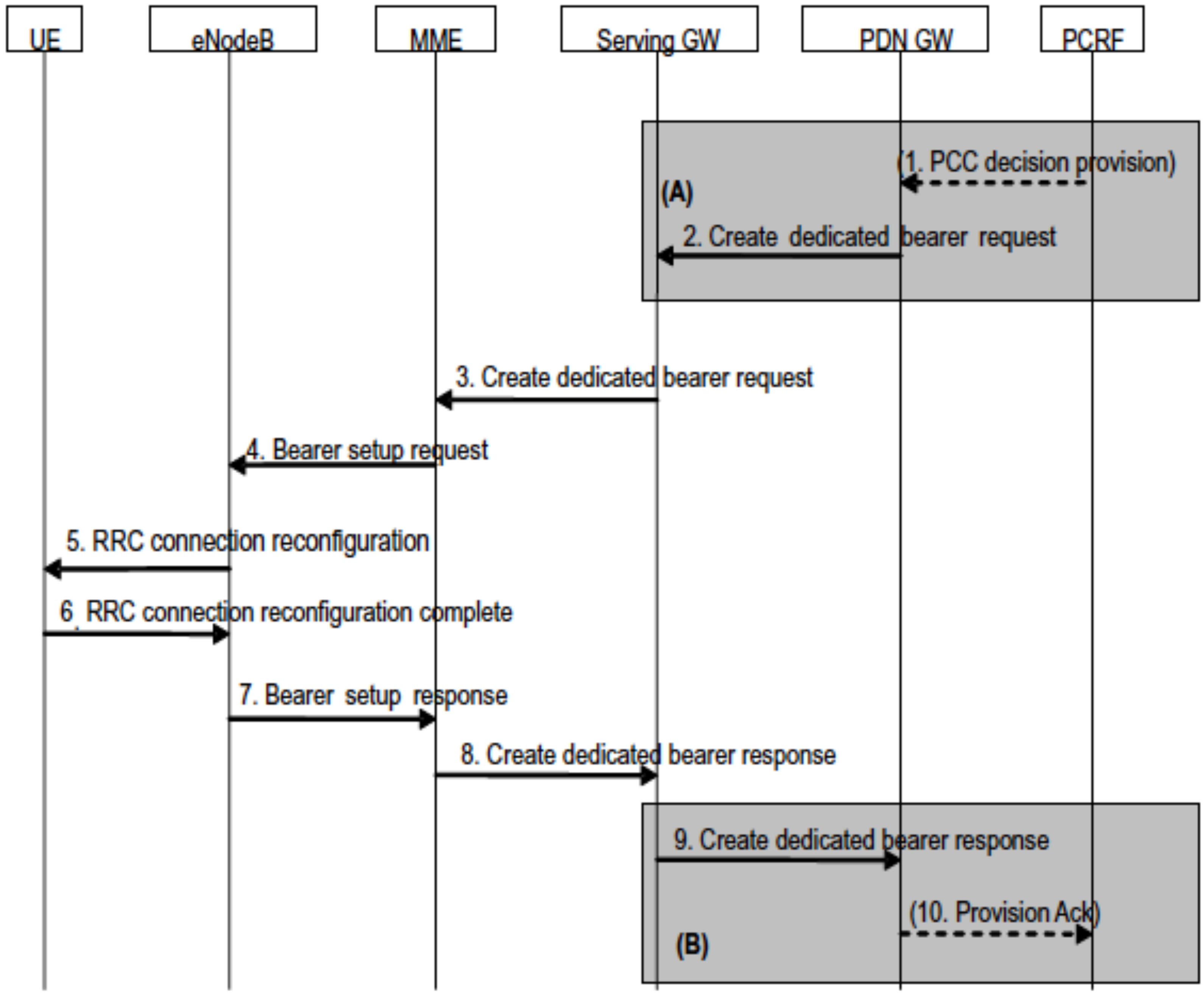
Network architecture



- Standardized interfaces among network elements

QoS and bearers

- Bearers
  - Minimum guaranteed bit rate
  - Non GBR bearers
- The eNodeB in the access network ensures the necessary QoS for a bearer over the radio interface
- Each bearer has an associated QoS Class Identifier and an Allocation and Retention Priority(the latter used for call admission)
  - QCI: priority, packet delay budget, acceptable packet loss rate
  - Determining how to perform scheduling, which queue management policy to use, with which priority

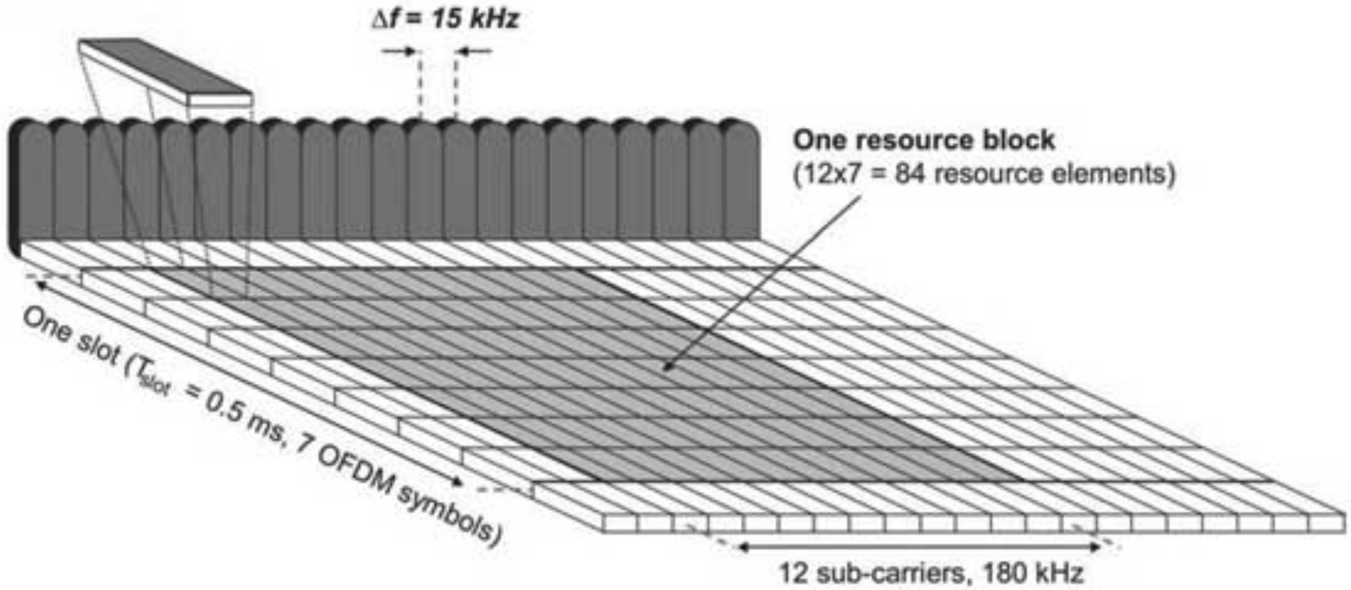

UE
eNodeB
MME
Serving GW
PDN GW
PCRF
(1. PCC decision provision)
(A)
2. Create dedicated bearer request
3. Create dedicated bearer request
4. Bearer setup request
5. RRC connection reconfiguration
6. RRC connection reconfiguration complete
7. Bearer setup response
8. Create dedicated bearer response
9. Create dedicated bearer response
(10. Provision Ack)
(B)

Scheduling

- The scheduler in the eNodeB distributes the available radio resources in one cell among the UEs, and among the radio bearers of each UE.
- eNodeB allocates downlink or uplink radio resources to each UE based on the downlink data buffered in the eNodeB and on Buffer Status Reports (BSRs) received from the UE, and based on channel quality indicator reports.
- eNodeB considers the QoS requirements of each configured radio bearer
  - *dynamic scheduling*: assignment of downlink transmission resources and uplink grant messages for the allocation of uplink transmission resources;
    - ✓ valid for specific single subframes, tx on Physical Downlink Control Channel
  - *persistent scheduling*: resources are semi-statically configured and allocated to a UE for a longer time period

Resource blocks and OFDMA

- LTE is based on orthogonal frequency-division multiplexing (OFDM)
- The OFDM symbols are grouped into resource blocks. The resource blocks have a total size of 180kHz in the frequency domain and 0.5ms in the time domain.



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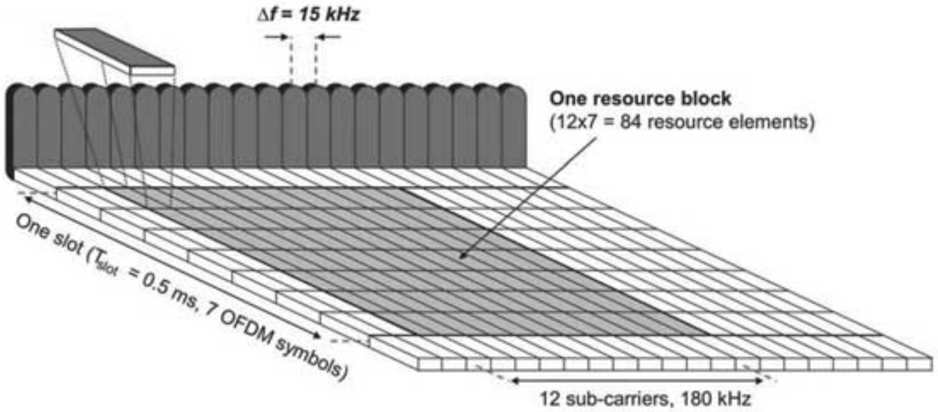
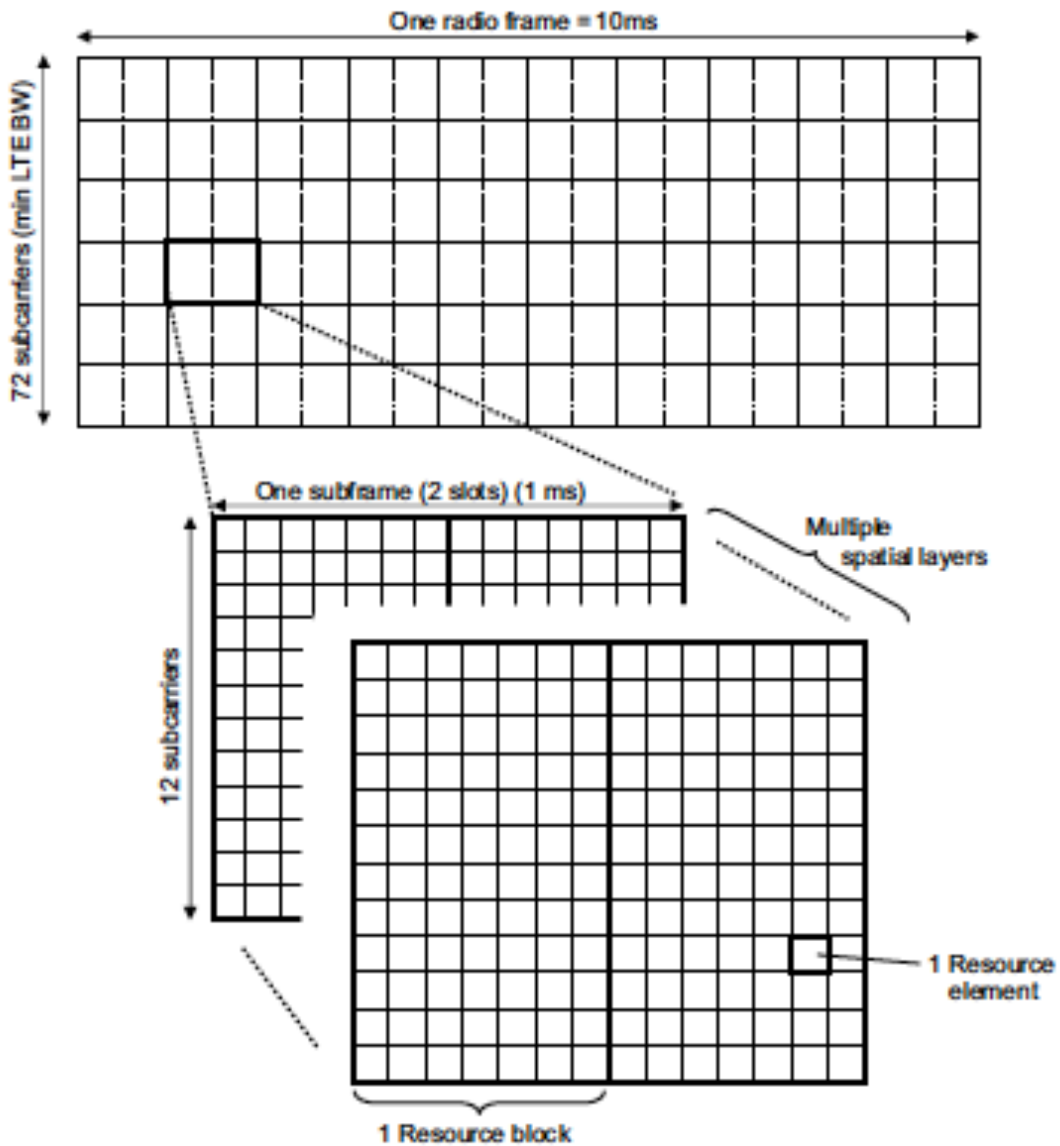
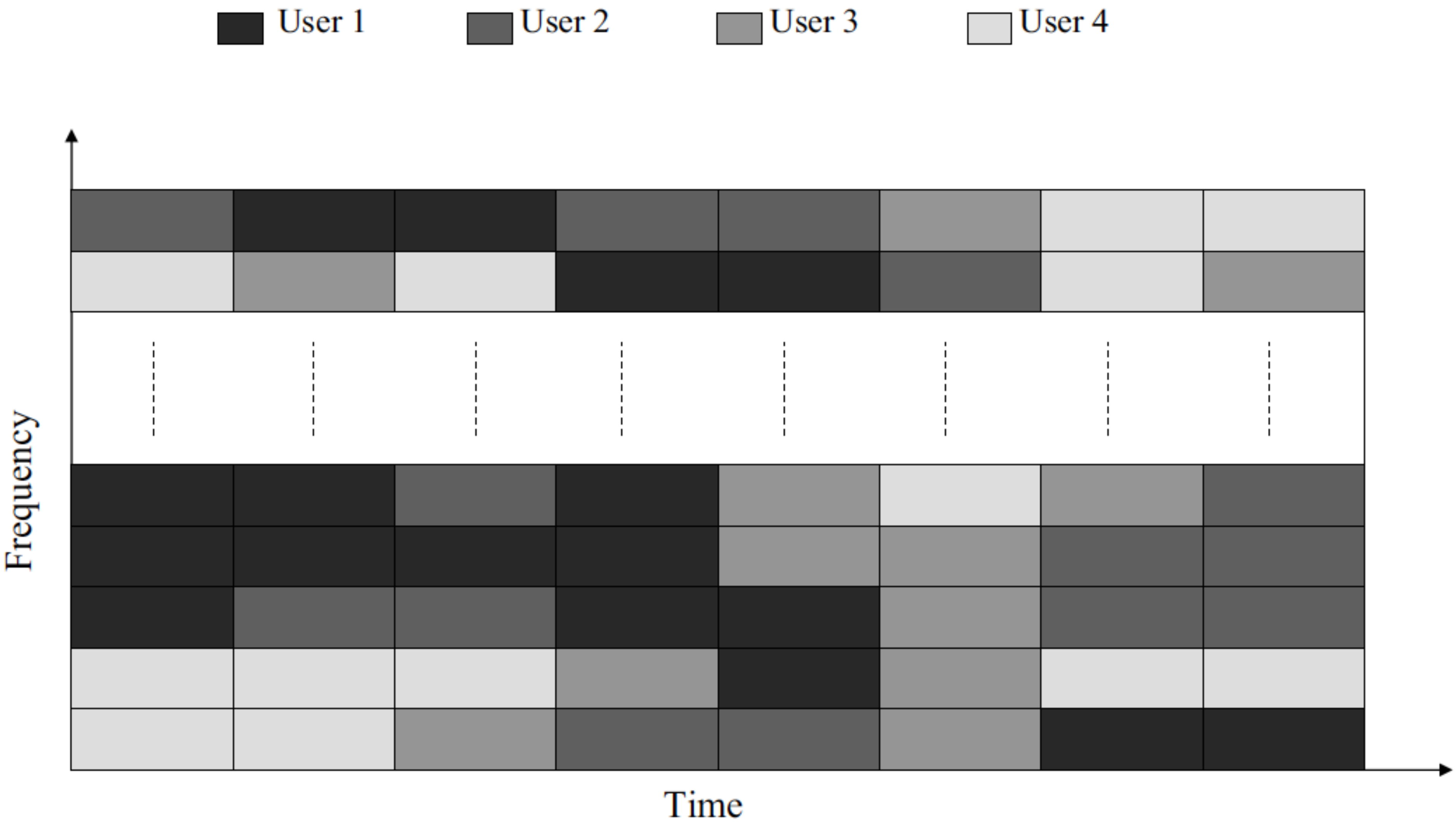


- Each user is allocated a number of so-called resource blocks in the time-frequency grid.
- The more resource blocks a user gets, and the higher the modulation used in the resource elements, the higher the bit-rate.
- Advanced scheduling techniques are used
- Based on feedback information about the frequency-selective channel conditions from each user, adaptive user-to-subcarrier assignment can be performed, enhancing considerably the total system spectral efficiency

Resource blocks



Resource block allocation
An example



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Phy layer adaptation

- Modulation scheme, code rate are dynamically selected based on predicted channel conditions

- Channel Quality Indicator provided as feedback by the UEs are used to estimate different channels conditions (based on user perceived quality of transmitted reference signals)

LTE summary

- LTE brings up to 50 times performance improvement and much better spectral efficiency to cellular networks.
- 300Mbps peak downlink and 75 Mbps peak uplink.
- LTE supports flexible carrier bandwidths, from 1.4 MHz up to 20 MHz as well as both FDD and TDD.
- All LTE devices have to support MIMO transmissions, allowing the base station to transmit several data streams over the same carrier simultaneously
- All interfaces between network nodes are now IP based
- Quality of Service (QoS) mechanism have been standardized on all interfaces
- Works with GSM/EDGE/UMTS systems utilizing existing 2G and 3G spectrum and new spectrum. Supports hand-over and roaming to existing mobile networks.