

# First OAI Foundation U.S. Hands-on Workshop

17-19 November 2025  
University of Texas at Austin

## 5G Operational Walkthrough with OAIBOX™ and OpenAirInterface

19/Nov/2025 | 14:00-17:00  
Avaya Auditorium



**Hugo Marques**  
Assistant Professor  
[hugo@ipcb.pt](mailto:hugo@ipcb.pt)



**Luis Pereira**  
Chief of 5G/6G R&D  
[lpereira@allbesmart.pt](mailto:lpereira@allbesmart.pt)



**Paulo Marques**  
Founder  
[pmarques@allbesmart.pt](mailto:pmarques@allbesmart.pt)

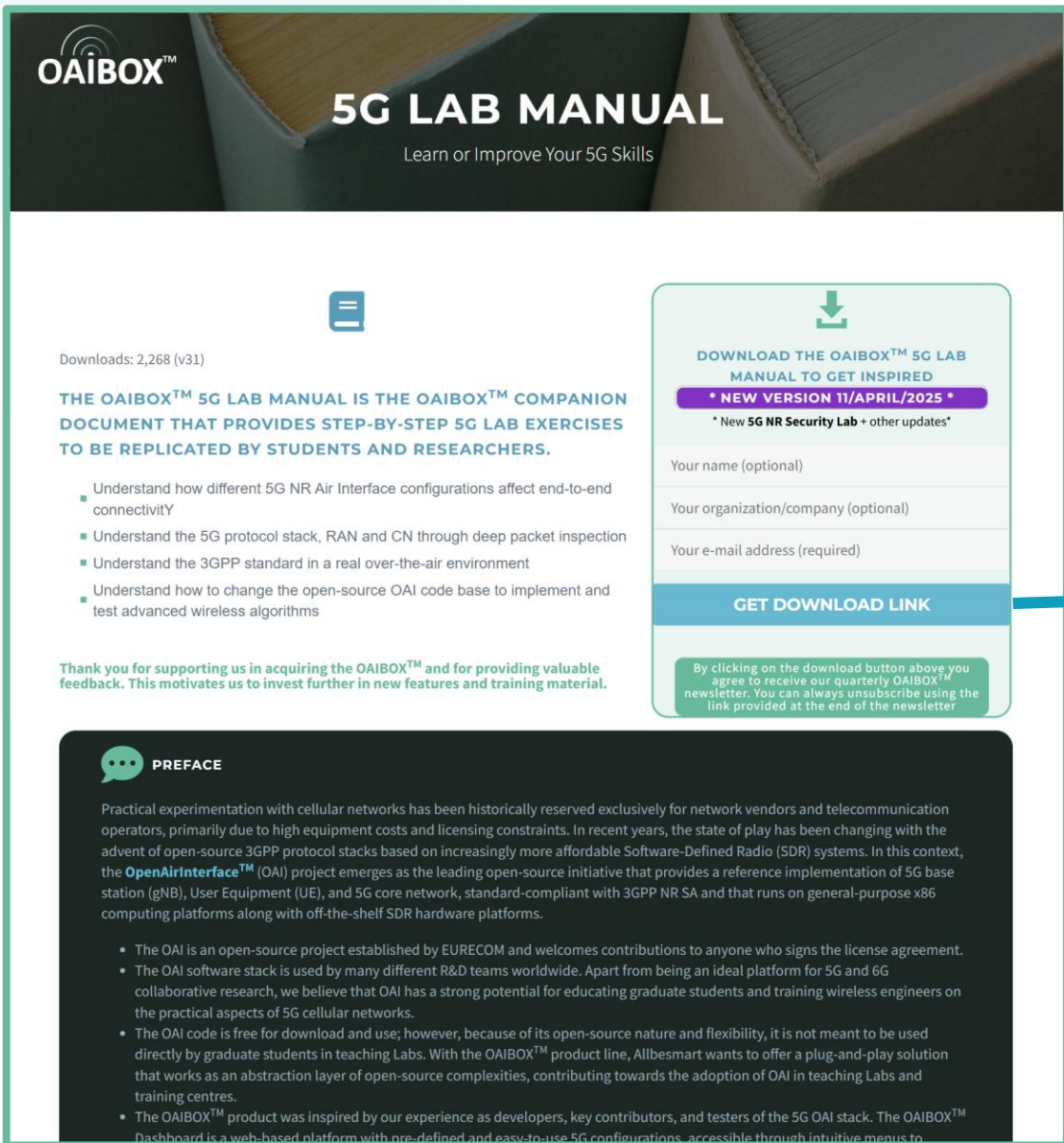
# OAIBOX™: Let's setup a 5G test network with OAIBOX™

- Today's setup



- OAIBOX™ website: <https://oaiibox.com>
- 5G LAB Manual: <https://oaiibox.com/5g-lab-manual/>

# OAIBOX™: The 5G Lab Manual



**OAIBOX™**  
**5G LAB MANUAL**  
Learn or Improve Your 5G Skills

Downloads: 2,268 (v3.1)

**THE OAIBOX™ 5G LAB MANUAL IS THE OAIBOX™ COMPANION DOCUMENT THAT PROVIDES STEP-BY-STEP 5G LAB EXERCISES TO BE REPLICATED BY STUDENTS AND RESEARCHERS.**

- Understand how different 5G NR Air Interface configurations affect end-to-end connectivity
- Understand the 5G protocol stack, RAN and CN through deep packet inspection
- Understand the 3GPP standard in a real over-the-air environment
- Understand how to change the open-source OAI code base to implement and test advanced wireless algorithms

**Thank you for supporting us in acquiring the OAIBOX™ and for providing valuable feedback. This motivates us to invest further in new features and training material.**

**DOWNLOAD THE OAIBOX™ 5G LAB MANUAL TO GET INSPIRED**  
**\* NEW VERSION 11/APRIL/2025 \***  
**\* New 5G NR Security Lab + other updates\***

Your name (optional)  
Your organization/company (optional)  
Your e-mail address (required)

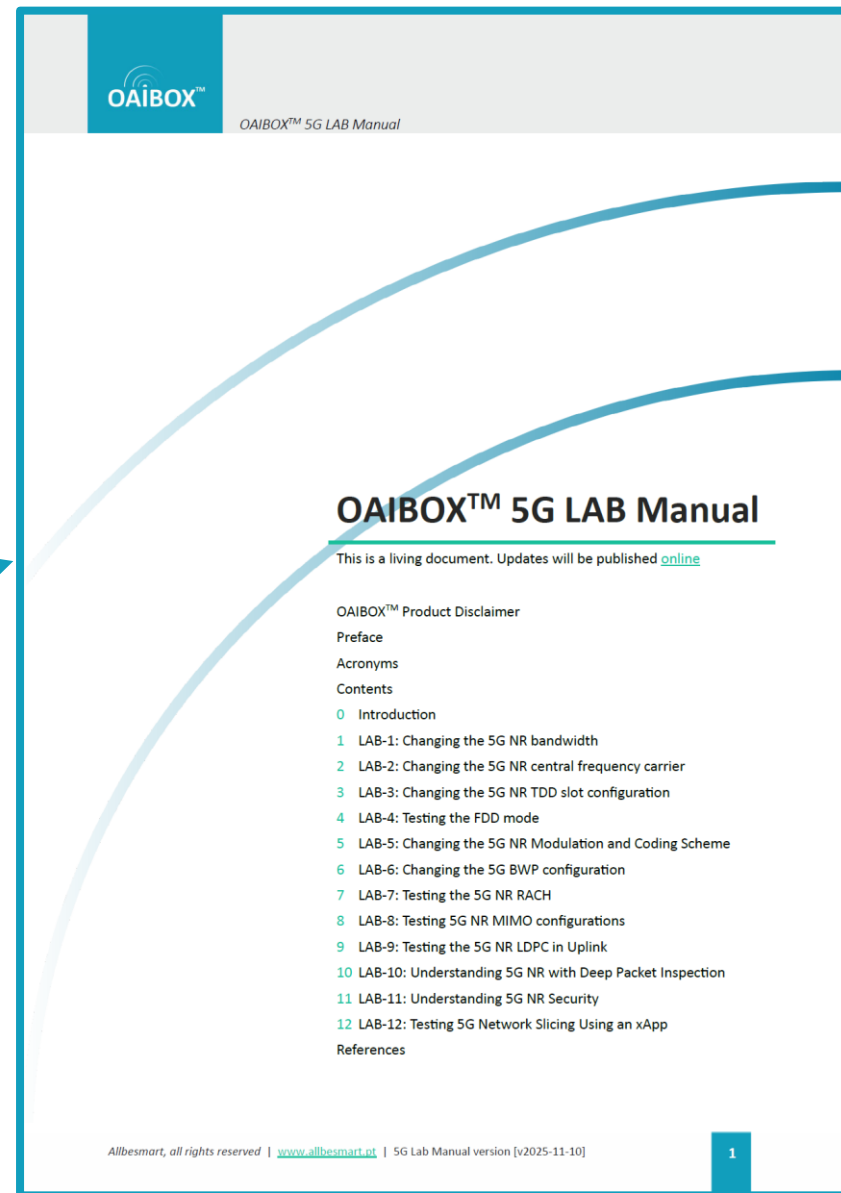
**GET DOWNLOAD LINK**

By clicking on the download button above you agree to receive our quarterly OAIBOX™ newsletter. You can always unsubscribe using the link provided at the end of the newsletter

**PREFACE**

Practical experimentation with cellular networks has been historically reserved exclusively for network vendors and telecommunication operators, primarily due to high equipment costs and licensing constraints. In recent years, the state of play has been changing with the advent of open-source 3GPP protocol stacks based on increasingly more affordable Software-Defined Radio (SDR) systems. In this context, the **OpenAirInterface™** (OAI) project emerges as the leading open-source initiative that provides a reference implementation of 5G base station (gNB), User Equipment (UE), and 5G core network, standard-compliant with 3GPP NR SA and that runs on general-purpose x86 computing platforms along with off-the-shelf SDR hardware platforms.

- The OAI is an open-source project established by EURECOM and welcomes contributions to anyone who signs the license agreement.
- The OAI software stack is used by many different R&D teams worldwide. Apart from being an ideal platform for 5G and 6G collaborative research, we believe that OAI has a strong potential for educating graduate students and training wireless engineers on the practical aspects of 5G cellular networks.
- The OAI code is free for download and use; however, because of its open-source nature and flexibility, it is not meant to be used directly by graduate students in teaching Labs. With the OAIBOX™ product line, Allbesmart wants to offer a plug-and-play solution that works as an abstraction layer of open-source complexities, contributing towards the adoption of OAI in teaching Labs and training centres.
- The OAIBOX™ product was inspired by our experience as developers, key contributors, and testers of the 5G OAI stack. The OAIBOX™ Dashboard is a web-based platform with pre-defined and easy-to-use 5G configurations, accessible through intuitive menus to



**OAIBOX™**  
OAIBOX™ 5G LAB Manual

## OAIBOX™ 5G LAB Manual

This is a living document. Updates will be published [online](#)

OAIBOX™ Product Disclaimer  
Preface  
Acronyms  
Contents

- Introduction
- LAB-1: Changing the 5G NR bandwidth
- LAB-2: Changing the 5G NR central frequency carrier
- LAB-3: Changing the 5G NR TDD slot configuration
- LAB-4: Testing the FDD mode
- LAB-5: Changing the 5G NR Modulation and Coding Scheme
- LAB-6: Changing the 5G BWP configuration
- LAB-7: Testing the 5G NR RACH
- LAB-8: Testing 5G NR MIMO configurations
- LAB-9: Testing the 5G NR LDPC in Uplink
- LAB-10: Understanding 5G NR with Deep Packet Inspection
- LAB-11: Understanding 5G NR Security
- LAB-12: Testing 5G Network Slicing Using an xApp

References

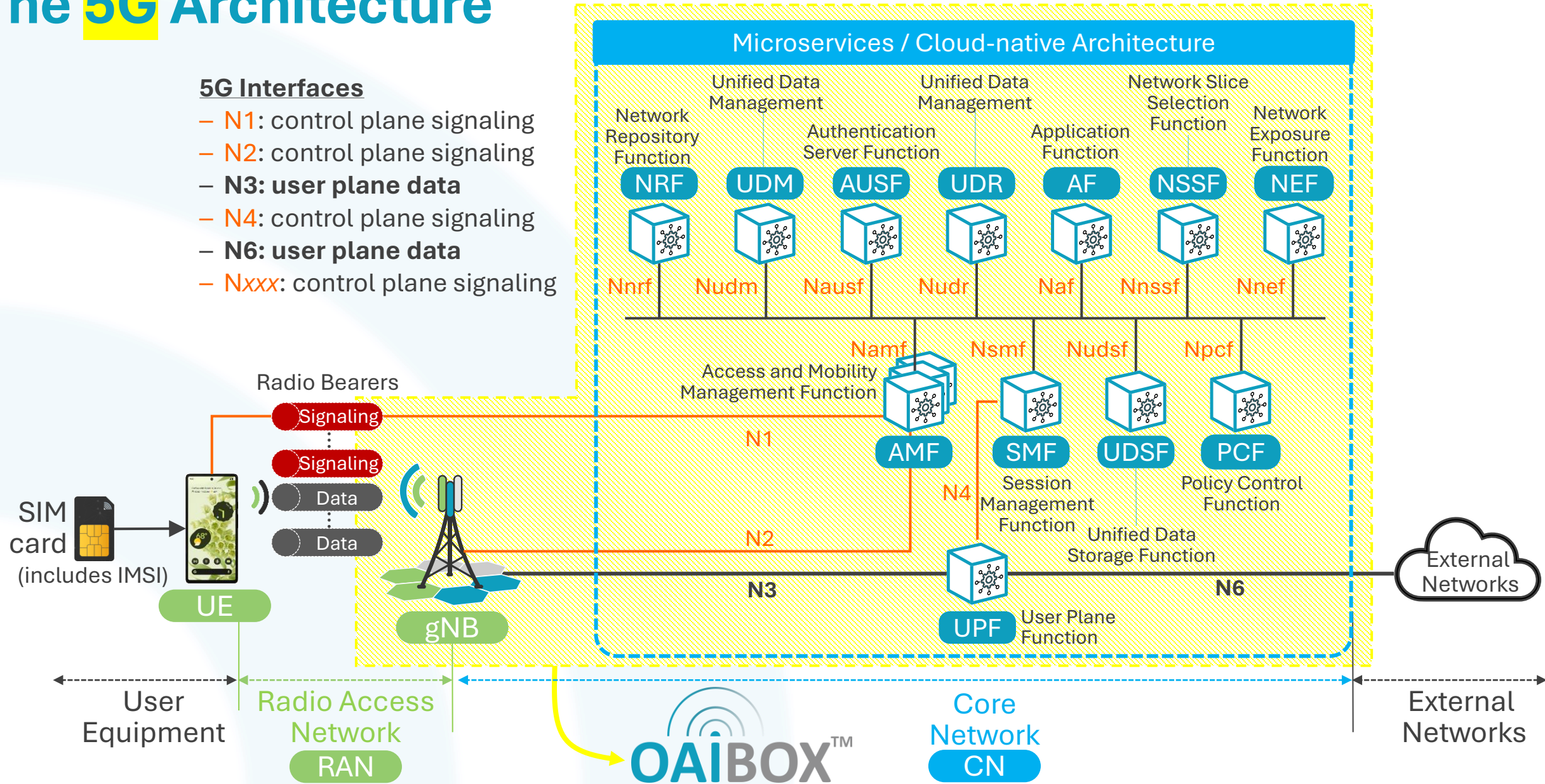
Allbesmart, all rights reserved | [www.allbesmart.at](http://www.allbesmart.at) | 5G Lab Manual version [v2025-11-10]

1

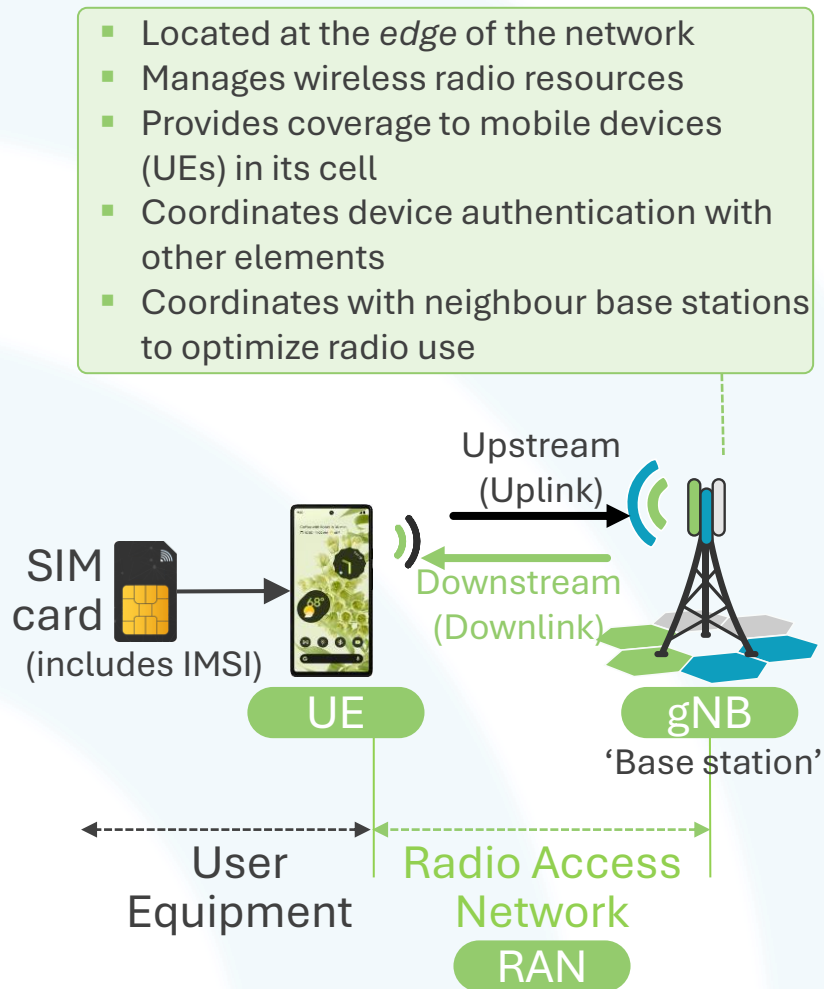
# The 5G Architecture

## 5G Interfaces

- N1: control plane signaling
- N2: control plane signaling
- N3: user plane data
- N4: control plane signaling
- N6: user plane data
- Nxxx: control plane signaling



# The 4G Radio Access Network (RAN)

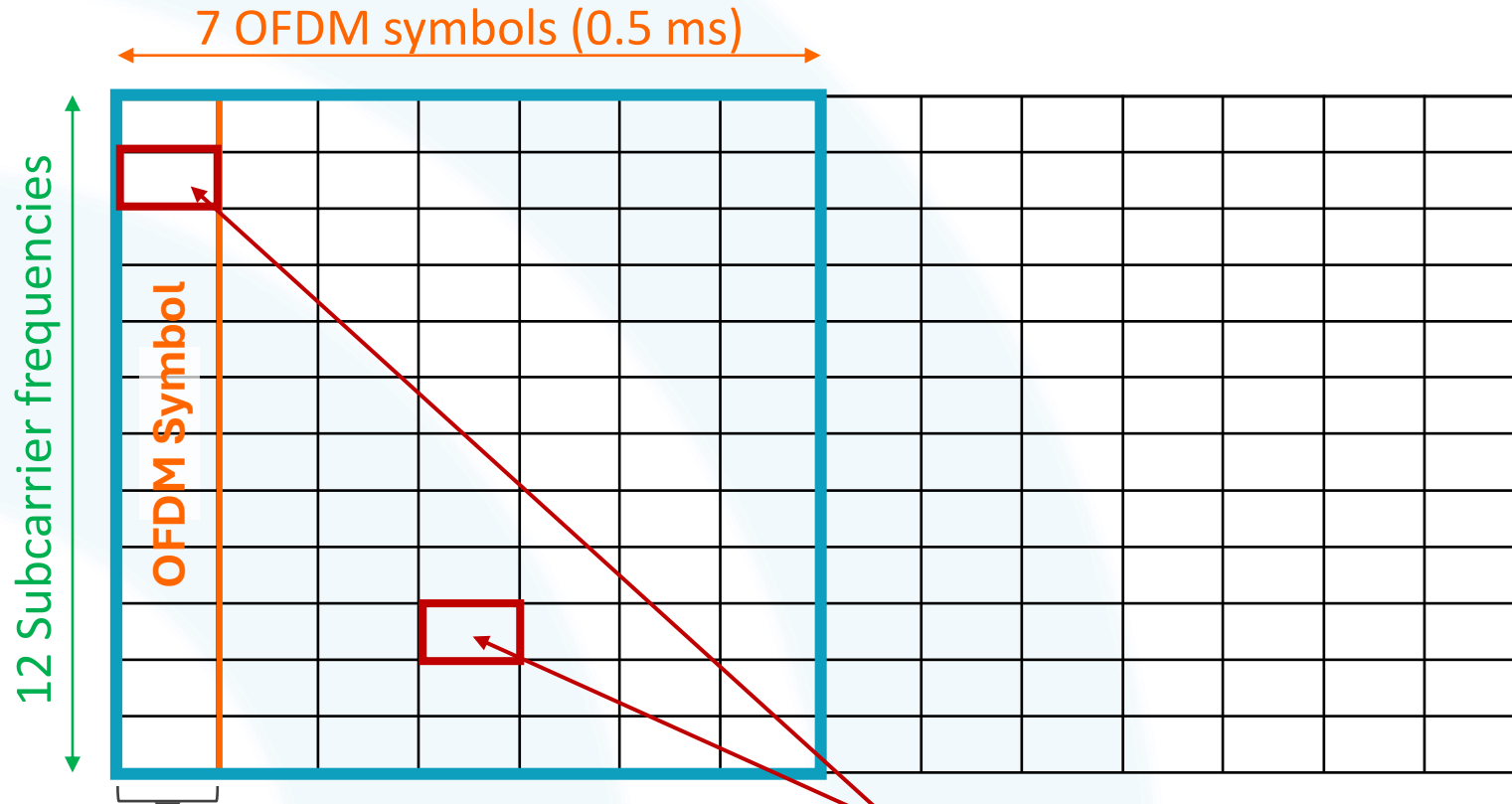


- Connects UEs to the ‘base station’
  - In 5G the ‘base station’ is called **gNode-B (gNB)**
  - multiple devices connected to each gNB
- Many different possible frequencies bands,
  - multiple channels in each band
  - popular 4G bands: 600, 700, 850, 1500, 1700, 1900, 2100, 2600, 3500 MHz
  - popular **TDD 5G** bands : 2496–2690MHz (n41), 3300–4200MHz (n77), 3300–3800MHz (n78)
  - popular **FDD 5G** bands: 703–803MHz (n28), 1800MHz (n3), 2100MHz (n1)
  - separate upstream and downstream channels
- Sharing radio channel among users:
  - **OFDM**: Orthogonal Frequency Division Multiplexing
    - combination of FDM, TDM



# The 4G RAN: OFDM Time Division & Physical Resource Blocks

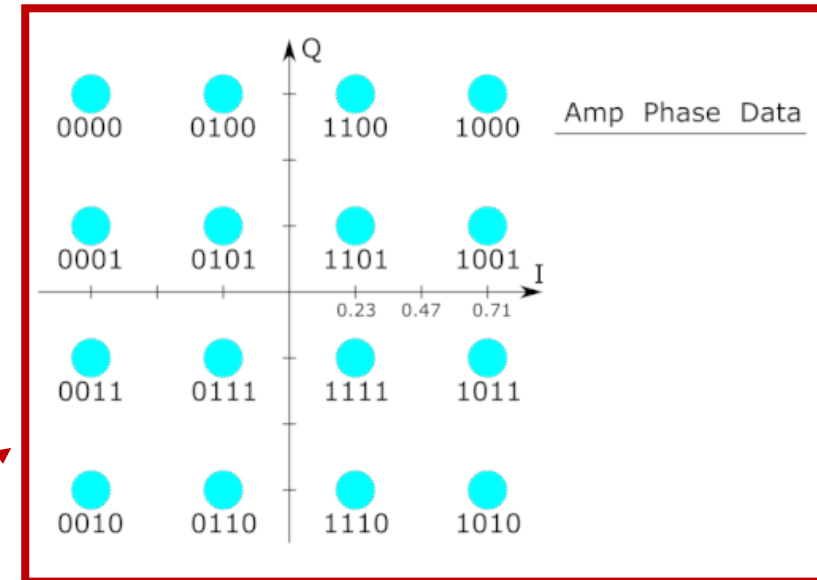
- 4G Physical Resource Block (**PRB**): block of  $7 \times 12 = 84$  Resource Elements
  - unit of transmission scheduling



(In 4G, the subcarrier spacing is fixed)

16-QAM

[wikipedia.org | author: GB PW]

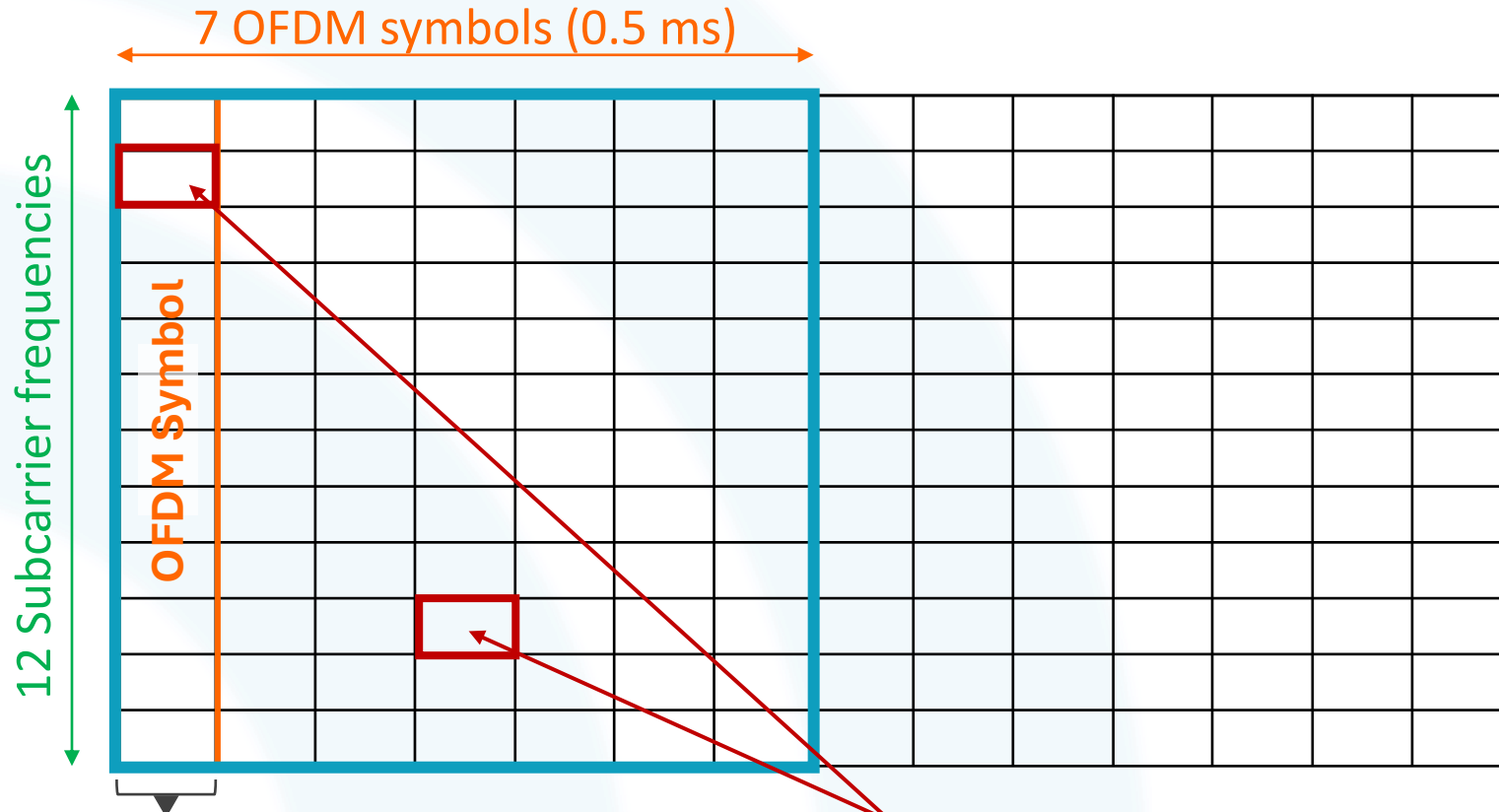


Time to transmit one **OFDM symbol** (on subcarrier frequency)

**Resource Element (RE)** (1 QAM modulation symbol)

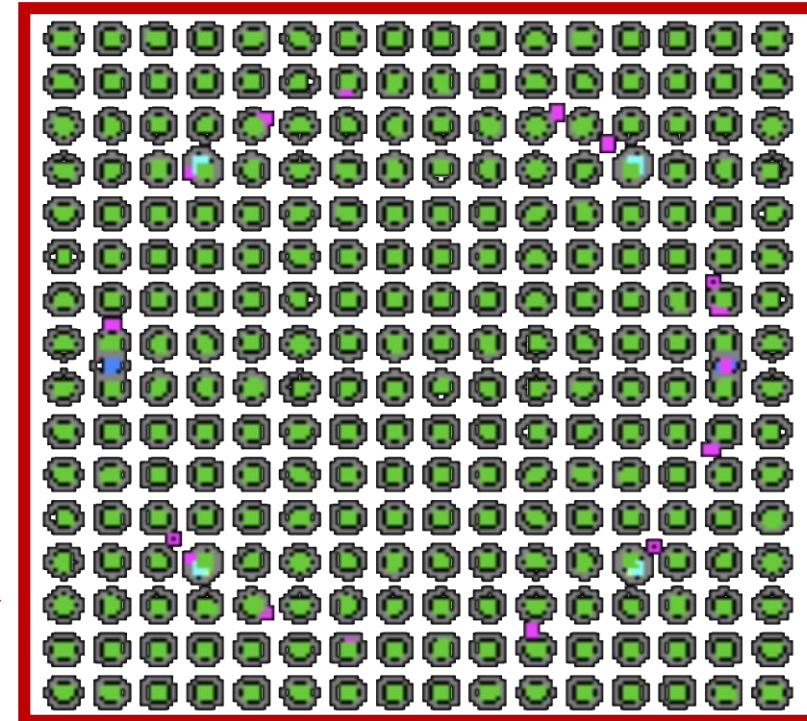
# The 4G RAN: OFDM Time Division & Physical Resource Blocks

- 4G Physical Resource Block (**PRB**): block of  $7 \times 12 = 84$  Resource Elements
  - unit of transmission scheduling



256-QAM

[adapted from Keysight  
Sowmya Rao, Santosh Pal

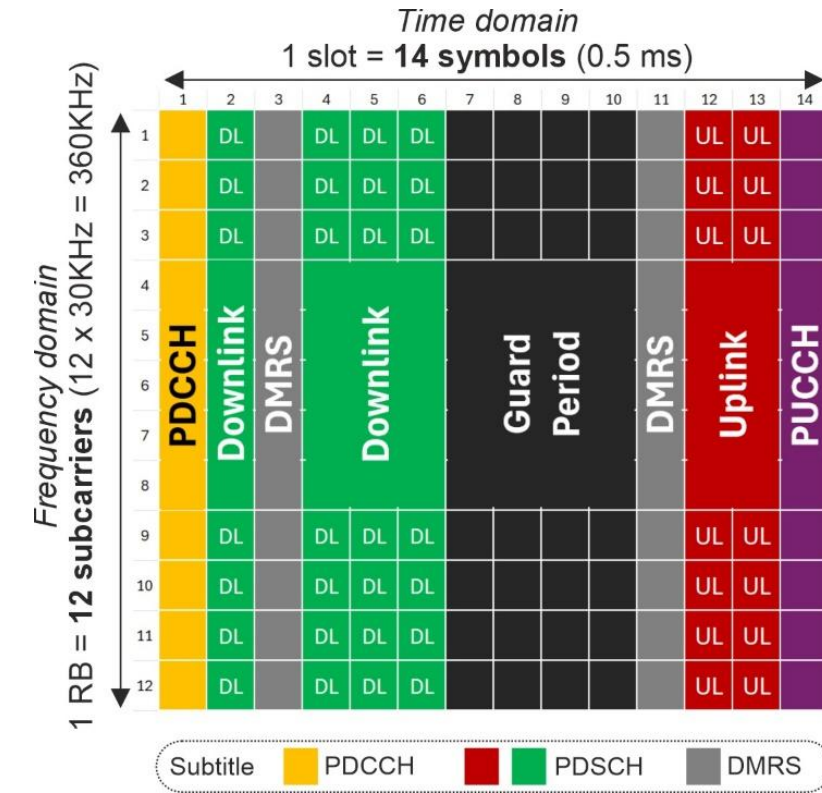
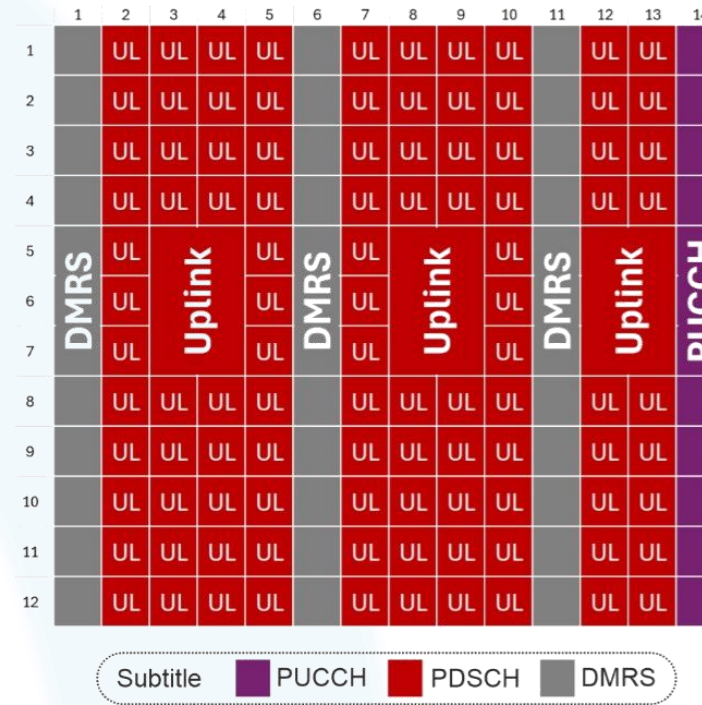
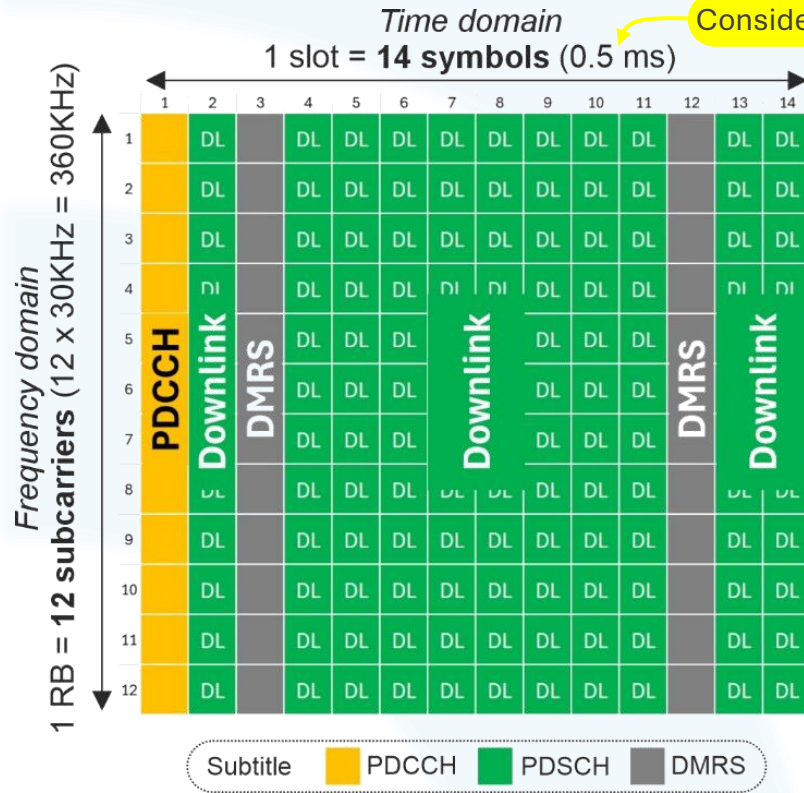


Time to transmit one **OFDM symbol**  
(on subcarrier frequency)

**Resource Element (RE)**  
(1 QAM modulation symbol)

# The 5G RAN: OFDM Time Division & Physical Resource Blocks

- 5G Physical Resource Block (PRB): block of  $14 \times 12 = 168$  Resource Elements
  - unit of transmission scheduling



**DMRS** - Demodulation Reference Signal  
**PDCCH** - Physical Downlink Control Channel  
**PDSCH** - Physical Downlink Shared Channel  
**PUCCH** - Physical Uplink Control Channel

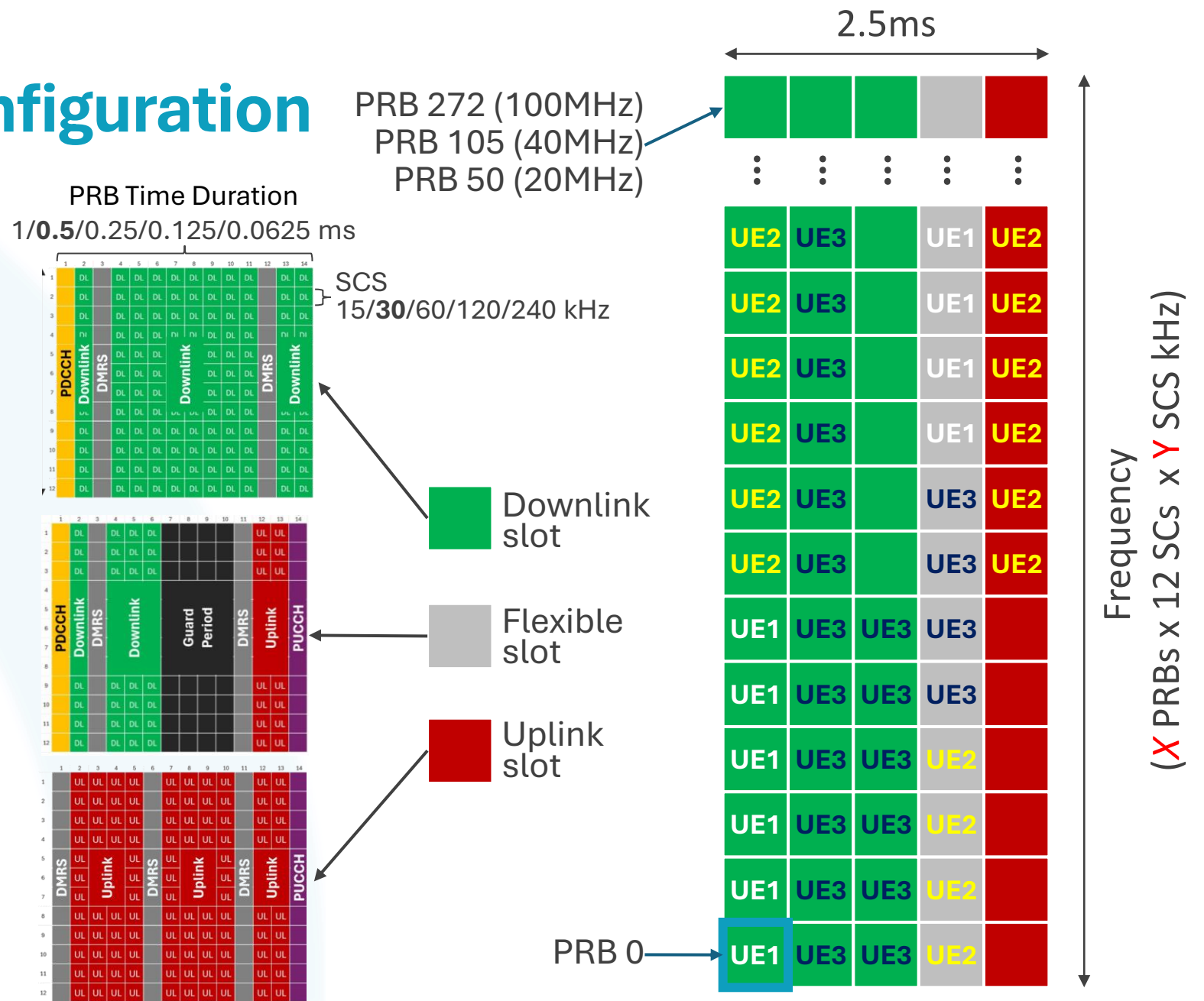
Maximum number of Resource Blocks used for transmission

Bandwidth [MHz]	5	10	15	20	25	30	40	50	60	70	80	90	100
$N_{RB}$	11	24	38	51	65	78	106	133	162	189	217	245	273

Subcarrier spacing for 5G:  
 $\Delta f = 15/30/60$  kHz (FR1)  
 $\Delta f = 60/120/240$  kHz (FR2)

# The 5G RAN: TDD Uplink-Downlink Configuration

- Example of transmission scheduling (3 UEs)
  - **Note:** some REs / Symbols are unavailable for user data because they are reserved for essential physical signals and control channels
- Figure shows the following TDD slot configuration
  - **DDDFU**



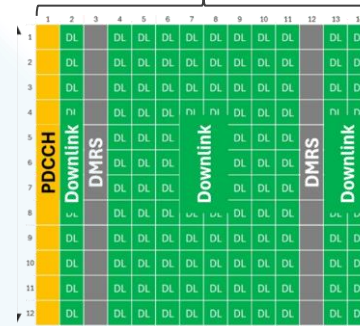
# The 5G RAN: TDD

## Uplink-Downlink Configuration

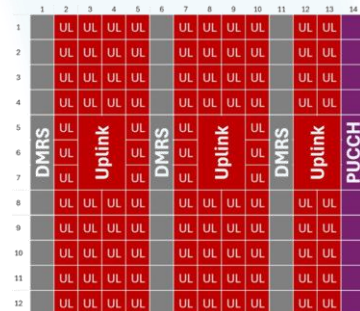
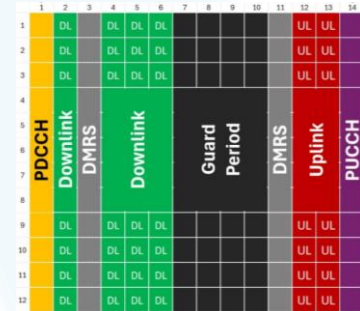
### Downlink calculation for 20MHz:

- Total REs in one **D** PRB:
  - 11 x 12 = 132 REs
- Total REs in one **F** PRB:
  - 4 x 12 = 48 REs
- Number of PRBs for 20MHz
  - 51 PRBs
- Number of **D** and **F** slots per TDD period
  - 3 **D** slots and 1 **F** slot
- Total number of REs per TDD period
  - (132 x 3 + 48 x 1) x 51 = 22,644 REs
- Total number of REs per second
  - 22,644 x 1000/2.5 = 9,057,600 REs
- Number of bits per RE (MCS 27)
  - 8 bit with code rate 0.925
- Total DL throughput in bps
  - 9,057,600 x 8 x 0.925 = 67,026,240.00
  - ~67 Mbps

PRB Time Duration  
1/0.5/0.25/0.125/0.0625 ms

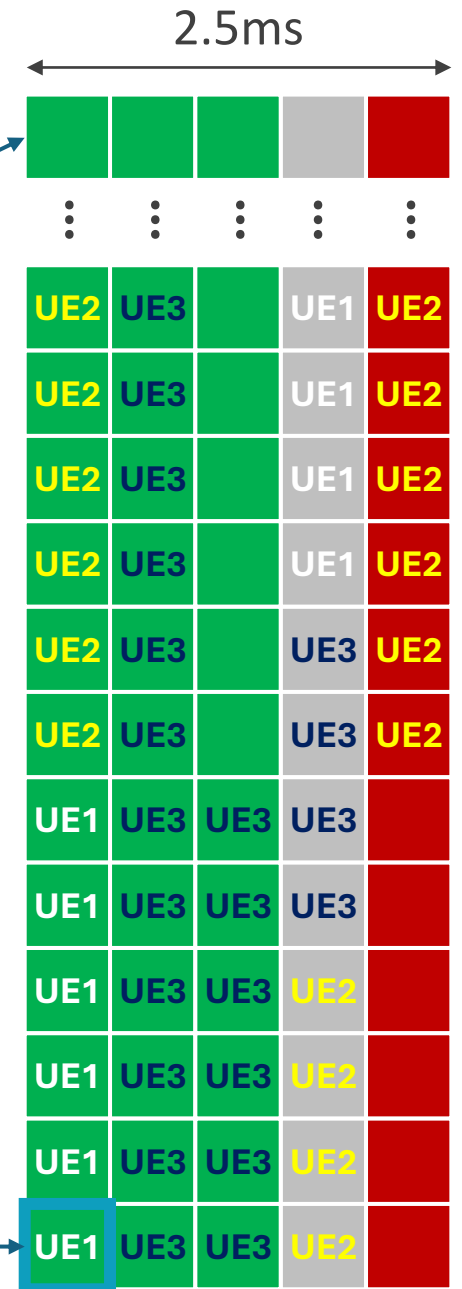


SCS  
15/30/60/120/240 kHz



- Downlink slot
- Flexible slot
- Uplink slot

PRB 272 (100MHz)  
PRB 105 (40MHz)  
PRB 50 (20MHz)



Frequency  
(X PRBs x 12 SCS x Y SCS kHz)

PRB 0

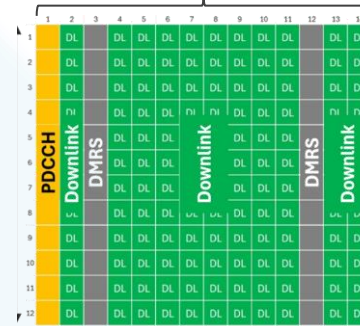
# The 5G RAN: TDD

## Uplink-Downlink Configuration

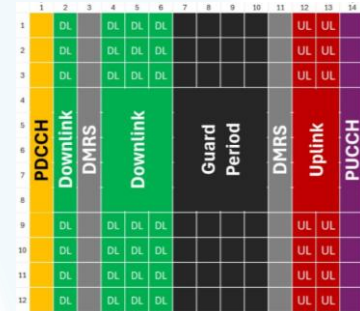
### Downlink calculation for 40MHz:

- Total REs in one **D** PRB:
  - 11 x 12 = 132 REs
- Total REs in one **F** PRB:
  - 4 x 12 = 48 REs
- Number of PRBs for 20MHz
  - 106 PRBs
- Number of **D** and **F** slots per TDD period
  - 3 **D** slots and 1 **F** slot
- Total number of REs per TDD period
  - (132 x 3 + 48 x 1) x 106 = 47,064 REs
- Total number of REs per second
  - 47,064 x 1000/2.5 = 18,825,600 REs
- Number of bits per RE (MCS 27)
  - 8 bit with code rate 0.925
- Total DL throughput in bps
  - 18,825,600 x 8 x 0.925 = 139,309,440
  - 139 Mbps

PRB Time Duration  
1/0.5/0.25/0.125/0.0625 ms

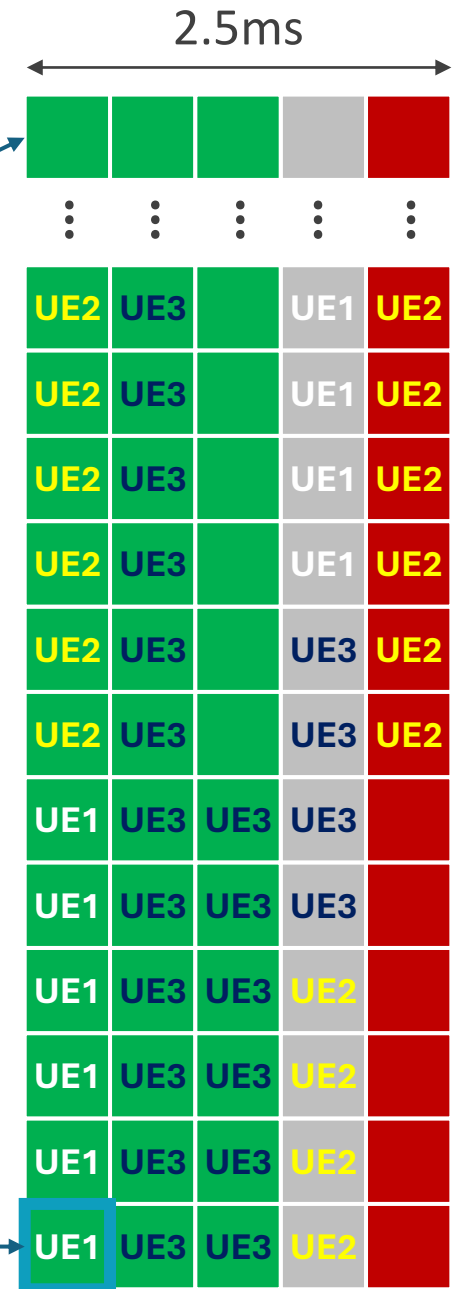


SCS  
15/30/60/120/240 kHz



- Downlink slot
- Flexible slot
- Uplink slot

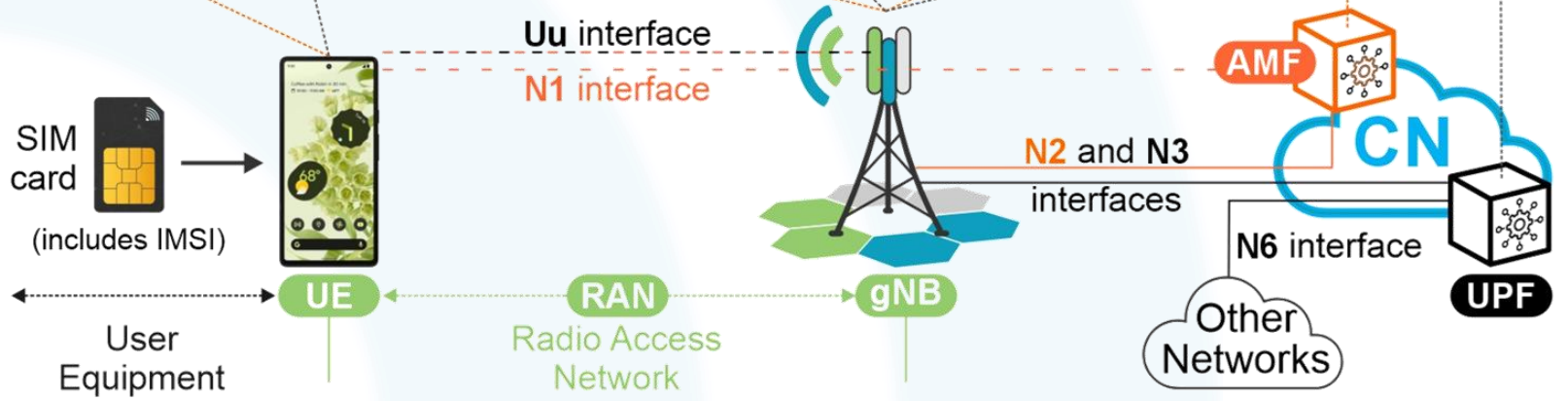
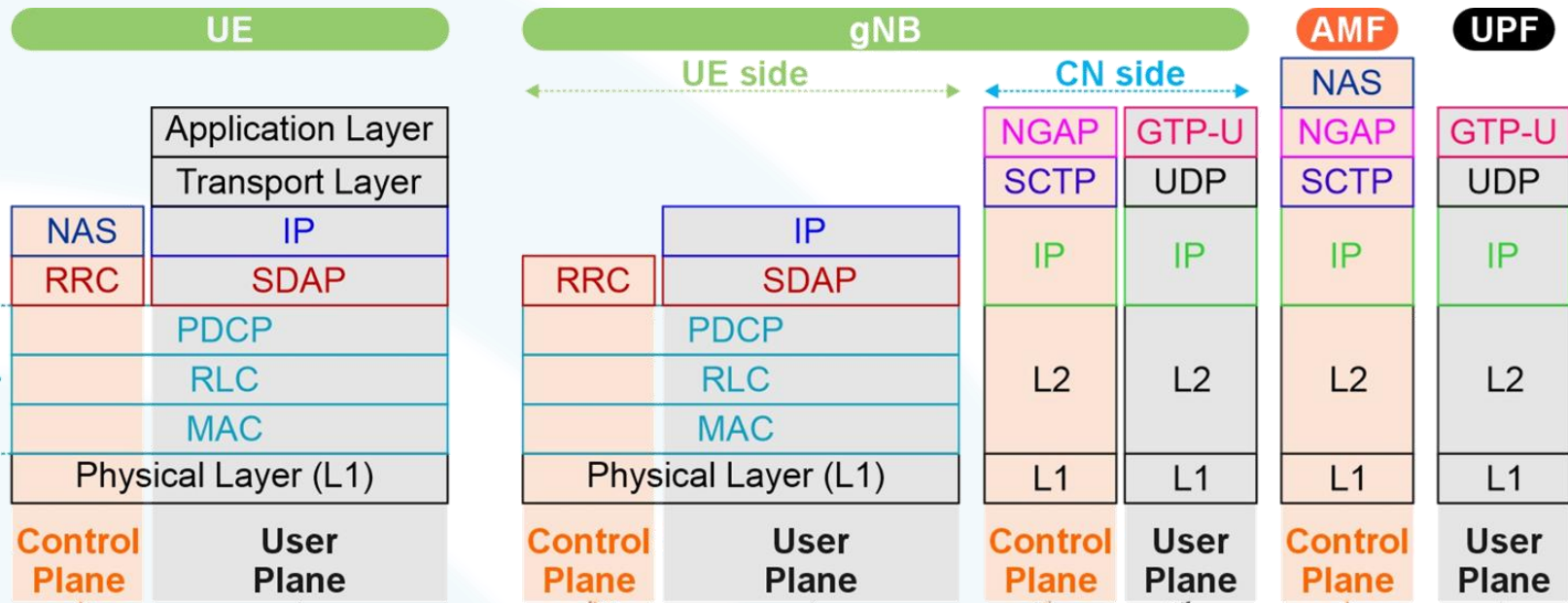
PRB 272 (100MHz)  
PRB 105 (40MHz)  
PRB 50 (20MHz)



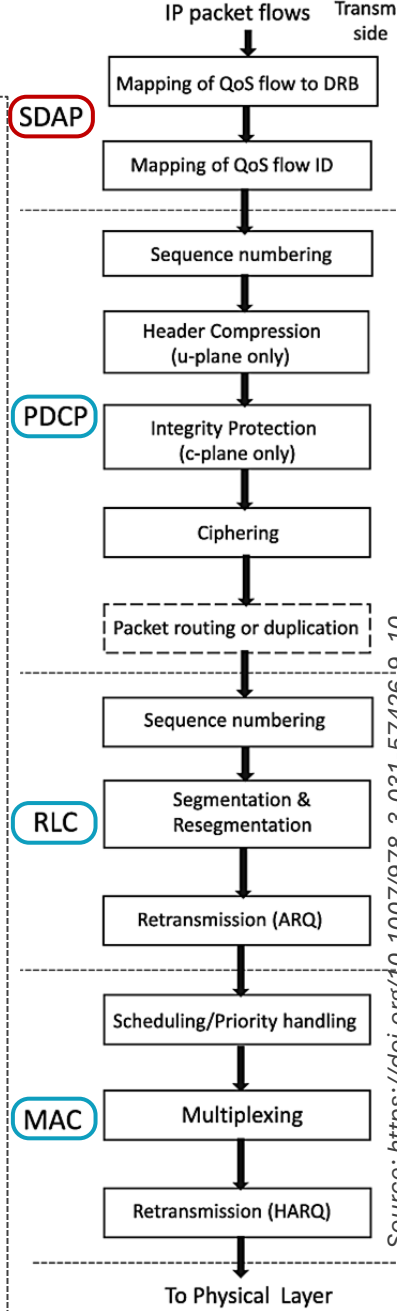
Frequency  
(X PRBs x 12 SCS x Y SCS kHz)

PRB 0

# The 5G Protocol Stack



- **NAS**: Non-Access Stratum
- **NGAP**: Next Generation Application Protocol
- **GTP-U**: GPRS Tunneling Protocol
- **SCTP**: Stream Control Transmission Protocol
- **IP**: Internet Protocol
- **SDAP**: Service Data Adaptation Protocol.
- **RRC**: Radio Resource Control
- **PDCP**: Packet Data Convergence Protocol
- **RLC**: Radio Link Control
- **MAC**: Medium Access Control



Source: [https://doi.org/10.1007/978-3-031-57426-9\\_10](https://doi.org/10.1007/978-3-031-57426-9_10)