Scheduling in LTE

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Outline

LTE Overview

- Network & Signals
- Physical Resources in Time & Frequency
- Radio Protocol Architecture
- Control Information for Scheduling Operation

Scheduling in LTE

- Scheduling Operation
- CQI Reporting for Scheduling
- Schedulers in LTE

Summary & References

LTE Overview

Network & Signals : E-UTRAN, OFDMA/SC-FDMA

Physical Resources : Physical Resources, Resource Unit, Scheduling Unit

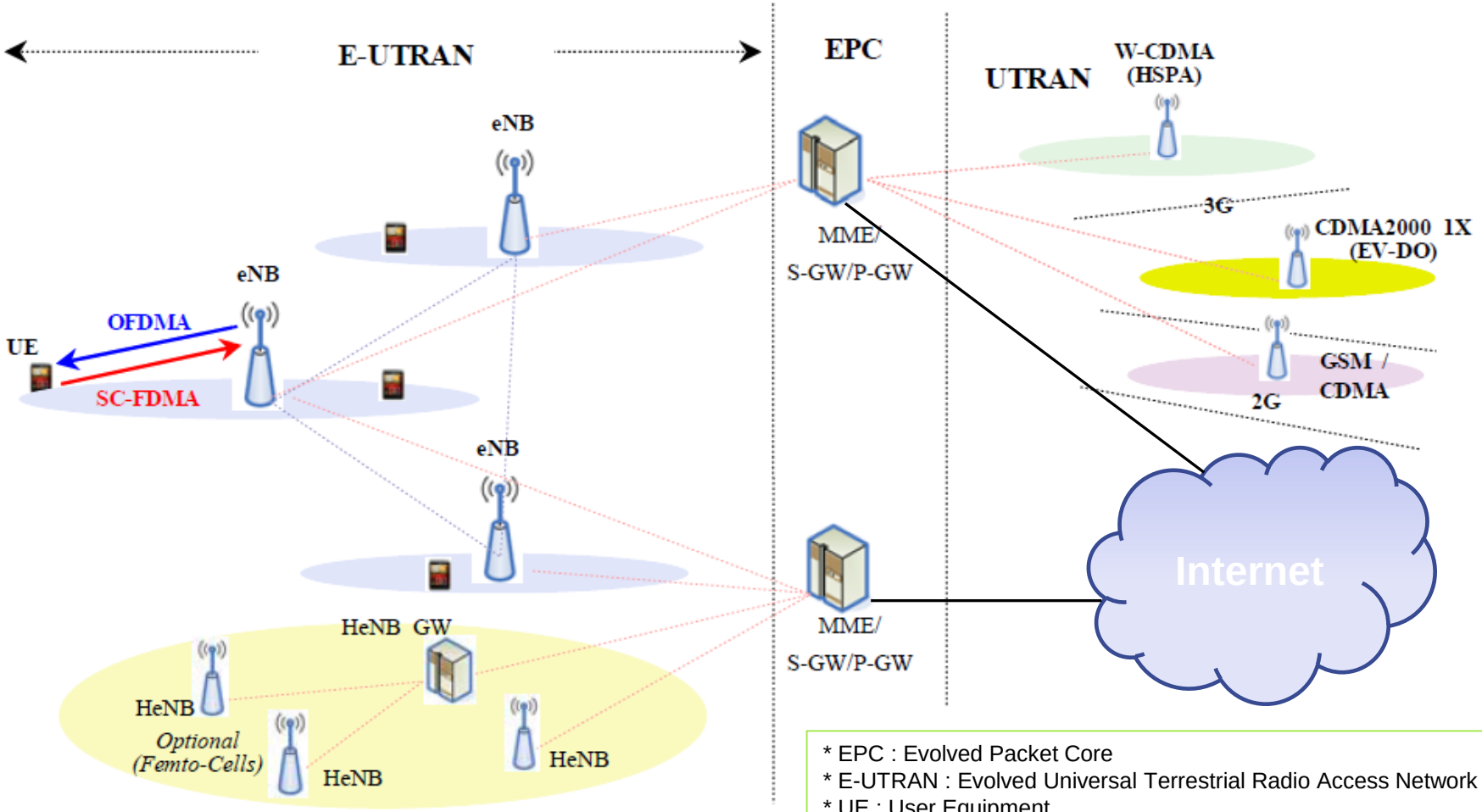
Radio Protocol Architecture : L1/L2/L3, Physical /Transport Channels

Control Information for Scheduling Information

- Control & Data Regions
- Control Information for Scheduling

LTE Network

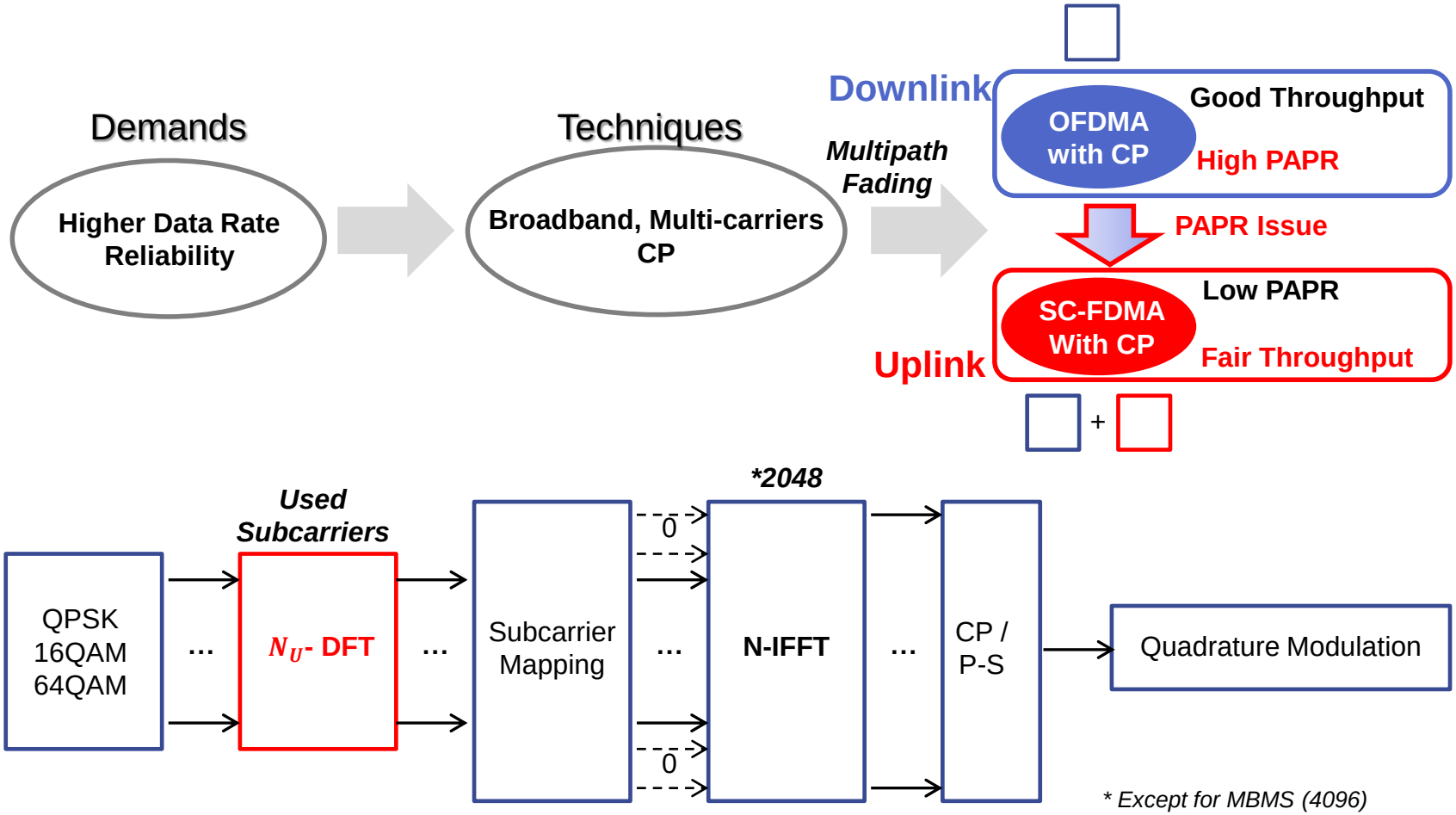
- **LTE Network (E-UTRAN)**



* EPC : Evolved Packet Core
* E-UTRAN : Evolved Universal Terrestrial Radio Access Network
* UE : User Equipment
* eNB : evolved Node B

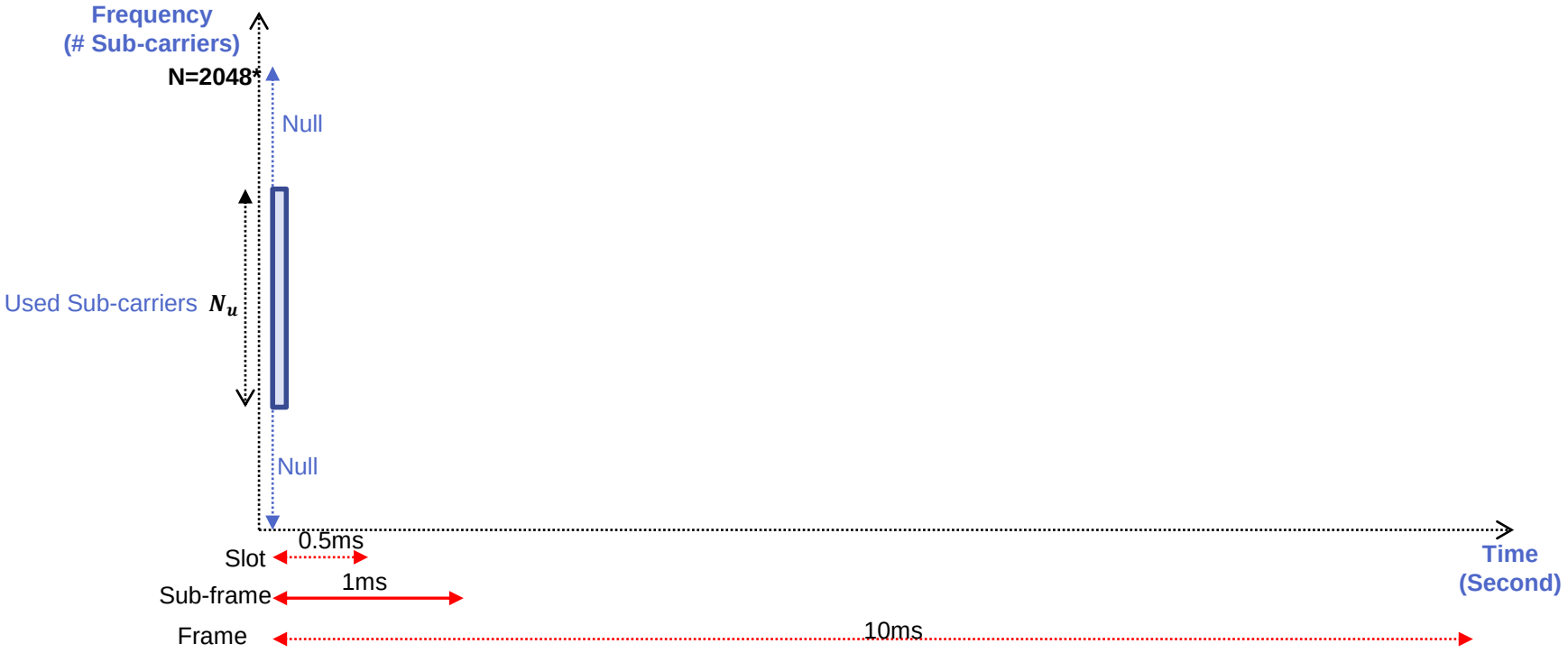
LTE Signals

- **OFDMA & SC-FDMA(DFTS-OFDMA)**



Physical Resources

- **Time & Frequency Resources**

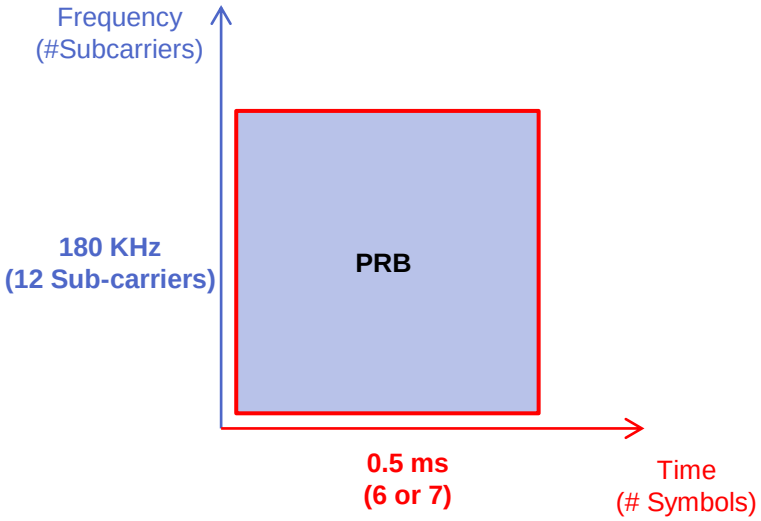


Parameters (Except for MBMS : 4096/7.5 KHz, 2*N_u)

System BW [MHz]	1.4	3	5	10	15	20
N / Freq. Spacing	2048 / 15 KHz					
# Used Subcarriers N_u	72	180	300	600	900	1200

Resource Unit

- **Physical Resource Block (PRB)**
  - ✓ **The Smallest User Assignment Resource Unit**



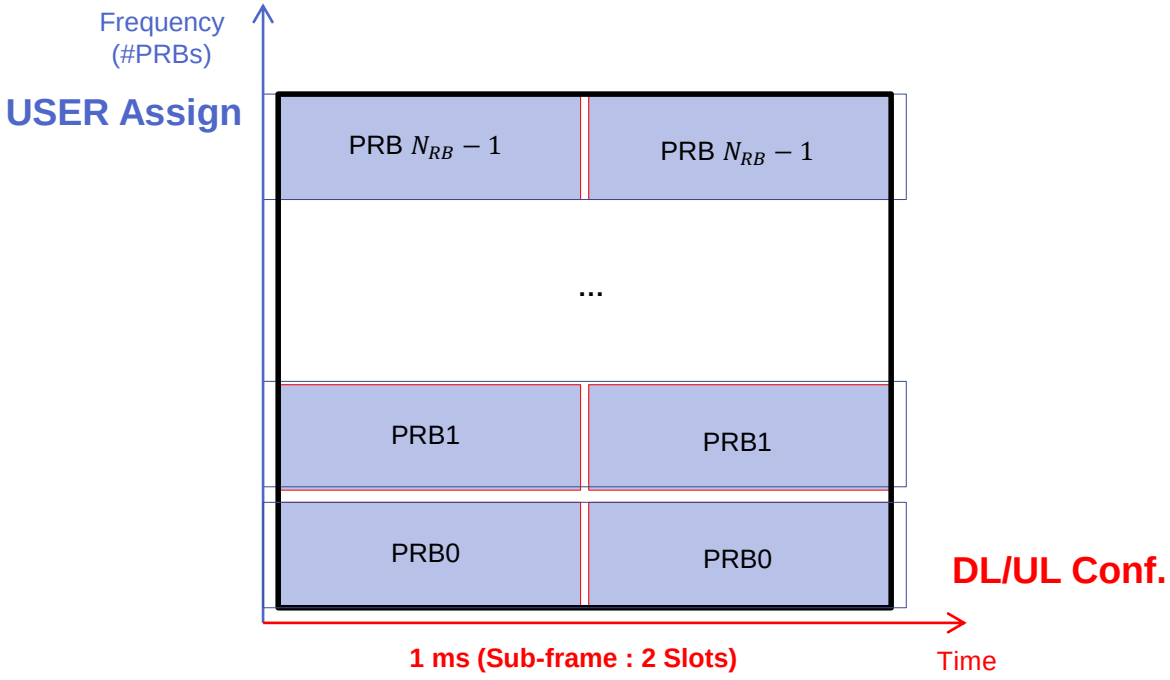
Parameters (Except for MBMS)

CP Type	# Symbols / Slot
Normal CP	7
Extended CP	6

Scheduling Unit

- **Sub-frame (2 Slots)**

  ✓ **Smallest Scheduling Time Interval : TTI (1ms)**

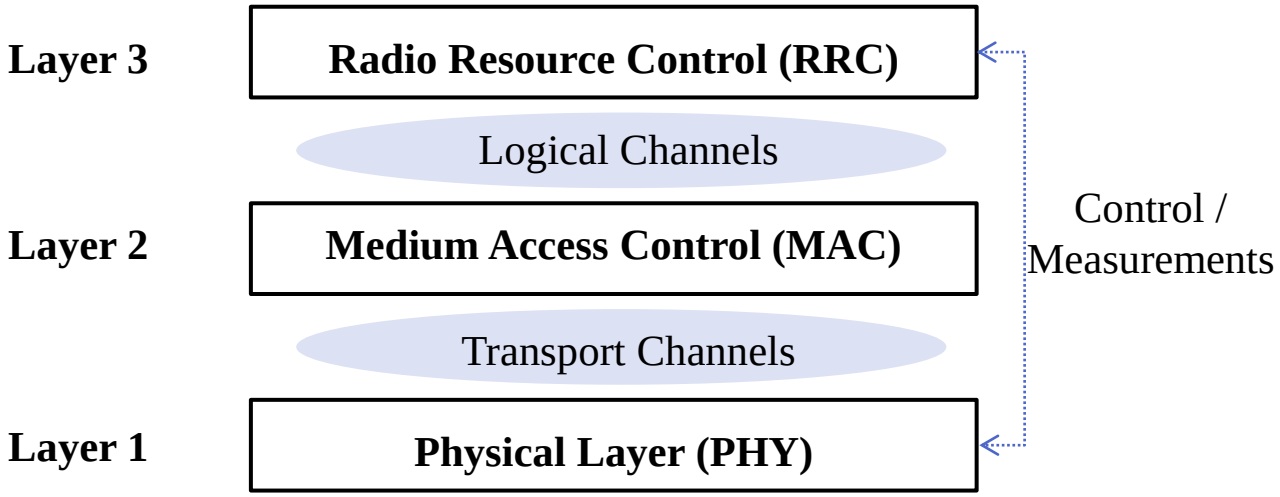


Parameters (Except for MBMS)

System BW [MHz]	1.4	3	5	10	15	20
# PRBs N_{RB} (# Used Subcarriers N_u)	**6** (72)	**15** (180)	**25** (300)	**50** (600)	**75** (900)	**100** (1200)

Radio Protocol Architecture

- **Protocol Architecture around PHY**

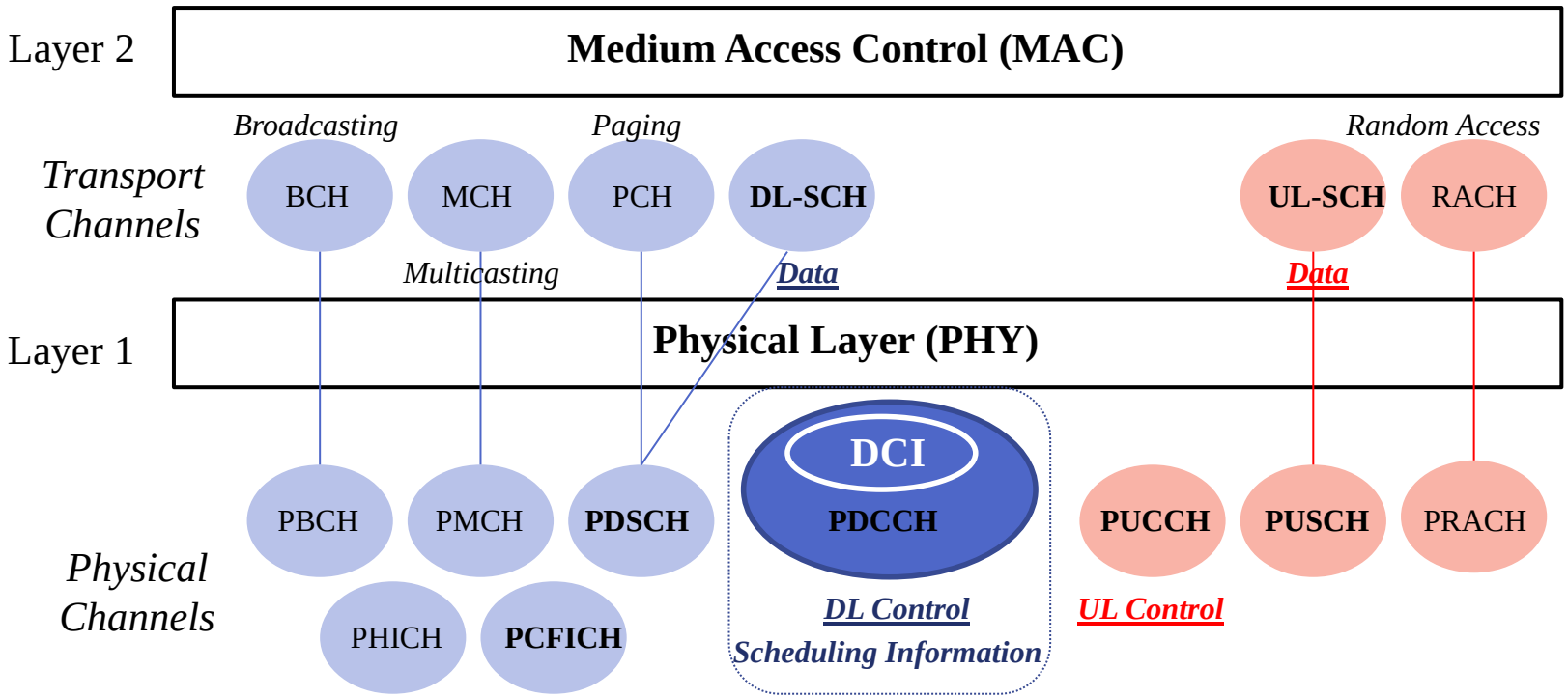


Logical Channels : Type of information

Transport Channels : How the information is transferred

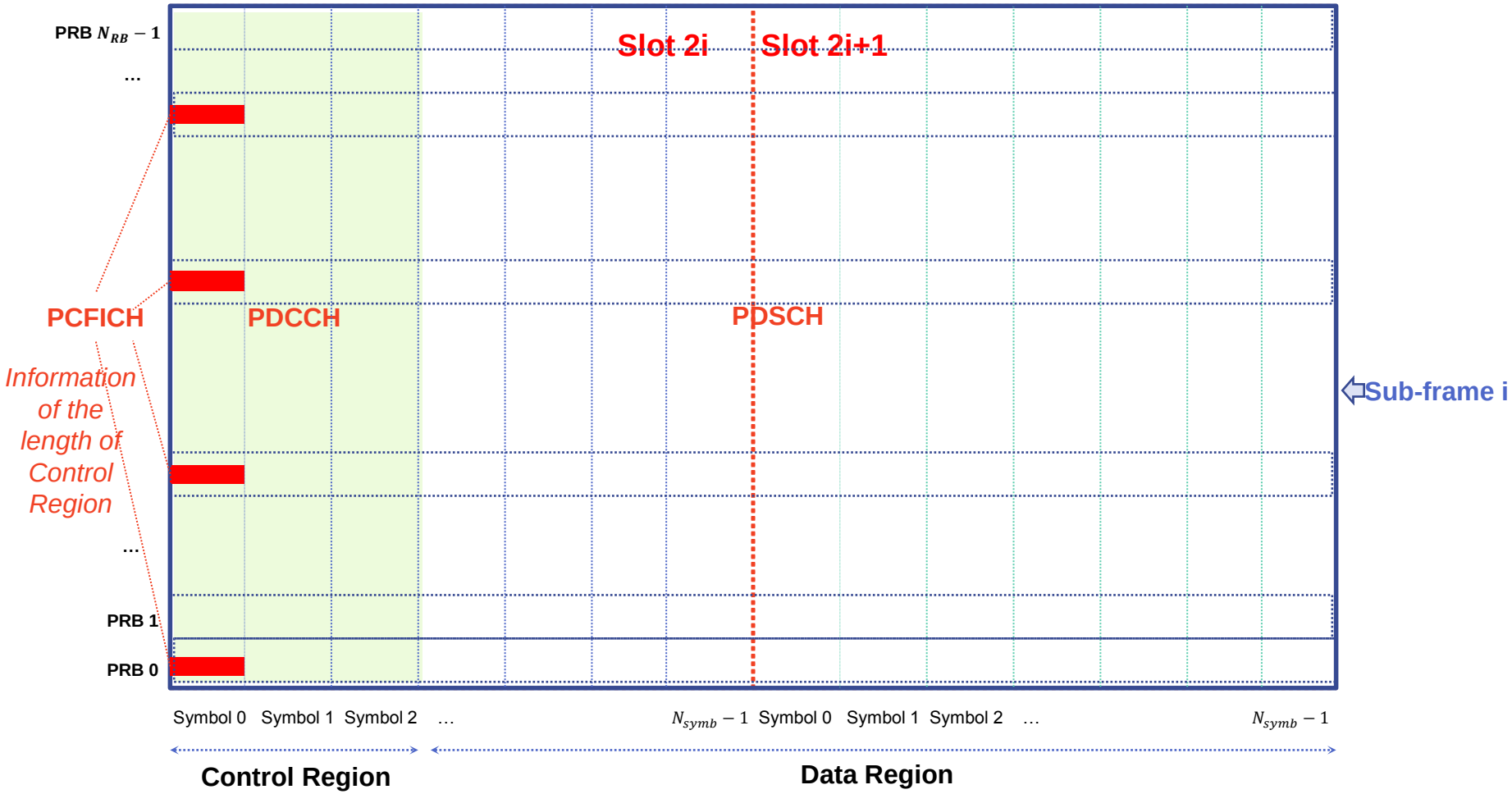
Physical/Transport Channels

- **Transport Channels – Physical Channel**



Control Information for Scheduling

- **Scheduling Information : PDCCH**



(Reference : p. 57 3GPP TS 36.211 V8.9.0 (2009-12))

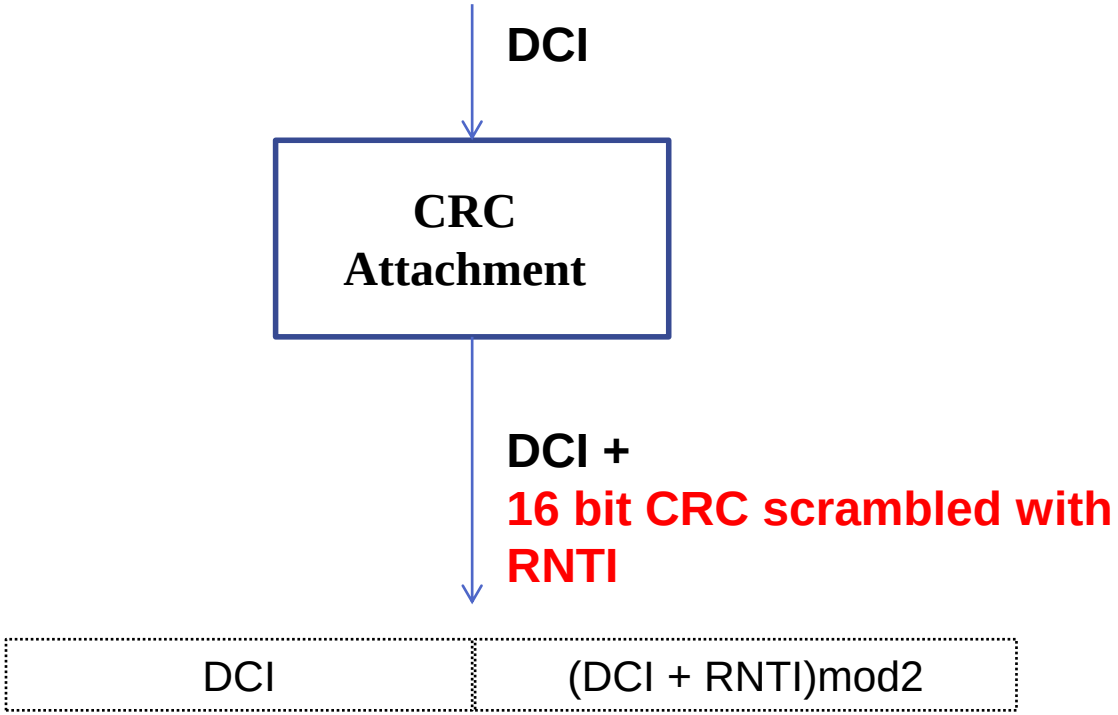
Scheduling Information : DCI in PDCCH

- **DCI Formats**

DCI Formats		Purpose
UL Scheduling	0	**Scheduling + TPC for PUSCH**
DL Scheduling	1	**Scheduling** for **PDSCH**, TPC for PUCCH
	1A	**Compact Scheduling** for **PDSCH**, TPC for PUCCH
	1B	**MIMO Compact Scheduling** for **PDSCH**, TPC for PUCCH
	1C	**Very Compact Scheduling** for **PDSCH**
	1D	**Compact** Scheduling for **PDSCH** with Power Offset, TPC for PUCCH
	2	**Closed Loop MIMO Compact Scheduling** for **PDSCH**, TPC for PUCCH
	2A	**Open Loop MIMO Compact Scheduling** for **PDSCH**, TPC for PUCCH
UL Power Control	**3**	TPC for PUCCH, PUSCH 2bit Power Adjustment
	3A	TPC for **PUCCH, PUSCH** 1bit Power Adjustment

User Identification – C-RNTI

- **User Identification**
  - ✓ **With C-RNTI (Cell specific Radio Network Temporary Identifier)**



(Reference : p. 56 3GPP TS 36.212 V8.8.0 (2009-12))

Scheduling in LTE

Basic Scheduling Operations

Resource Assignment

CQI Reporting for Schedulers

Schedulers in LTE

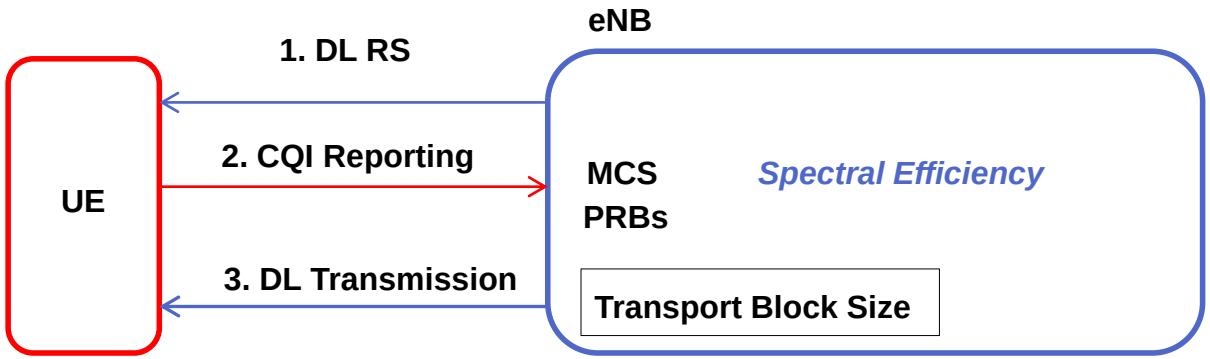
Example : DL Scheduling

Basic Scheduling Operation

- **Purpose**
  - ✓ Efficient **SCH(Data)** Resources Assignments
- **Consideration**
  - ✓ Traffic Volume, QoS (Buffer Status, Priority…)
  - ✓ ***Channel Condition***
- **Scheduling Interval**
  - ✓ Dynamic Scheduling by MAC : One TTI (1ms : One Sub-frame)
  - ✓ Semi-Persistent for VoIP : Multiple TTIs by RRC
- **Resource Assignment** : **PRBs** & **Associated MCS**

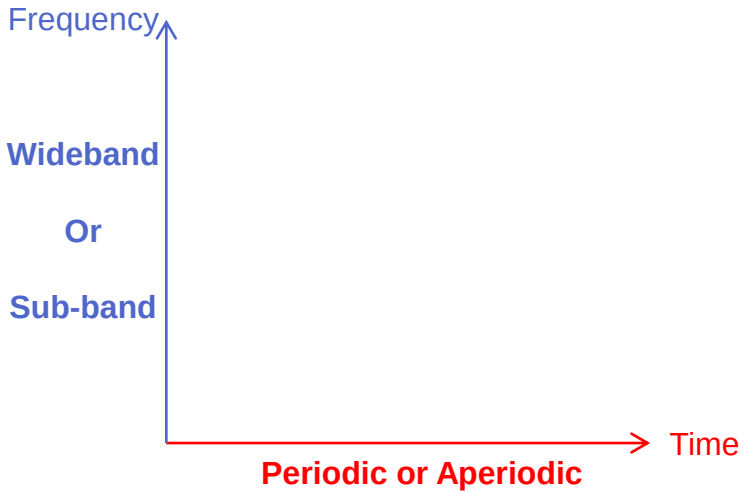
Resource Assignment

- **Per UE # PRBs Assignment**
  - ✓ **Channel Dependent Resource Allocation**
    - User Assignment based on Channel Quality
- **CQI / MCS / TBS**



CQI Reporting for Scheduling

- **Reporting modes**



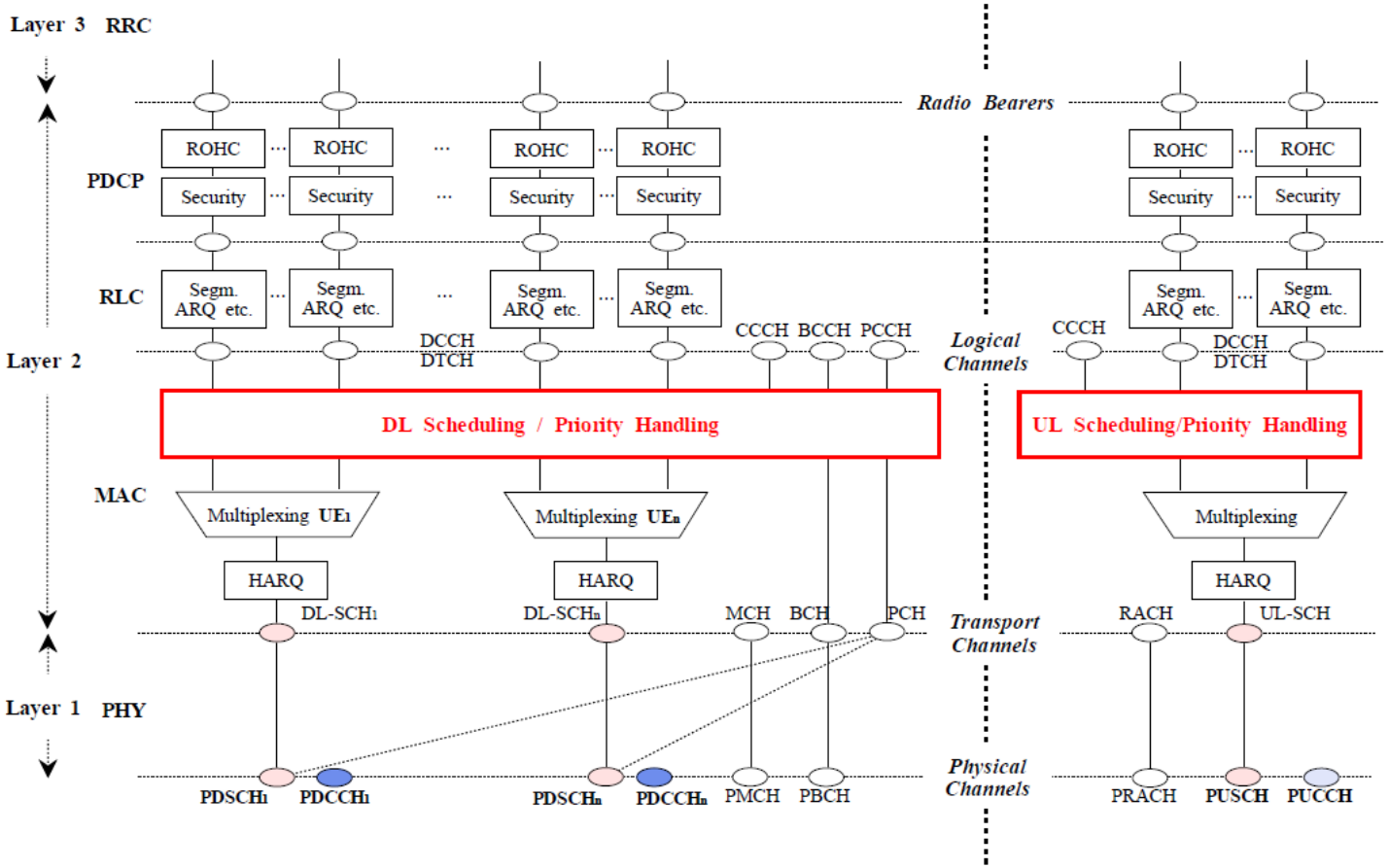
✓ **In time** : Periodic (PUCCH/PUSCH) & Aperiodic (PUSCH)

✓ **In Frequency**

- Wide-band CQI : 4 bit
- Differential Sub-band CQI : 2 bit (Sub-band CQI – Wideband CQI)
- Differential Spatial CQI : 3bit for MIMO

Schedulers in LTE

- **MAC Schedulers**

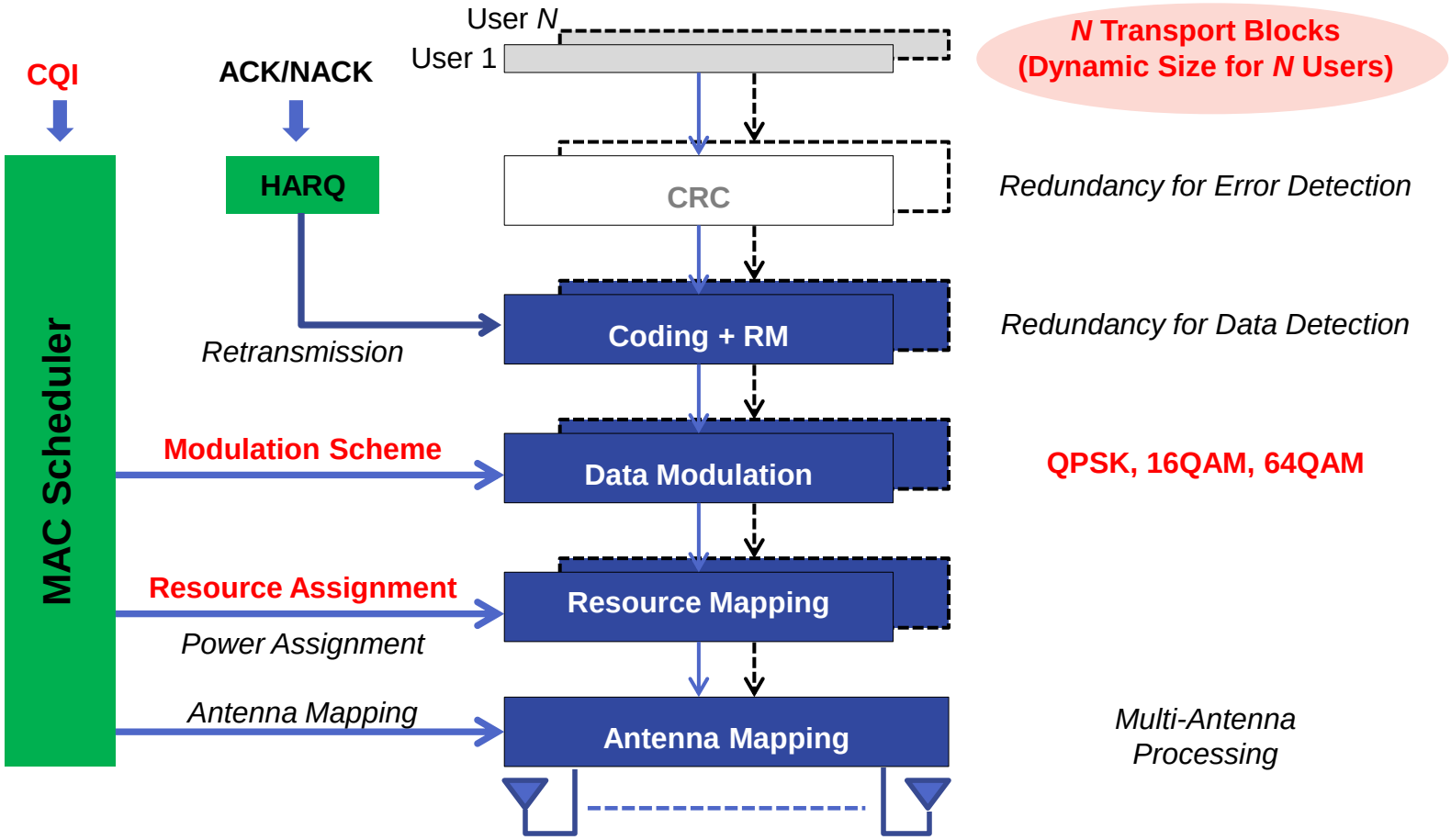


PDCP : Packet Data Convergence Protocol
ARQ : Automatic Repeat Request

ROHC : Robust Header Compression
HARQ : Hybrid ARQ

DL Scheduling

- **DL MAC Scheduler**



Conclusion & References

Summary

- **LTE Overview**
  - ✓ LTE Network, Physical Resources
  - ✓ Signaling Scheduling Information in PHY
- **Scheduling in LTE**
  - ✓ PRB & MCS Assignment
  - ✓ CQI Reporting Process for Schedulers
  - ✓ MAC Schedulers in LTE
  - ✓ DL Scheduling Process

References

- **LTE Web**

  www.3gpp.org

- **LTE L1(PHY) Standards**

  TS 36201 : LTE PHY Overview

  TS 36211 : LTE PHY Modulation

  TS 36212 : LTE Multiplexing and Channel Coding

  TS 36213 : LTE PHY related Procedures

  TS 36214 : LTE Measurements

- **LTE L2/L3(MAC/RRC) Standards**

  TS 36300 : LTE L2/L3 Overview

  TS 36321 : LTE MAC

  TS 36331 : LTE RRC