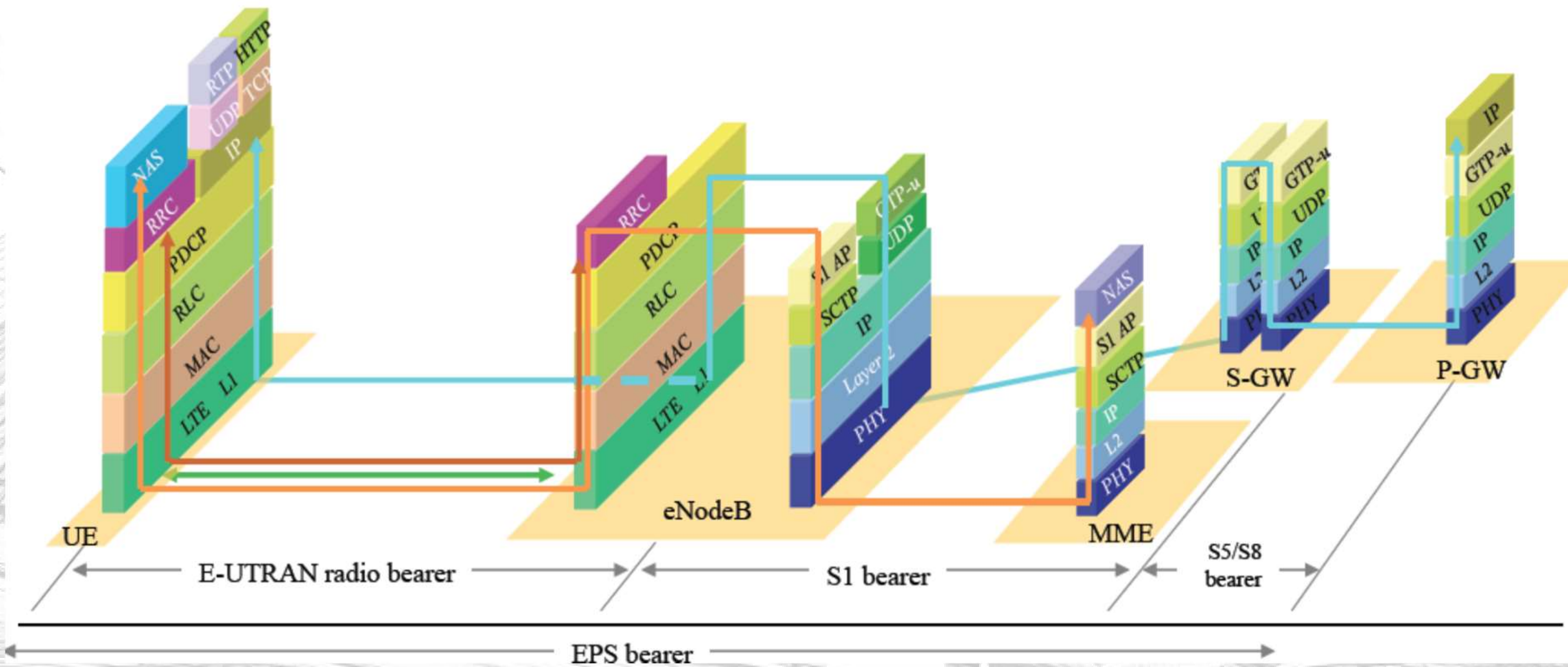
EPS BEARER

- Internal E-UTRAN signaling,
- NAS signalling
- Data traffic : E-UTRradio bearer+S1 bearer+S5/S8 bearer
- L1/L2 control channel



Source : David Tipper, Wireless Network II, Telecommunication and Networking Program, University of Pittsburgh

LOGICAL CHANNELS

- Logical Control Channel
  - Broadcast Control Channel (BCCH)
    - Downlink common channel to broadcast system control information to Ues, such as tracking area, antenna configuration, system bandwidth
  - Multicast Control Channel (MCCH)
    - For UE receiving broadcast or multicast services
  - Paging Control Channel (PCCH)
    - Searching for UE not connected to the network in idle mode
  - Common Control Channel (CCCH)
    - Bidirectional channel for control information when UE is not attached to the network
  - Dedicated Control Channel
    - Bi-directional dedicated control information between UE and network, whereby UE has RRC connection

LOGICAL CHANNELS

- Logical traffic channel
  - Dedicated Traffic Channel (DTCH)
    - Dedicated point to point channel between UE and the network
    - Can exist in uplink and downlink
  - Multicast Traffic Channel (MTCH)
    - One way channel from the network to multicast or broadcast to group of UE. This is only for downlink only

TRANSPORT CHANNELS

- Downlink
  - Downlink Shared Channel (DL-SCH)
    - Transmit downlink data, including traffic and control
    - Support HARQ, dynamic link adaption and beamforming
  - Broadcast Channel
    - Broadcast system information over entire cell
  - Multicast Channel (MCF)
    - Transmit the same information from multiple base station on the same radio resource to multiple Ues
  - Paging Channel (PCH)
    - Associated with the logical PCCH to broadcast paging over the entire coverage area
- Uplink
  - Uplink Shared Channel (UL-SCH)
  - Random Access Channel (RACH)

TRANSPORT CHANNELS

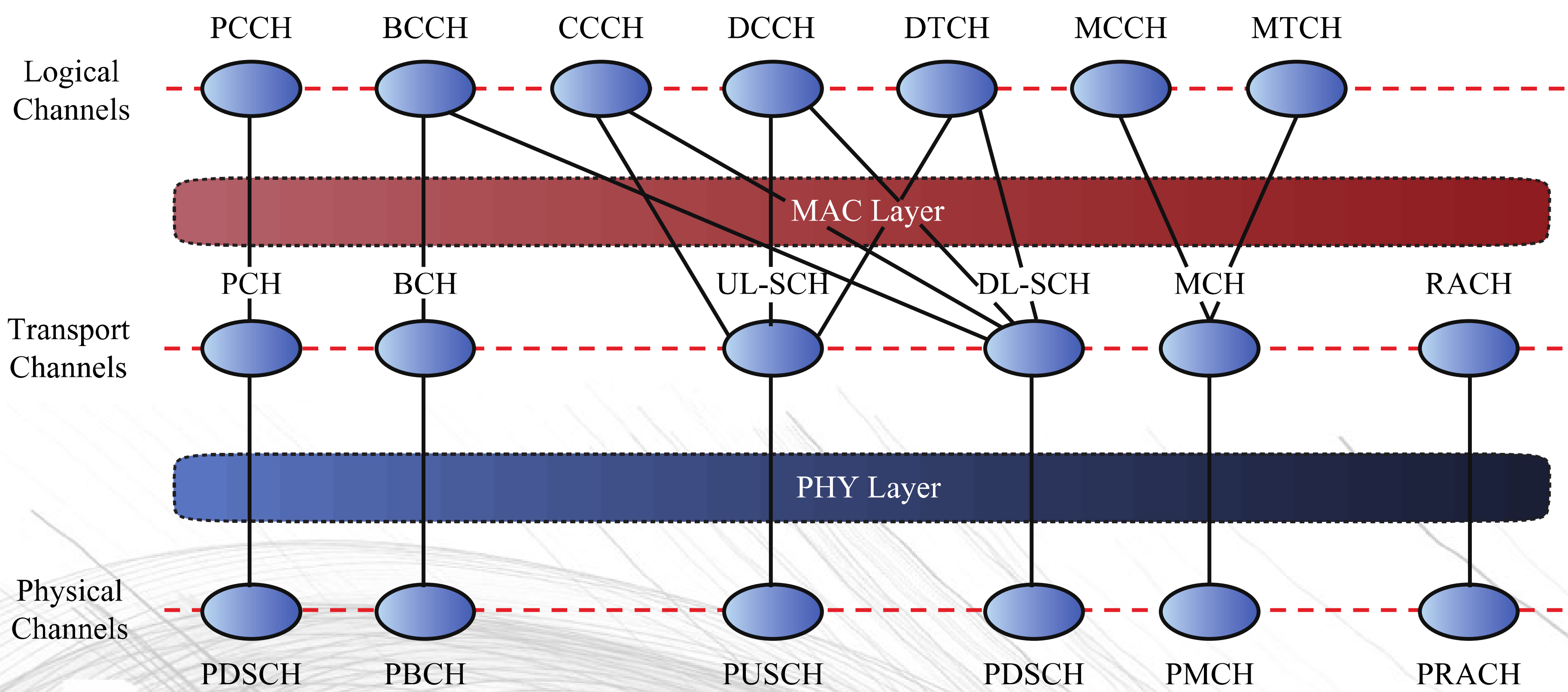
- In addition to transport channels, MAC layer adds control info to PHY layer
  - Downlink Control Information(DCI)
    - Uplink/Downlink Transmit Power Control (TPC)
    - Sent over Physical Downlink Control Channel (PDDCH)
  - Control Format Indicator (CFI)
    - How many symbols of DCI spans in subframe sent over Physical Control Format Indicator Channel (PCFICH)
  - H-ARQ indicator
    - ACK/NAK to uplink transmission, sent over Physical Hybrid ARQ indicator Channel (PHICH)
  - Uplink Control Information
    - Measurement, scheduling request, sent over Physical Uplink Control Channel

PHYSICAL CHANNELS

- Downlink
  - Physical Downlink Control Channel (PDCCH)
    - Carries information about the format and resources related to DL-SCH and PCH transmission
      - Download Control Information (DCI) : Uplink AMC and Transmit Power Control
  - Physical Downlink Shared Channel (PDSCH)
    - Carries the user data and signaling for higher layers
  - Physical Broadcast Channel (PBCH)
    - Carries the BCH transport channel
  - Physical Multicast Channel (PMCH)
  - Physical H-ARQ Indicator Channel (PHICH)
    - Carries HARQ ACK/NAK
  - Physical Control Format Indicator Channel
    - Informs UE about number of OFDM symbols used by the PDDCH

PHYSICAL CHANNEL

- Uplink
  - Physical Uplink Control Channel (PUCCH)
    - Carries control information using Channel Quality Indicators (CQIs) :
      - Uplink Control Information : To inform measurement, scheduling request, HARQ ACKs/NAKs
  - Physical Uplink Shared Channel (PUSCH)
    - Carries the user data and signaling for higher layers
    - Supports the UL-SCH transport channel



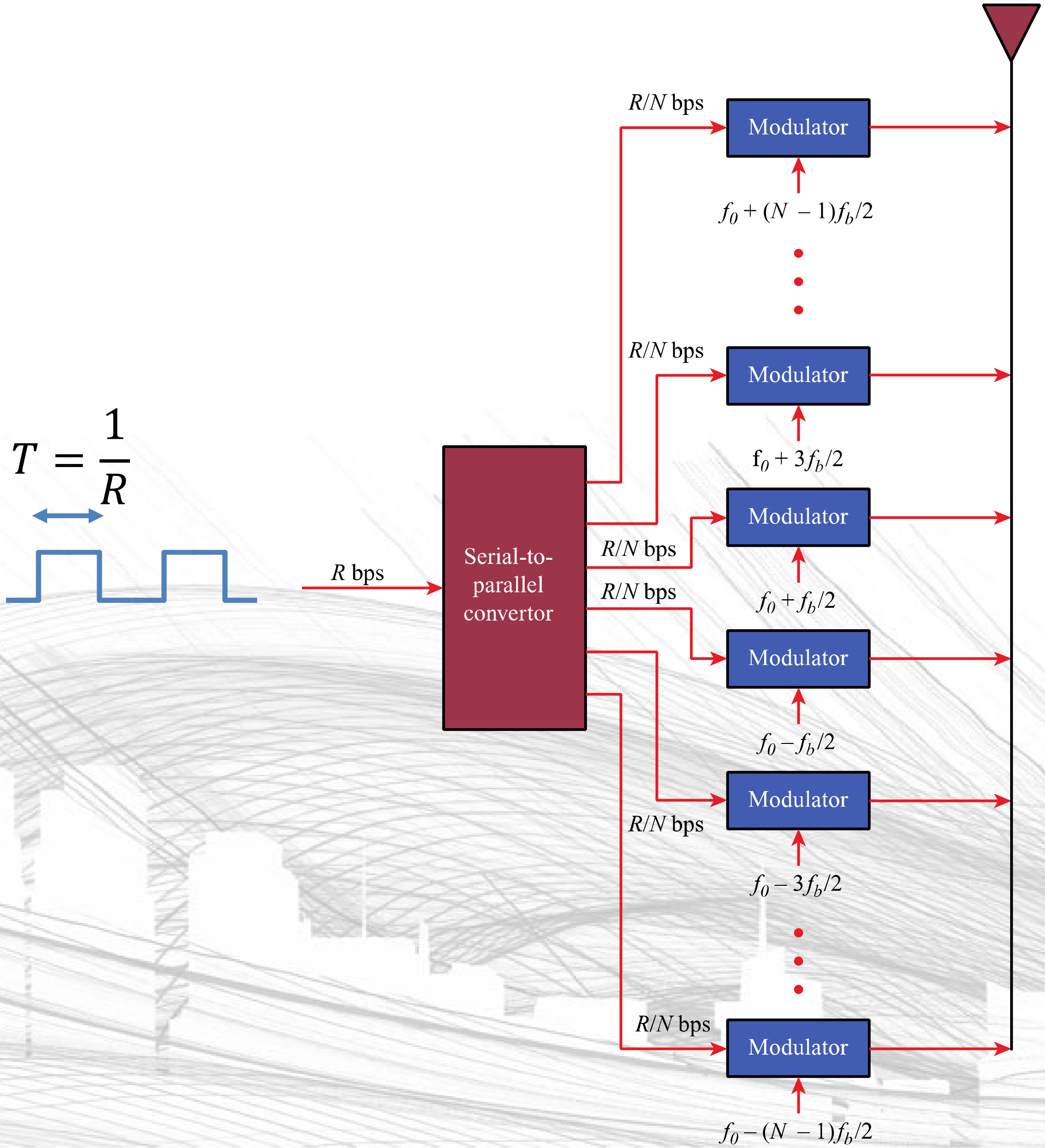
14.9 MAPPING OF LOGICAL, TRANSPORT, AND PHYSICAL CHANNELS

LTE RADIO ACCESS NETWORK

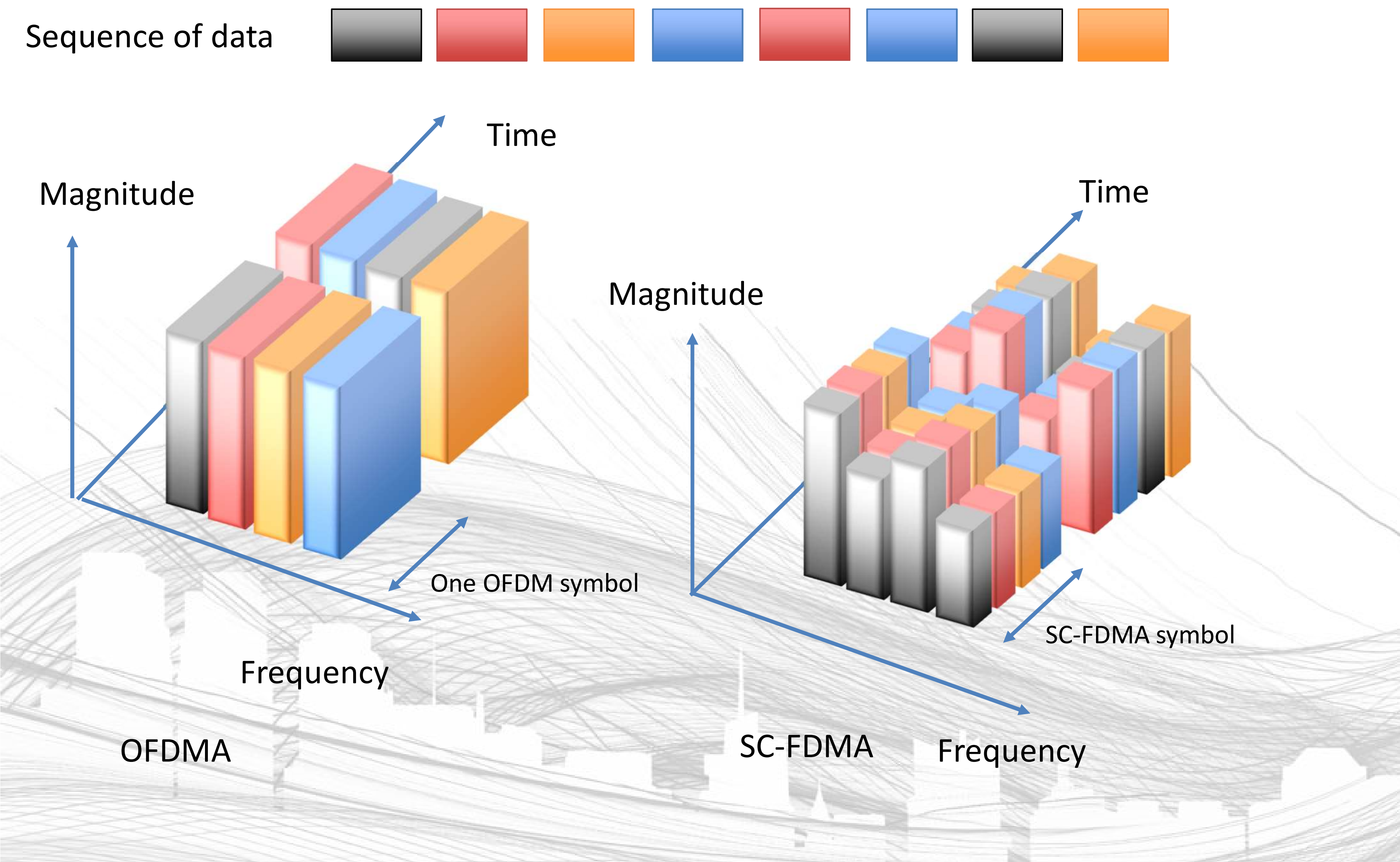
- LTE uses MIMO and OFDM
  - OFDMA on the downlink
  - SC-OFDM on the uplink, which provides better energy and cost efficiency for battery-operated mobiles
- LTE uses subcarriers 15 kHz apart
  - Maximum FFT size is 2048
  - Basic time unit is

    $$T_s = 1/(15000 \times 2048) = 1/30{,}720{,}000 \text{ seconds.}$$
  - Downlink and uplink are organized into *radio frames*
    - Duration 10 ms., which corresponds to $307200T_s$.

REVISIT : OFDM IN CONCEPT

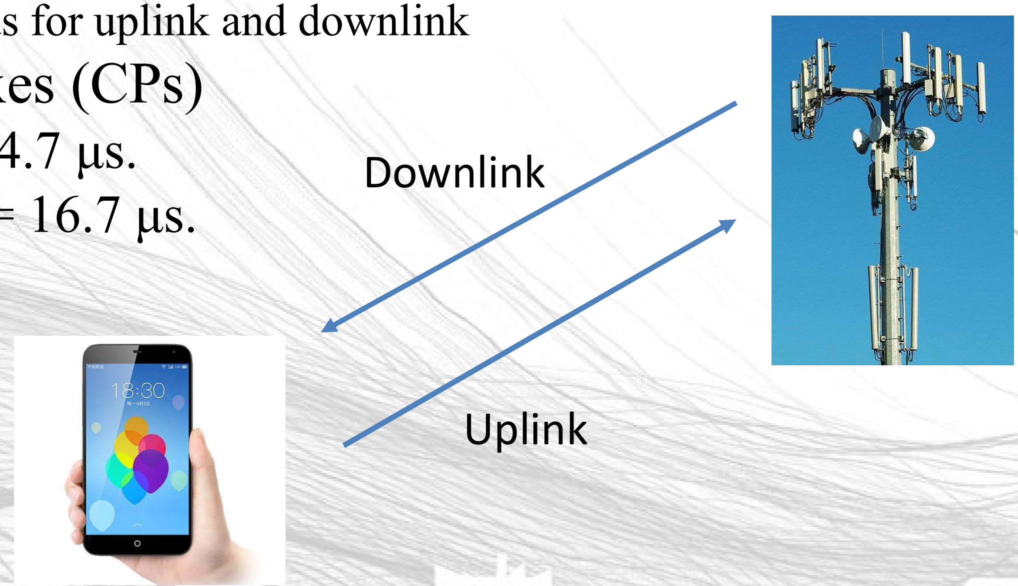


SC-FDMA VS OFDMA



LTE RADIO ACCESS NETWORK

- LTE uses both TDD and FDD
  - Both have been widely deployed
  - Time Division Duplexing (TDD)
    - Uplink and downlink transmit in the same frequency band, but alternating in the time domain
  - Frequency Division Duplexing (FDD)
    - Different frequency bands for uplink and downlink
- LTE uses two cyclic prefixes (CPs)
  - Normal CP = $144 \times T_s = 4.7$ µs.
  - Extended CP = $512 \times T_s = 16.7$ µs.
    - For worse environments

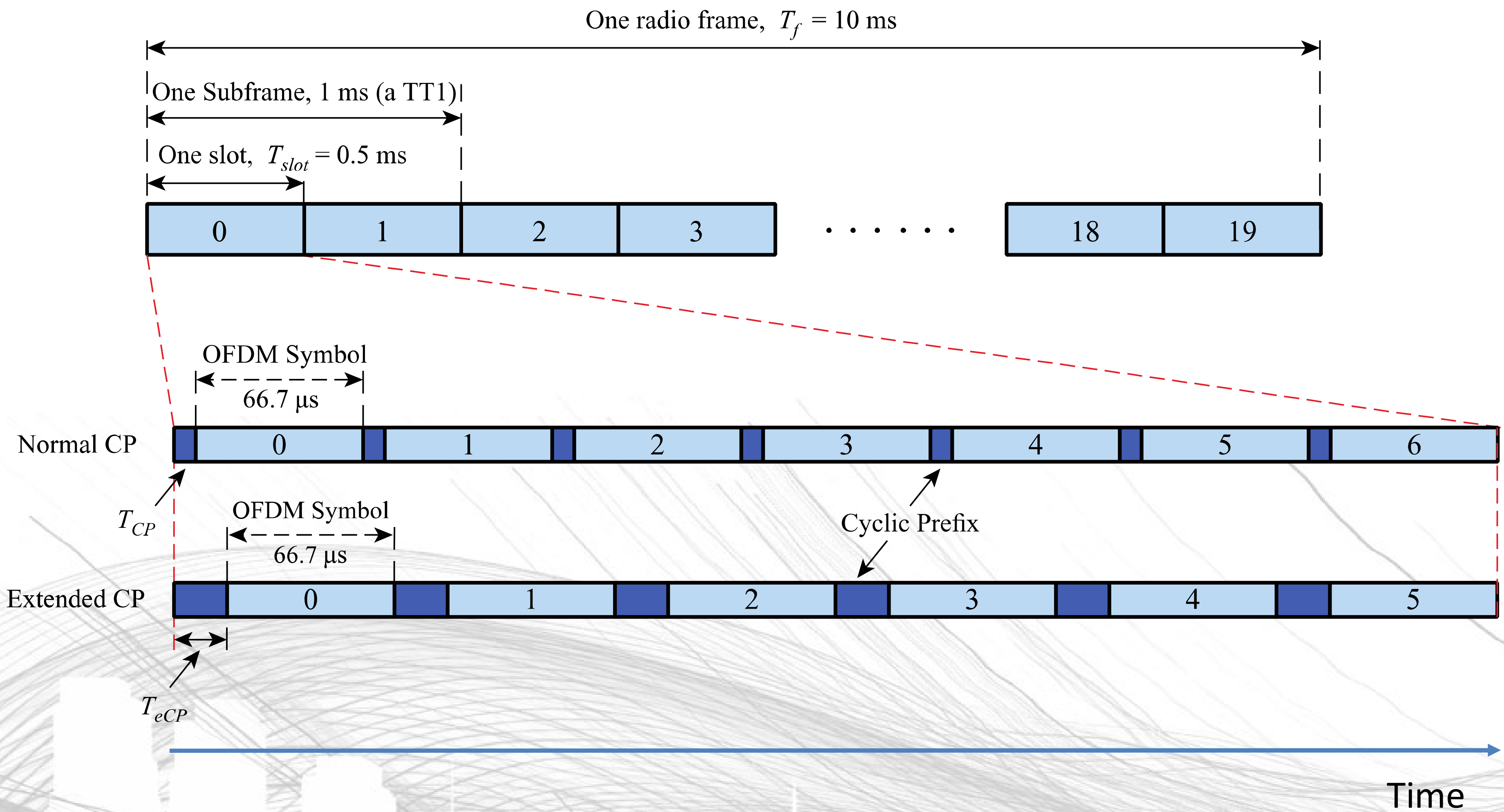


FDD FRAME STRUCTURE TYPE 1

- Three different time units
  - The *slot* equals $T_{slot} = 15360 \times T_s = 0.5$ ms
  - Two consecutive slots comprise a *subframe* of length 1 ms.
    - Channel dependent scheduling and link adaptation (otherwise known as adaptive modulation and coding) occur on the time scale of a subframe (1000 times/sec.).
  - 20 slots (10 subframes) equal a *radio frame* of 10 ms.
    - Radio frames schedule distribution of more slowly changing information, such as system information and reference signals.

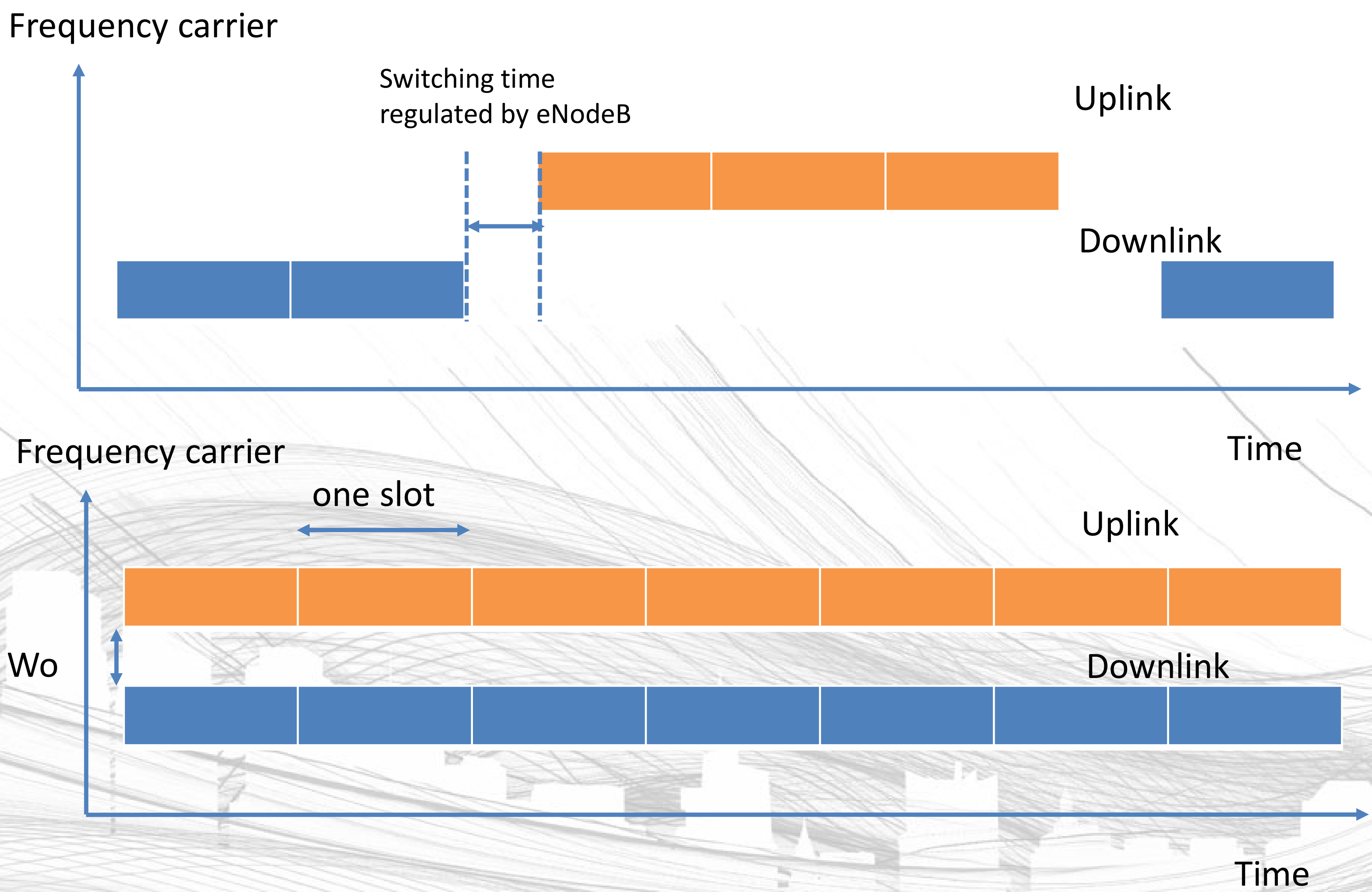
FDD FRAME STRUCTURE TYPE 1

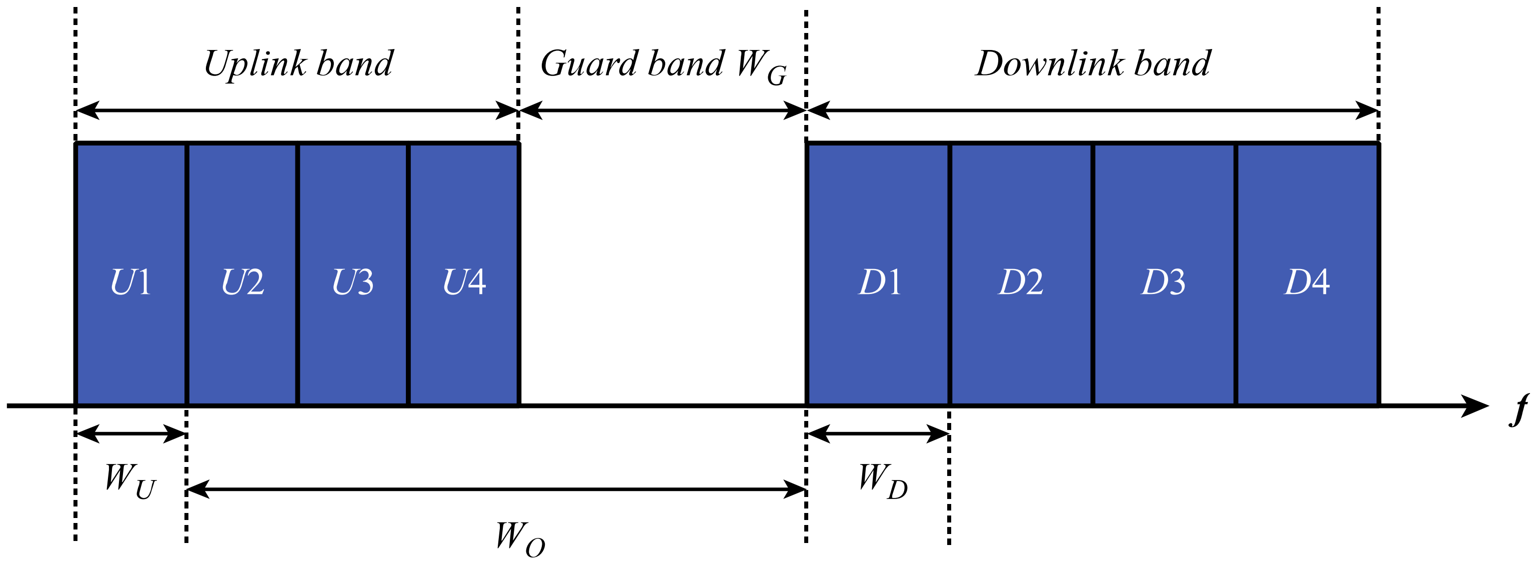
- Normal CP allows 7 OFDM symbols per slot
- Extended CP only allows time for 6 OFDM symbols
  - Use of extended CP results in a 1/7 = 14.3% reduction in throughput
  - But provides better compensation for multipath
- Requires large frequency separation between uplink and downlink
  - UE may have separate component for transmit and receive, allowing a full duplex operation → $$$, but fast
  - Simple transmitter and receiver to allow half duplex operation → $, but slow, requires eNodeB to schedule



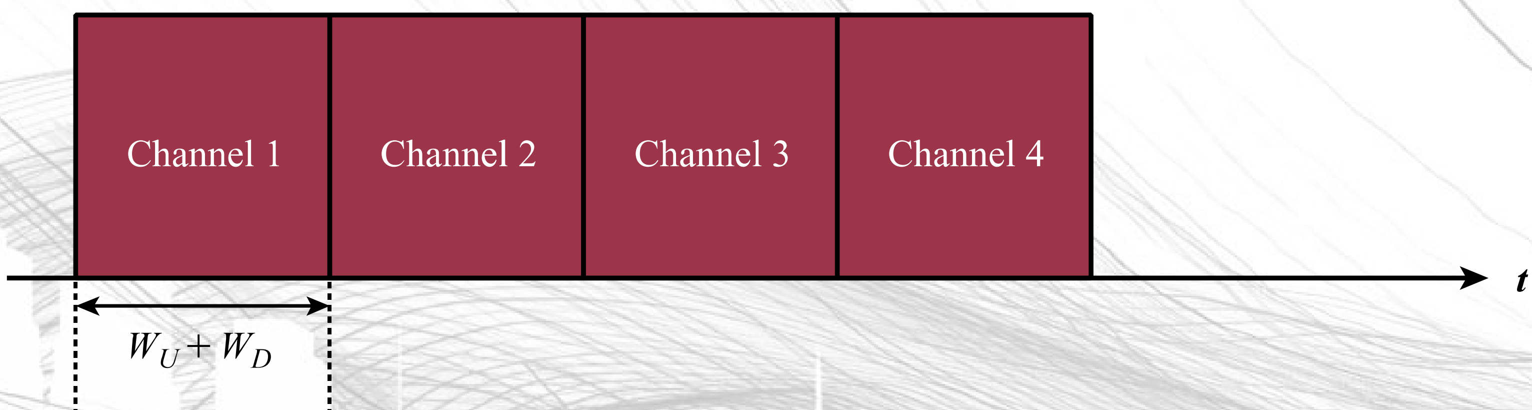
14.11 FDD FRAME STRUCTURE, TYPE 1

HALF AND FULL DUPLEX





(a) FDD

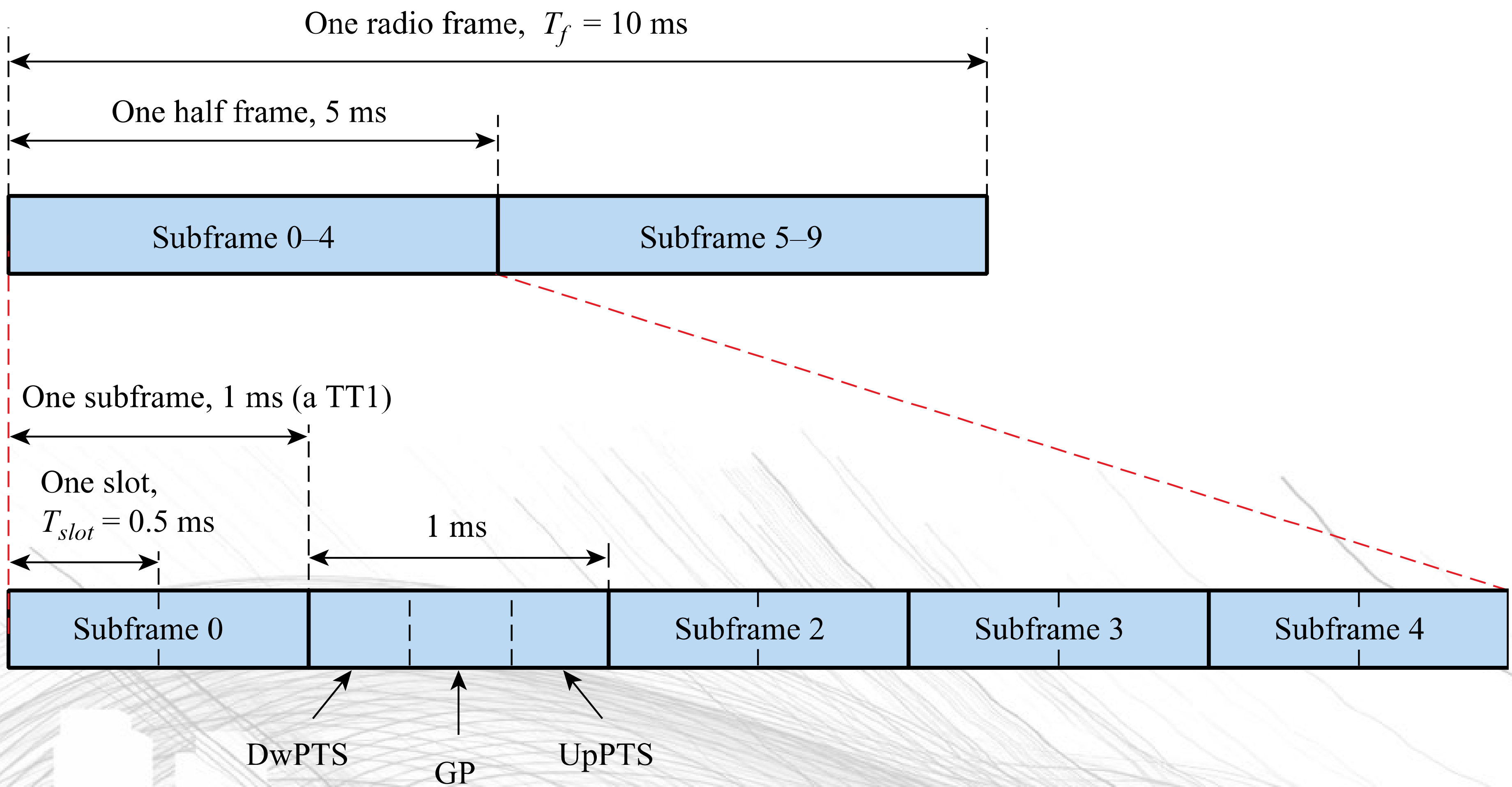


(b) TDD

14.10 SPECTRUM ALLOCATION FOR FDD AND TDD

TDD FRAME STRUCTURE TYPE 2

- Radio frame is again 10 ms.
- Includes special subframes for switching downlink-to-uplink
  - Special subframes are allowed in subframe 1 and 6
    - Downlink Pilot TimeSlot (DwPTS): Ordinary but shorter downlink subframe of 3 to 12 OFDM symbols
    - Uplink Pilot TimeSlot (UpPTS): Short duration of one or two OFDM symbols for sounding reference signals or random access preambles
    - Guard Period (GP): Remaining symbols in the special subframe in between to provide time to switch between downlink and uplink



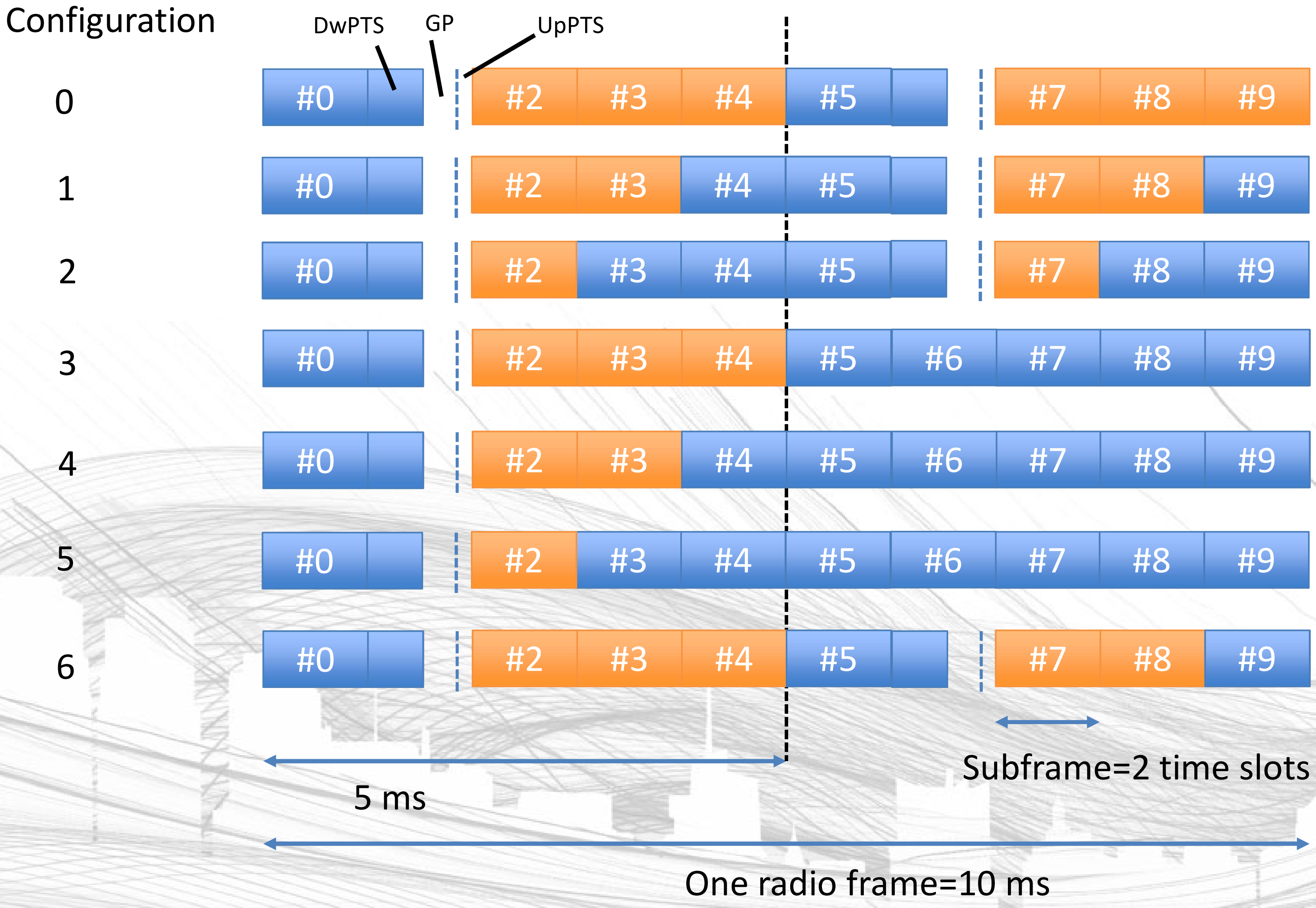
14.12 TDD FRAME STRUCTURE, TYPE 2

TDD FRAME STRUCTURE TYPE 2

- Standard defines 7 configuration for DL/UL split

Configuration	DL/UL ratio	DL/UL switch point
0	2:3	5 ms
1	3:2	5 ms
2	4:1	5 ms
3	7:3	10 ms
4	8:2	10 ms
5	9:1	10 ms
6	5:5	5 ms

TDD FRAME STRUCTURE TYPE 2



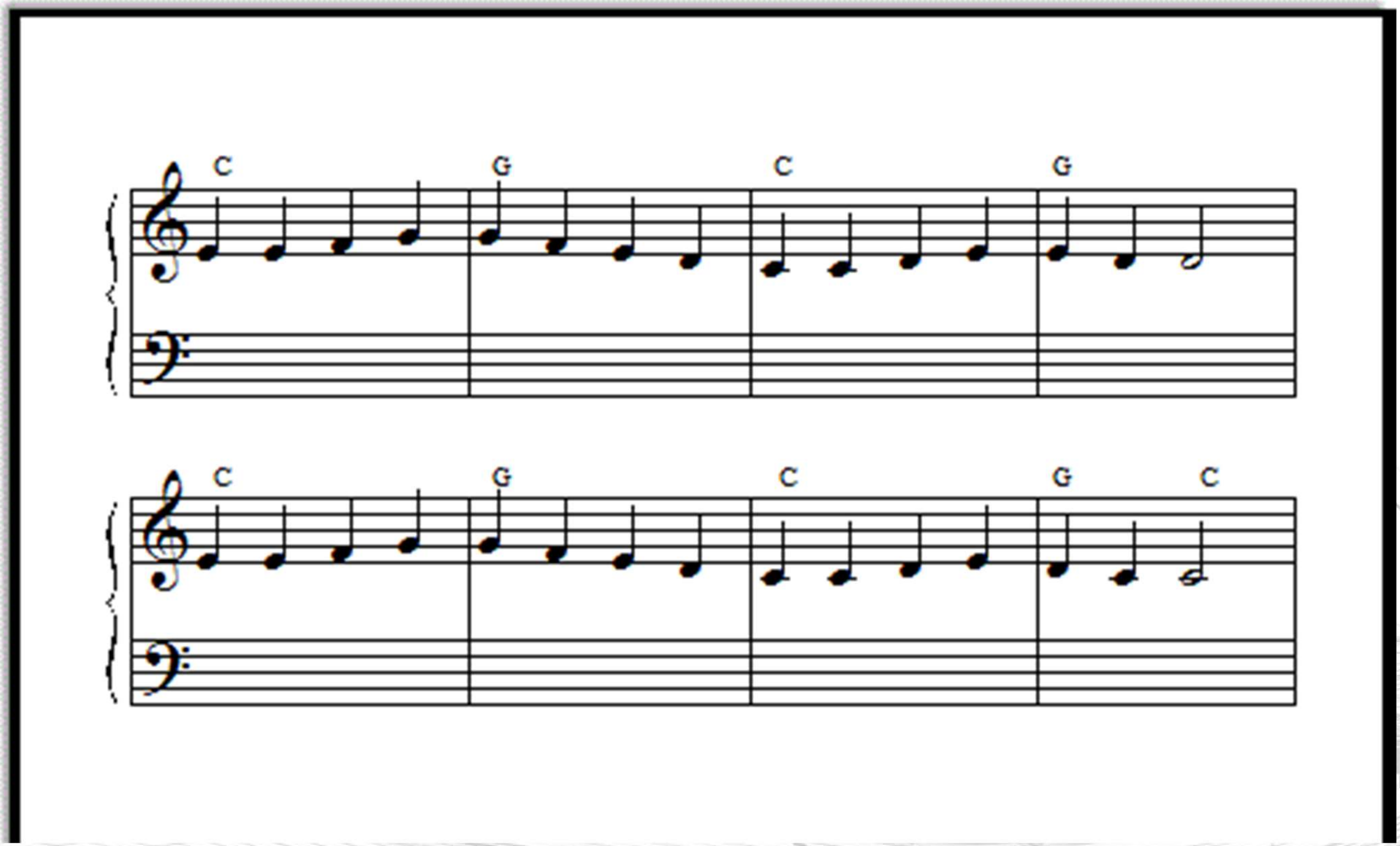
RESOURCE BLOCKS

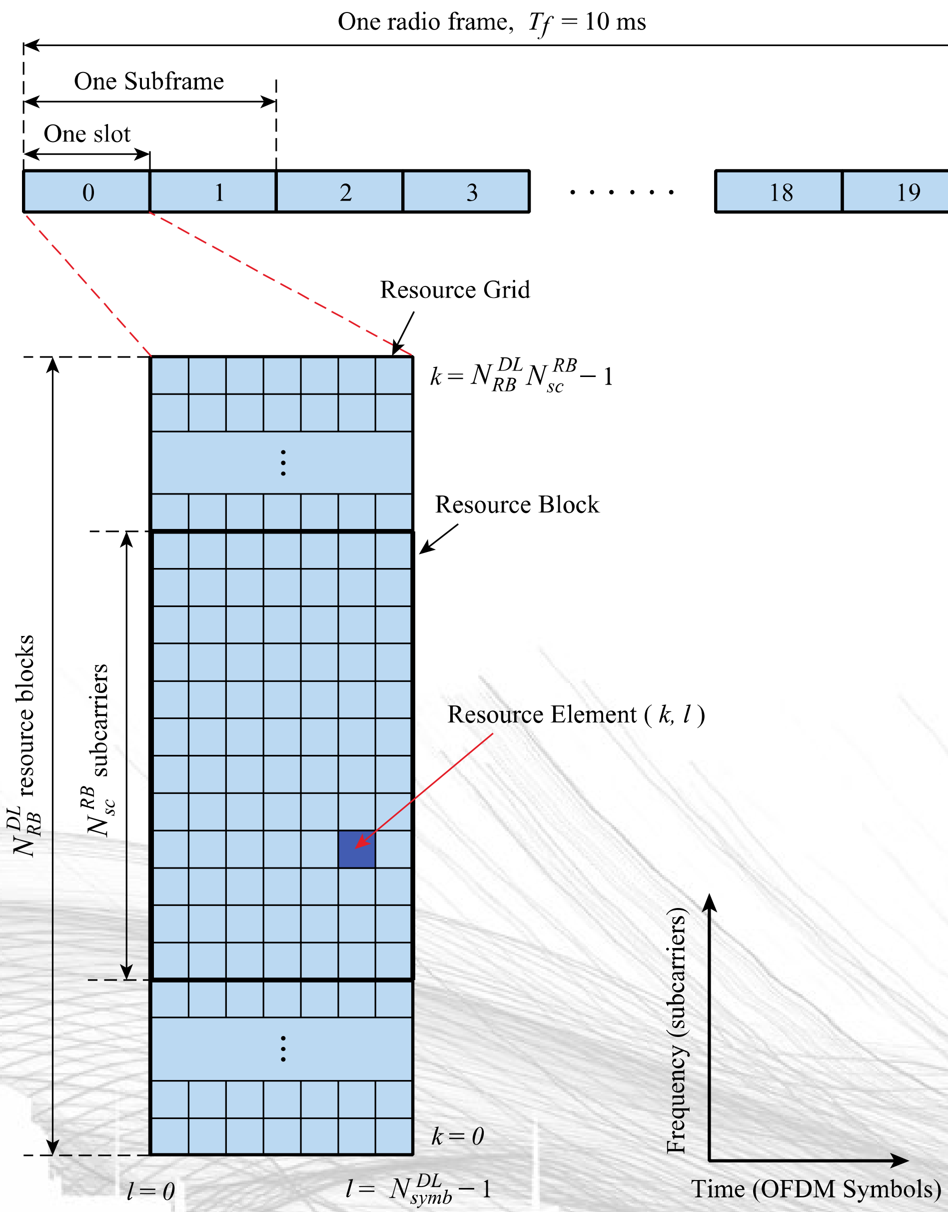
- A time-frequency grid is used to illustrate allocation of physical resources
- Each column is 6 or 7 OFDM symbols per slot
- Each row corresponds to a subcarrier of 15 kHz
  - Some subcarriers are used for guard bands
  - 10% of bandwidth is used for guard bands for channel bandwidths of 3 MHz and above

RESOURCE BLOCKS

- Resource Block
  - 12 subcarriers
  - 6 or 7 OFDM symbols
  - Results in 72 or 84 *resource elements* in a *resource block* (*RB*)
- For the uplink, contiguous frequencies must be used for the 12 subcarriers
  - Called a *physical resource block*
- For the downlink, frequencies need not be contiguous
  - Called a *virtual resource block*

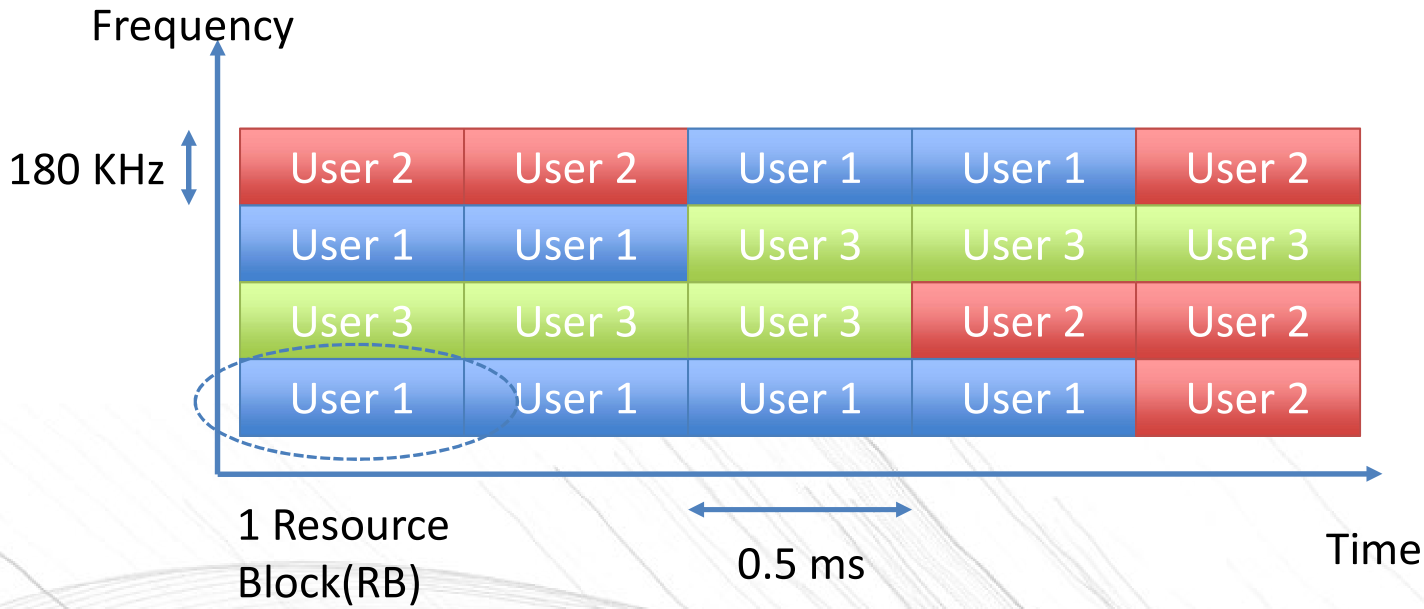
INTERMEZZO: MUSICAL NOTES





14.13 LTE RESOURCE GRID

CHANNEL BANDWIDTH



Channel BW (MHz)	1.4	3	5	10	15	20
Max Tx BW (MHz)	1.08	2.7	4.5	9.0	13.5	18
Max #RB	6	{ }	{ }	{ }	{ }	{ }