

# Random Access of Cellular Systems

**Lecturer: Dr. Rui Wang**

# Recap: Distributed Coordination Function (DCF)

- DCF uses CSMA/CA for transmission coordination
  - **CSMA/CA:** Carrier sense multiple access with collision avoidance
- Procedure
  - **Carrier sensing:** a STA having a packet to transmit checks the state of the medium.
  - **Wait:** the STA waits if it senses a busy medium. Moreover, it determines a random back-off period by setting an internal timer to an integer number of slot times.
  - **Still wait:** the station defers until the medium is idle for one DIFS period.
  - **Countdown:** after DIFS, an internal timer is set. If the timer reaches zero, the station begins transmission.
  - **Suspension:** however, if the channel is seized by another station before the timer reaches zero, the timer setting is suspended at the decremented value for subsequent transmission.

# Up to now

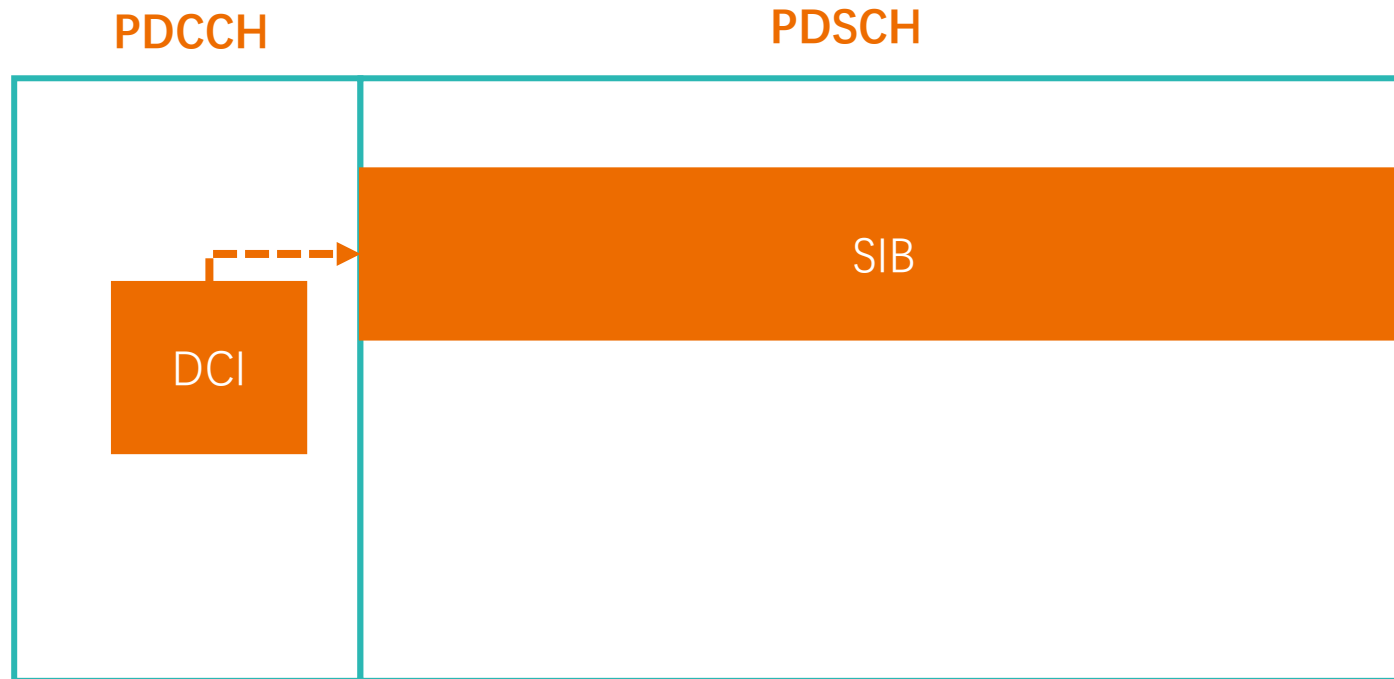
- **PSS & SSS:** Synchronize with the desired cell
- **PBCH:** detect the MIB, including bandwidth and FFT size
- **PDCCH:** detect the allocation of PDSCH
- What is the following procedure?
- More BS and network information will be broadcast via **SIB (System Information Block)**

# SIB (TS36.331)

- SIB is sent by PDSCH
- As the functionalities of LTE evolves, the list of SIB is getting longer and longer.
- For example
  - **SIB 1** : Cell Selection, Cell Access, SI Scheduling
  - **SIB 2** : RACH, Access Barring, UL frequency Information, MBSFN Config
  - **SIB 3** : Intra Frequency Cell Reselection
  - **SIB 4** : Intra Frequency Neighbour Cell
  - **SIB 5** : Inter Frequency Neighbour Cell
- Etc.

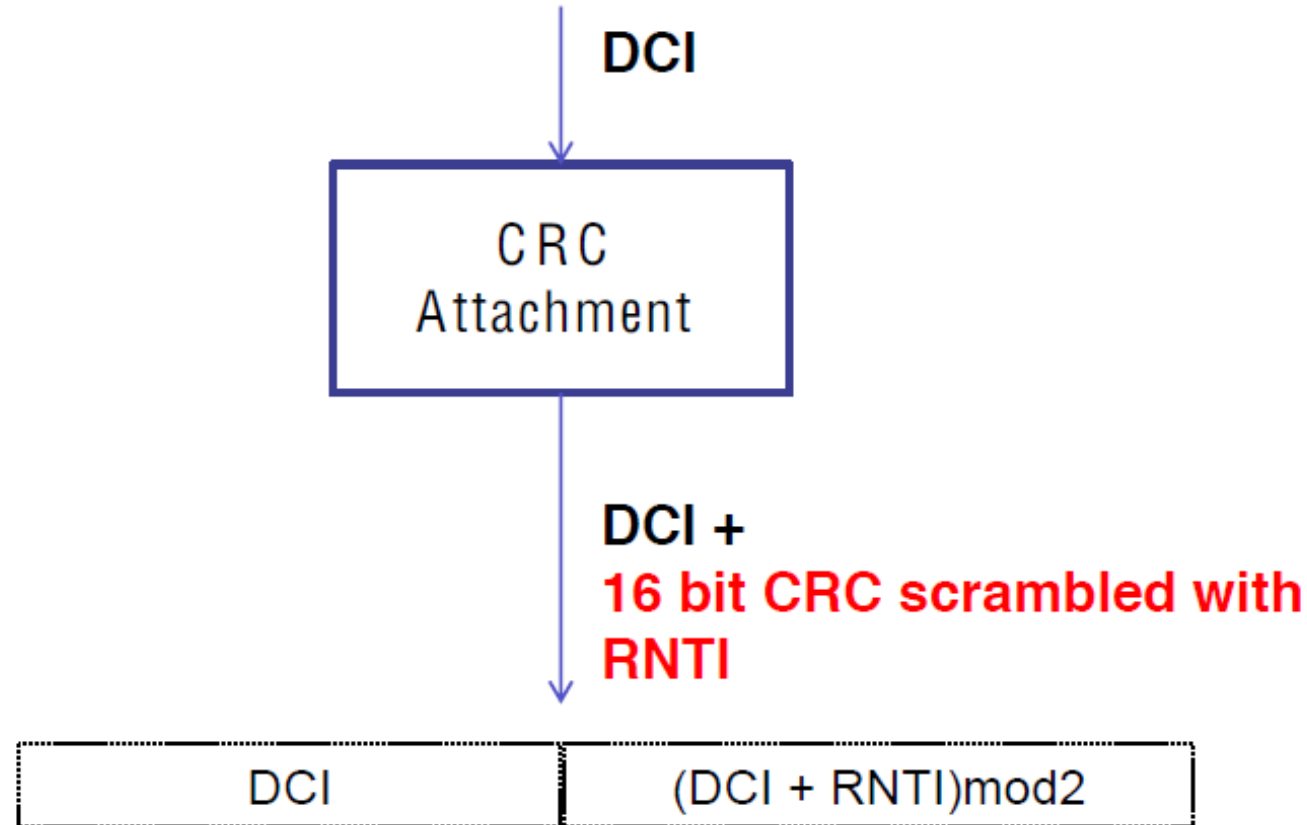
# SIB (TS36.331)

- SIB is sent by PDSCH



# Recap: Whose PDCCH?

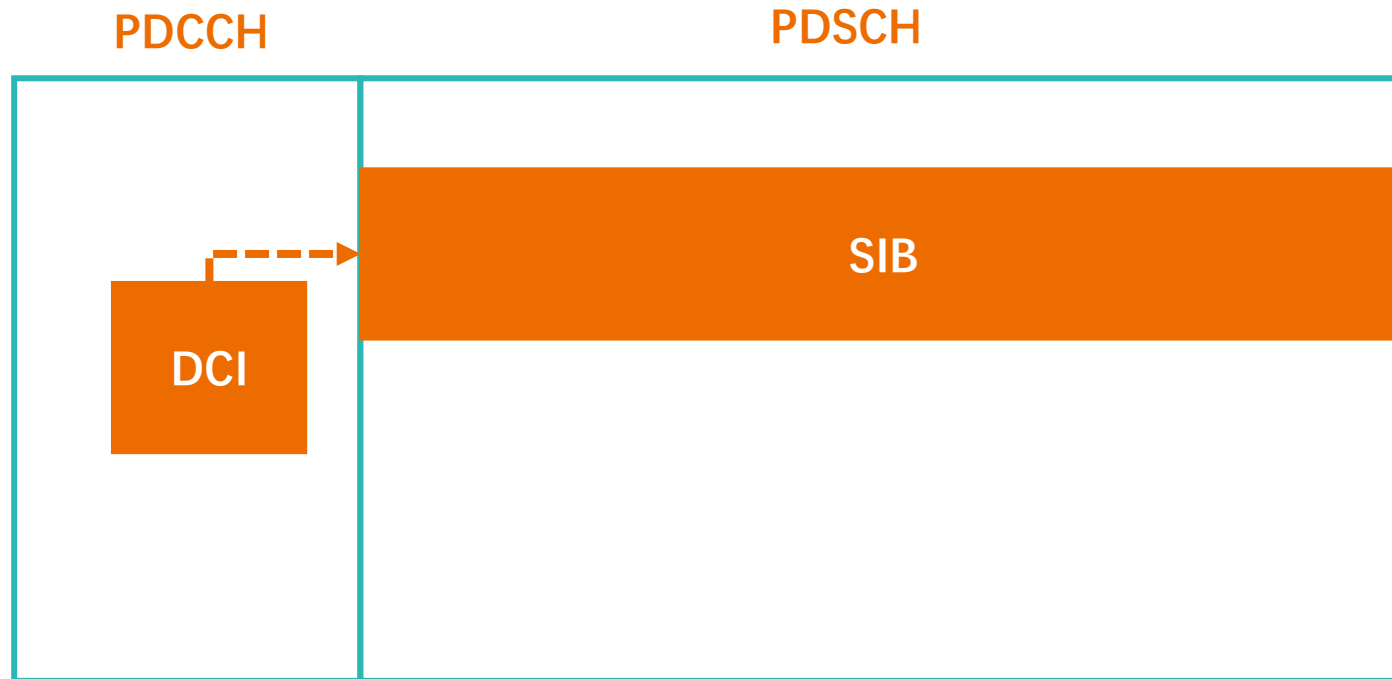
- ✓ With **RNTI** (Radio Network Temporary Identifier) : **User Identification**



# SIB (TS36.331)

- SIB is sent by PDSCH

Scrambled with SI-RNTI  
SI-RNTI: **FFFF** (16bits)  
TS36.321-c70 Table 7.1-1



# RNTI Table

Value (hexa-decimal) ↵	RNTI ↵
0000 ↵	N/A ↵
0001-003C ↵	RA-RNTI, C-RNTI, Semi-Persistent Scheduling C-RNTI, Temporary C-RNTI, eIMTA-RNTI, TPC-PUCCH-RNTI, TPC-PUSCH-RNTI and SL-RNTI (see note) ↵
003D-FFF3 ↵	C-RNTI, Semi-Persistent Scheduling C-RNTI, eIMTA-RNTI, Temporary C-RNTI, TPC-PUCCH-RNTI, TPC-PUSCH-RNTI and SL-RNTI ↵
FFF4-FFFC ↵	Reserved for future use ↵
FFFD ↵	M-RNTI ↵
FFFE ↵	P-RNTI ↵
FFFF ↵	SI-RNTI ↵

36.321-c70 Table 7.1-1: RNTI values

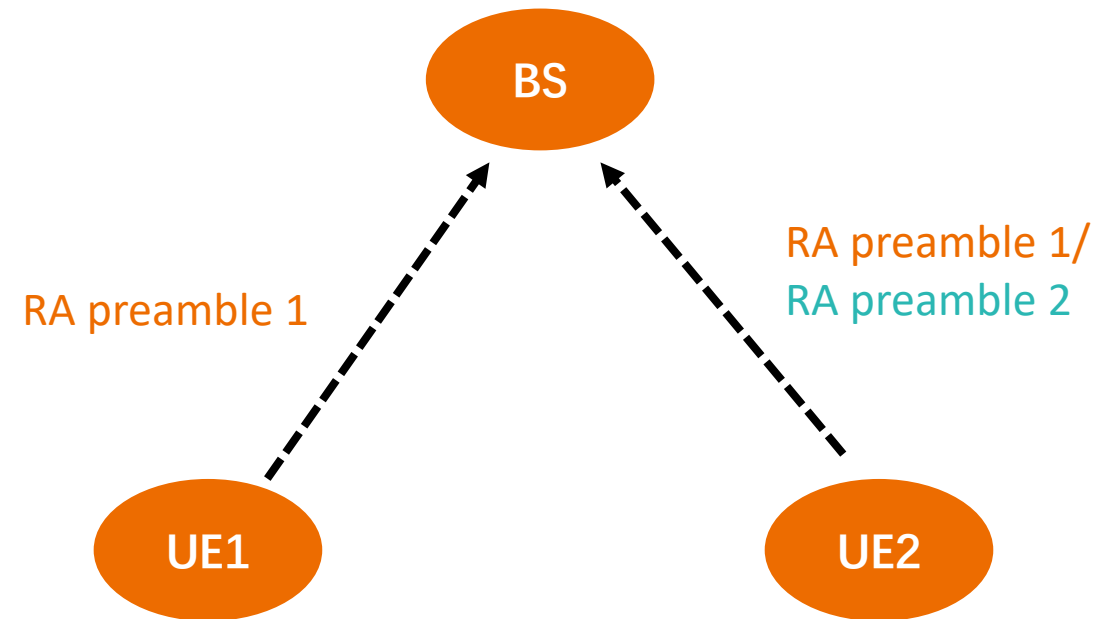


# Random Access

- In IEEE802.11, the access requests of multiple STAs can be resolved via **CSMA/CA** mechanism.
  - Contention is resolved via **random backoff**.
- In LTE, there are both contention-based and contention-free mechanisms for the uplink transmission of UEs.
  - **Contention-free**: the BS is aware of the uplink transmission demands of UEs, and scheduled dedicated resource to them. E.g., **Semi-Persistent Scheduling**.
  - **Contention-based**: users proactively content/request for the uplink transmission opportunities. Contention is resolved in **code space**.

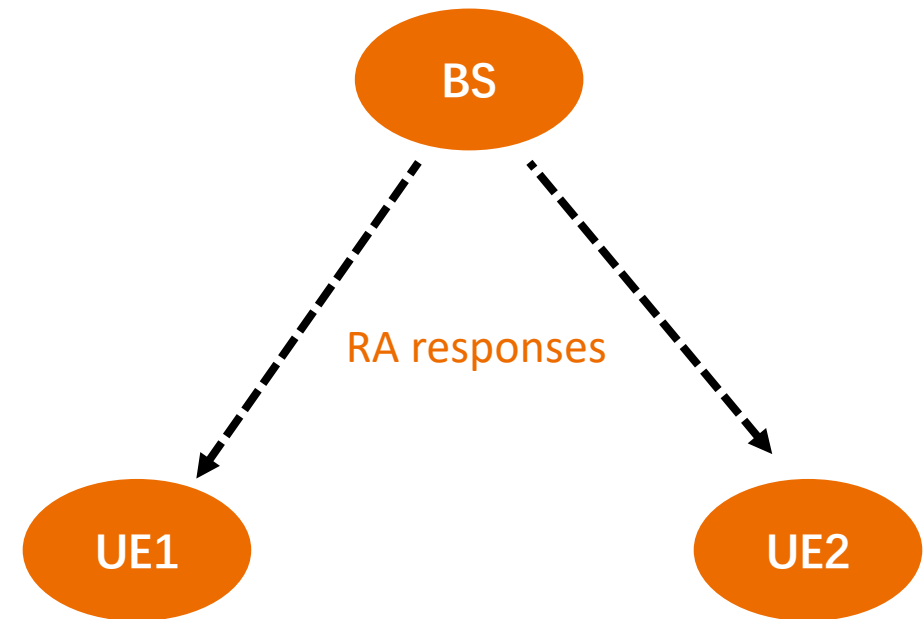
# Random Access

- Contention-based RA is necessary for one mobile device just powered on
- UEs transmit **RA preambles** to BS in **PRACH**
- UEs are separated via different preambles and transmission time-frequency
- **But collision is still possible**



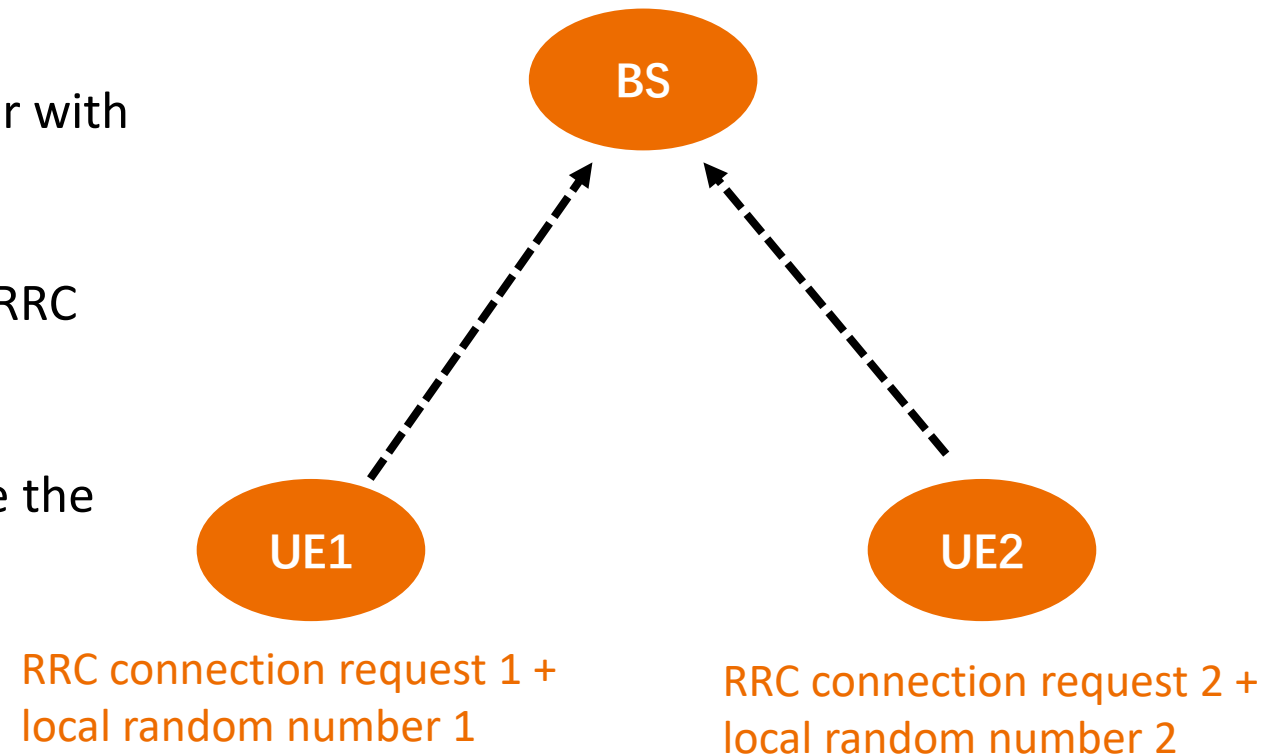
# Random Access

- Contention-based RA is necessary for one mobile device just powered on
- BS replies with **RA responses**, indicating the UL transmission opportunities for further handshaking
- If two UEs can be separated, the following random access has no problem
- Otherwise, contention is still unsolved



# Random Access

- Contention-based RA is necessary for one mobile device just powered on
- UEs transmit **RRC connection requests**, together with local random number
- BS acknowledges on the successful receiving of RRC connection request
- One UE can detect RA failure, if it cannot receive the acknowledge



# PRACH

- **Physical random access channel (PRACH)** is for uplink contention
- The time-frequency location of transmitting PRACH in each frame is identified via **SIB2**
- The UEs can transmit preambles via PRACH

# Which subframe for PRACH?

Table 5.7.1-2: Frame structure type 1 random access configuration for preamble formats 0-3

PRACH Configuration Index	Preamble Format	System frame number	Subframe number	PRACH Configuration Index	Preamble Format	System frame number	Subframe number
0	0	Even	1	32	2	Even	1
1	0	Even	4	33	2	Even	4
2	0	Even	7	34	2	Even	7
3	0	Any	1	35	2	Any	1
4	0	Any	4	36	2	Any	4
5	0	Any	7	37	2	Any	7
6	0	Any	1, 6	38	2	Any	1, 6
7	0	Any	2, 7	39	2	Any	2, 7
8	0	Any	3, 8	40	2	Any	3, 8
9	0	Any	1, 4, 7	41	2	Any	1, 4, 7
10	0	Any	2, 5, 8	42	2	Any	2, 5, 8
11	0	Any	3, 6, 9	43	2	Any	3, 6, 9
12	0	Any	0, 2, 4, 6, 8	44	2	Any	0, 2, 4, 6, 8
13	0	Any	1, 3, 5, 7, 9	45	2	Any	1, 3, 5, 7, 9
14	0	Any	0, 1, 2, 3, 4, 5, 6, 7, 8, 9	46	N/A	N/A	N/A
15	0	Even	9	47	2	Even	9
16	1	Even	1	48	3	Even	1
17	1	Even	4	49	3	Even	4
18	1	Even	7	50	3	Even	7
19	1	Any	1	51	3	Any	1
20	1	Any	4	52	3	Any	4

BS broadcasts SIB2 periodically:

```
sib2
  radioResourceConfigCommon
    rach-ConfigCommon
      preambleInfo
        numberOfRA-Preambles: n52 (12)
        preambleGroupAConfig
          sizeOfRA-PreamblesGroupA: n48 (11)
          messageSizeGroupA: b56 (0)
          messagePowerOffsetGroupB: dB5 (2)
        powerRampingParameters
          powerRampingStep: dB2 (1)
          preambleInitialReceivedTargetPower: dBm-104 (8)
      ra-SupervisionInfo
        preambleTransMax: n6 (3)
        ra-ResponseWindowSize: sf10 (7)
        mac-ContentionResolutionTimer: sf48 (5)
      maxHARQ-Msg3Tx: 4
    ...
  prach-Config
    rootSequenceIndex: 22
    prach-ConfigInfo
      prach-ConfigIndex: 3
      ..0. .... highSpeedFlag: False
      zeroCorrelationZoneConfig: 5
      prach-FreqOffset: 4
```

# Which subframe for PRACH?

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1	0	Even	4	33	2	Even	4
2	0	Even	7	34	2	Even	7
3	0	Any	1	35	2	Any	1
4	0	Any	4	36	2	Any	4
5							7
6							1, 6
7	0	Any	2, 7	39	2	Any	2, 7
8	0	Any	3, 8	40	2	Any	3, 8
9	0	Any	1, 4, 7	41	2	Any	1, 4, 7
10	0	Any	2, 5, 8	42	2	Any	2, 5, 8
11	0	Any	3, 6, 9	43	2	Any	3, 6, 9
12	0	Any	0, 2, 4, 6, 8	44	2	Any	0, 2, 4, 6, 8
13	0	Any	1, 3, 5, 7, 9	45	2	Any	1, 3, 5, 7, 9
14	0	Any	0, 1, 2, 3, 4, 5, 6, 7, 8, 9	46	N/A	N/A	N/A
15	0	Even	9	47	2	Even	9
16	1	Even	1	48	3	Even	1
17	1	Even	4	49	3	Even	4
18	1	Even	7	50	3	Even	7
19	1	Any	1	51	3	Any	1
20	1	Any	4	52	3	Any	4

The PRACH starts from the 1<sup>st</sup> subframe

BS broadcasts SIB2 periodically:

```

sib2
  radioResourceConfigCommon
    rach-ConfigCommon
      preambleInfo
        numberOfRA-Preambles: n52 (12)
        preambleGroupAConfig
          sizeOfRA-PreamblesGroupA: n48 (11)
          messageSizeGroupA: b56 (0)
          messagePowerOffsetGroupB: dB5 (2)
        powerRampingParameters
          powerRampingStep: dB2 (1)
          preambleInitialReceivedTargetPower: dBm-104 (8)
      ra-SupervisionInfo
        preambleTransMax: n6 (3)
        ra-ResponseWindowSize: sf10 (7)
        mac-ContentionResolutionTimer: sf48 (5)
      maxHARQ-Msg3Tx: 4
    ...
  prach-Config
    rootSequenceIndex: 22
    prach-ConfigInfo
      prach-ConfigIndex: 3
      ..0. .... highSpeedFlag: False
      zeroCorrelationZoneConfig: 5
      prach-FreqOffset: 4
  
```

# Exact Location of PRACH

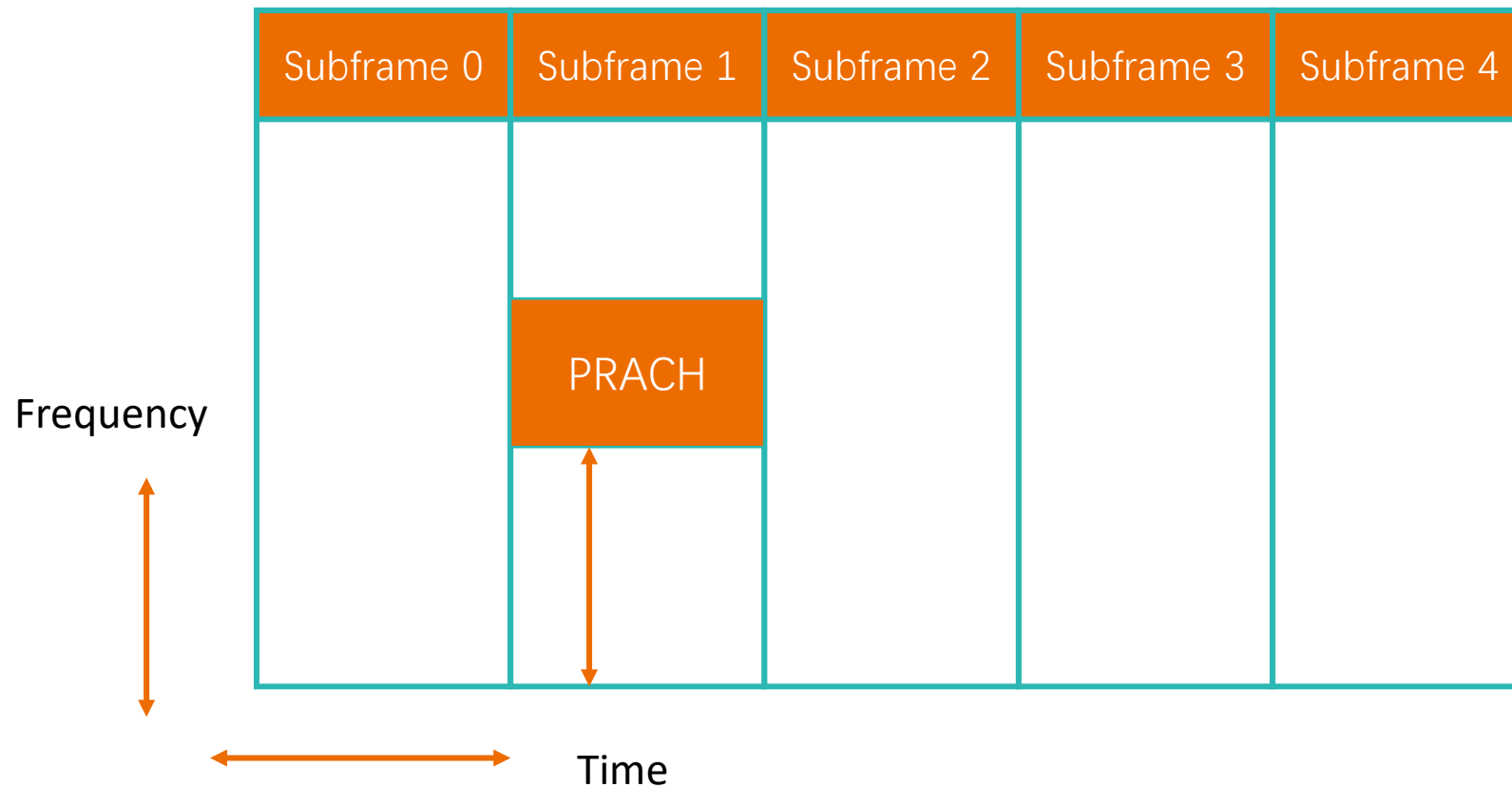
- Example: PRACH Configuration Index = 3 → Subframe Number = 1

Subframe 0	Subframe 1	Subframe 2	Subframe 3	Subframe 4
	PRACH			



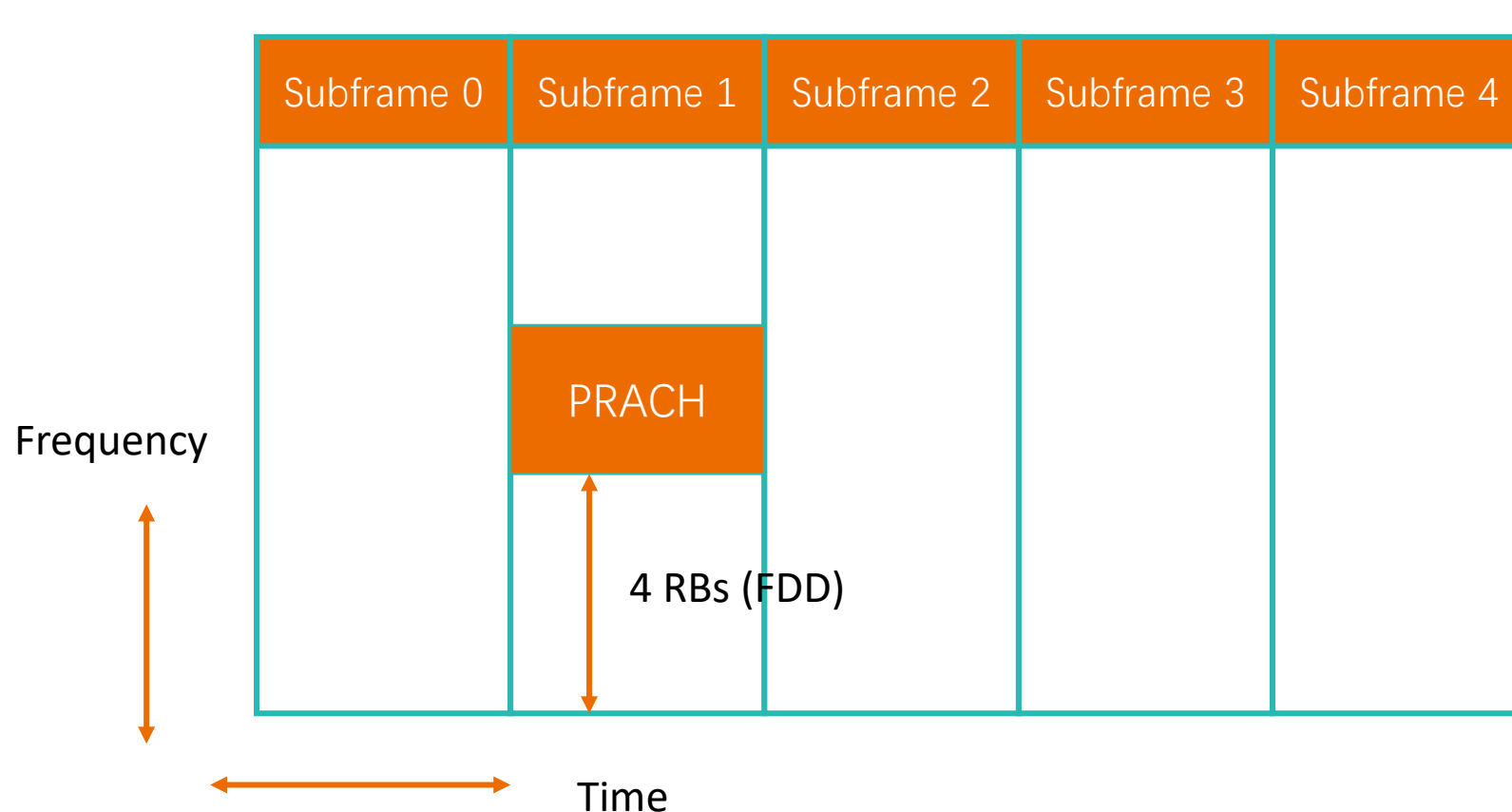
# Exact Location of PRACH

- Example: PRACH Configuration Index = 3 → Subframe Number = 1



# Exact Location of PRACH

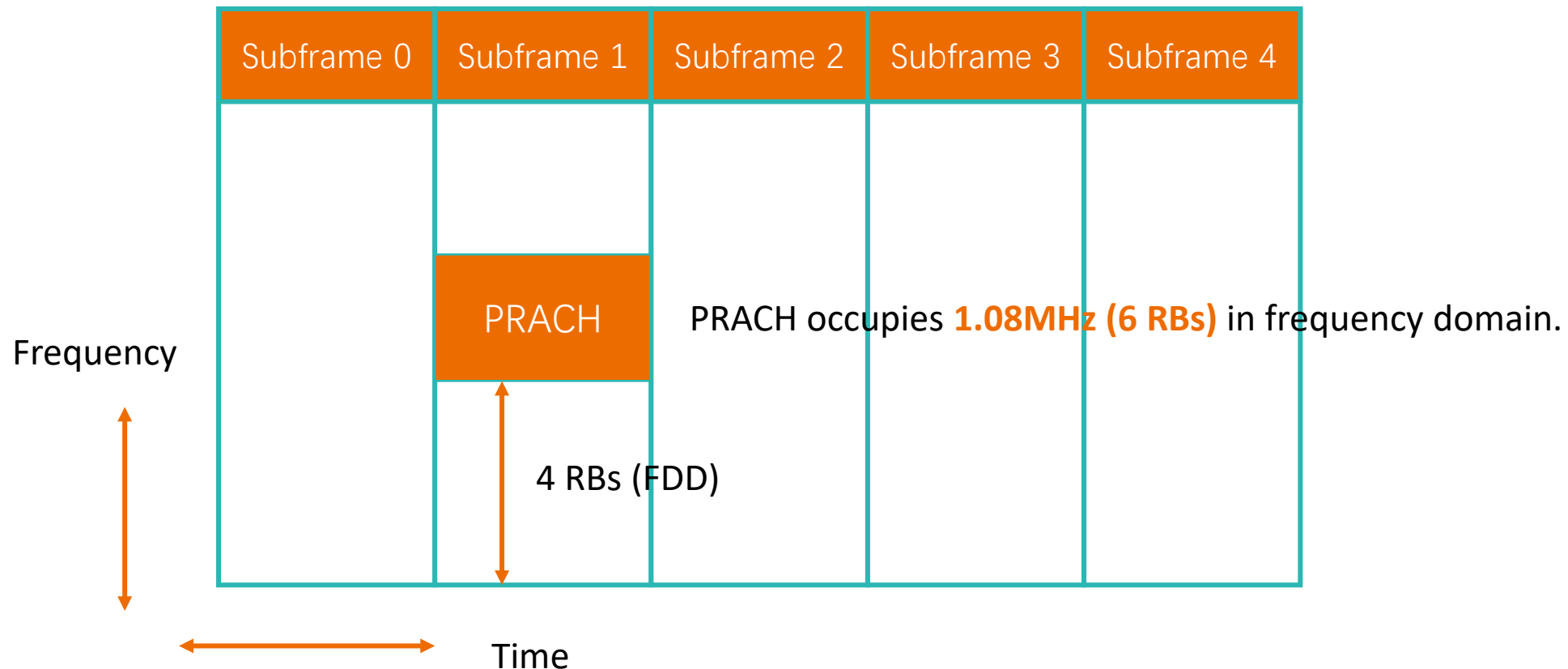
- Example: PRACH Configuration Index = 3 → Subframe Number = 1



```
sib2
radioResourceConfigCommon
rach-ConfigCommon
preambleInfo
  numberOfRA-Preambles: n52 (12)
  preambleGroupAConfig
    sizeOfRA-PreamblesGroupA: n48 (11)
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    preambleInitialReceivedTargetPower: dBm-104 (8)
  ra-SupervisionInfo
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    ra-ResponseWindowSize: sf10 (7)
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    zeroCorrelationZoneConfig: 5
    prach-FreqOffset: 4
...
```

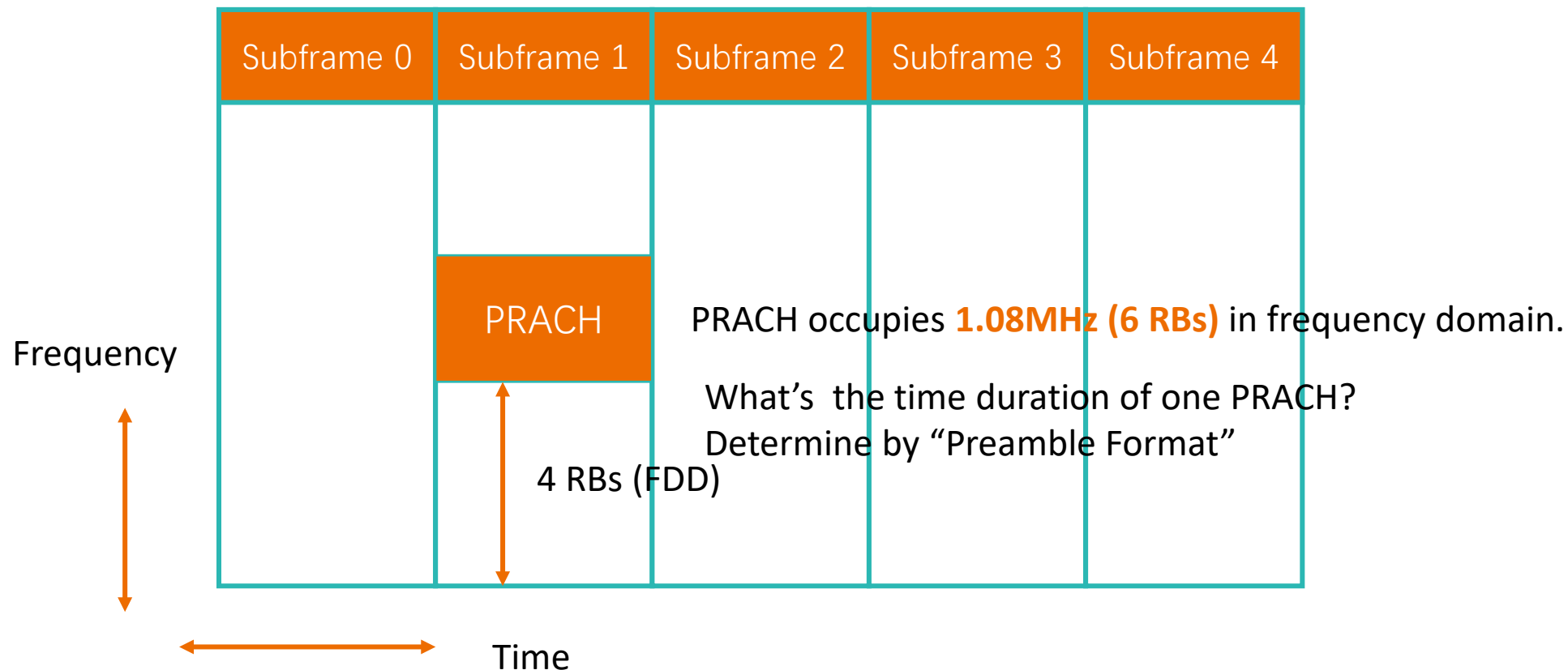
# Exact Location of PRACH

- Example: PRACH Configuration Index = 3 → Subframe Number = 1

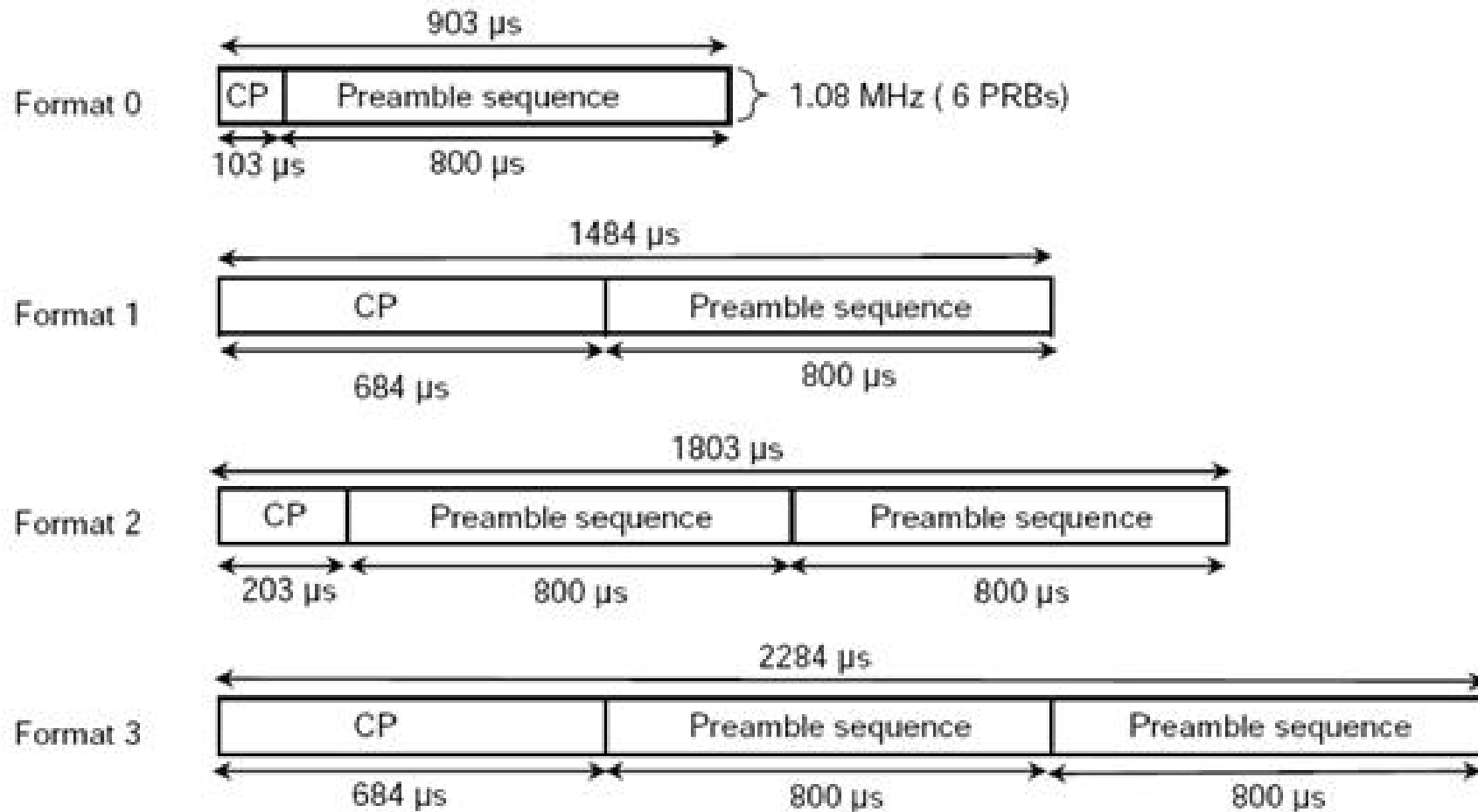


# Exact Location of PRACH

- Example: PRACH Configuration Index = 3 → Subframe Number = 1

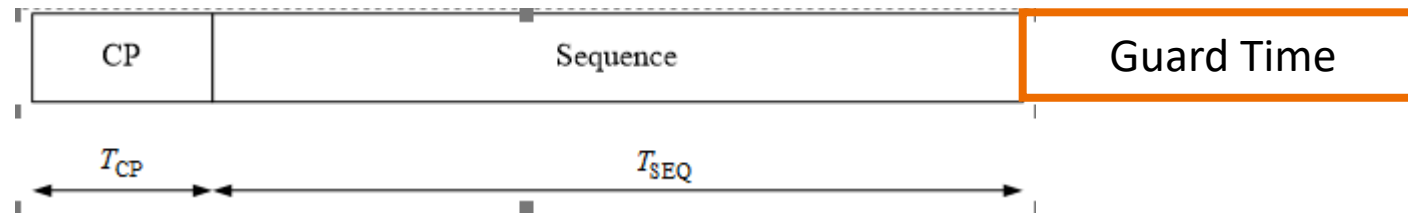


# Preamble Formats



# Preamble Formats

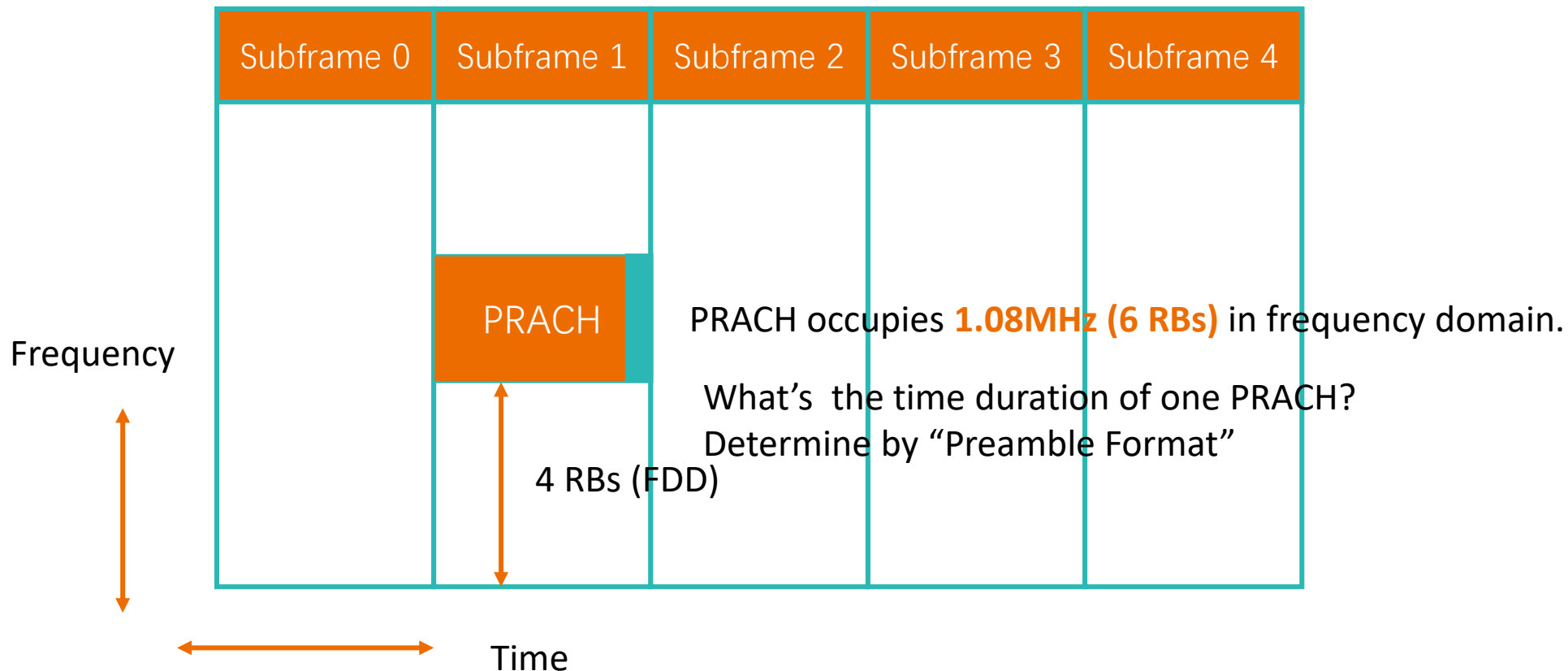
- **Preamble** is transmitted in PRACH

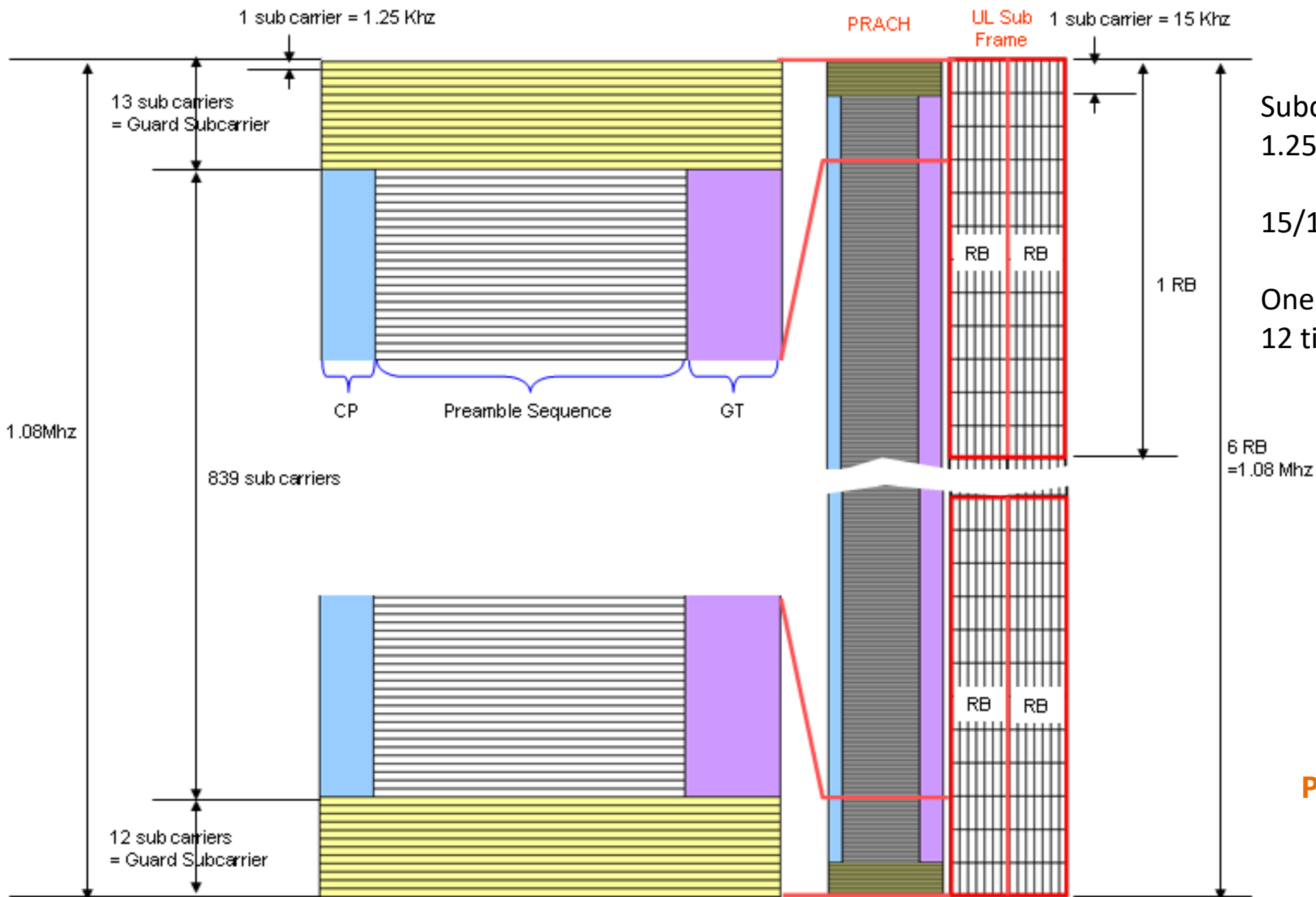


Preamble Format	T_CP (in Ts)	T_CP (in ms)	T_SEQ (in Ts)	T_SEQ (in ms)	Total Length (in ms)	Number of Subframes	Guard Time (in ms)	Cell Radius
0	3168	0.103	24576	0.800	0.903	1	0.097	~ 14 km
1	21024	0.684	24576	0.800	1.484	2	0.516	~ 75 km
2	6240	0.203	2 x 24576	1.600	1.803	2	0.197	~ 28 km
3	21024	0.684	2 x 24576	1.600	2.284	3	0.716	~ 108 km
4	448	0.015	4096	0.133	0.148			

# Exact Location of PRACH

- Example: PRACH Configuration Index = 3 → Subframe Number = 1





Subcarrier spacing for PRACH = 1.25khz

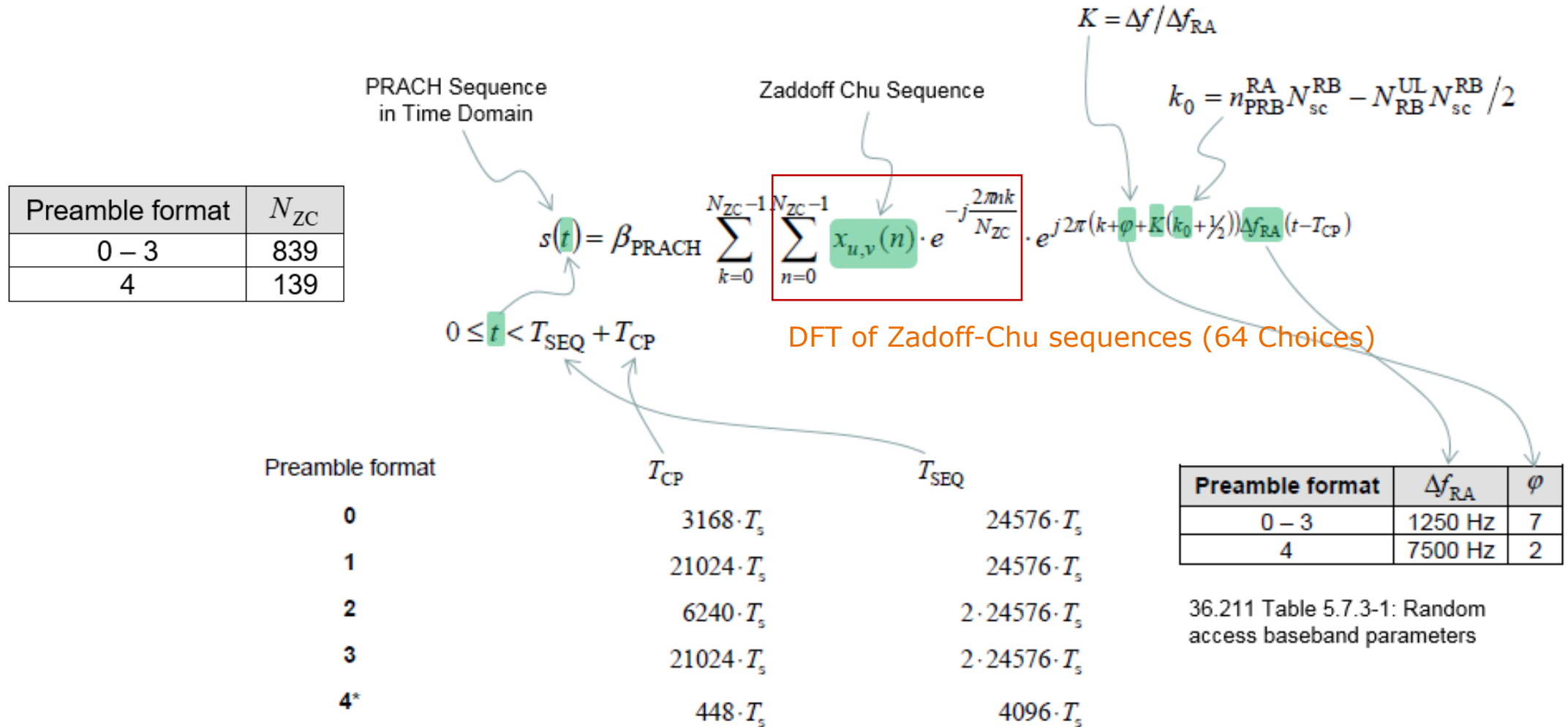
$$15/1.25 = 12$$

One OFDM symbol for PRACH is 12 times longer

**Preamble Format 0**



# Baseband Signal Generation



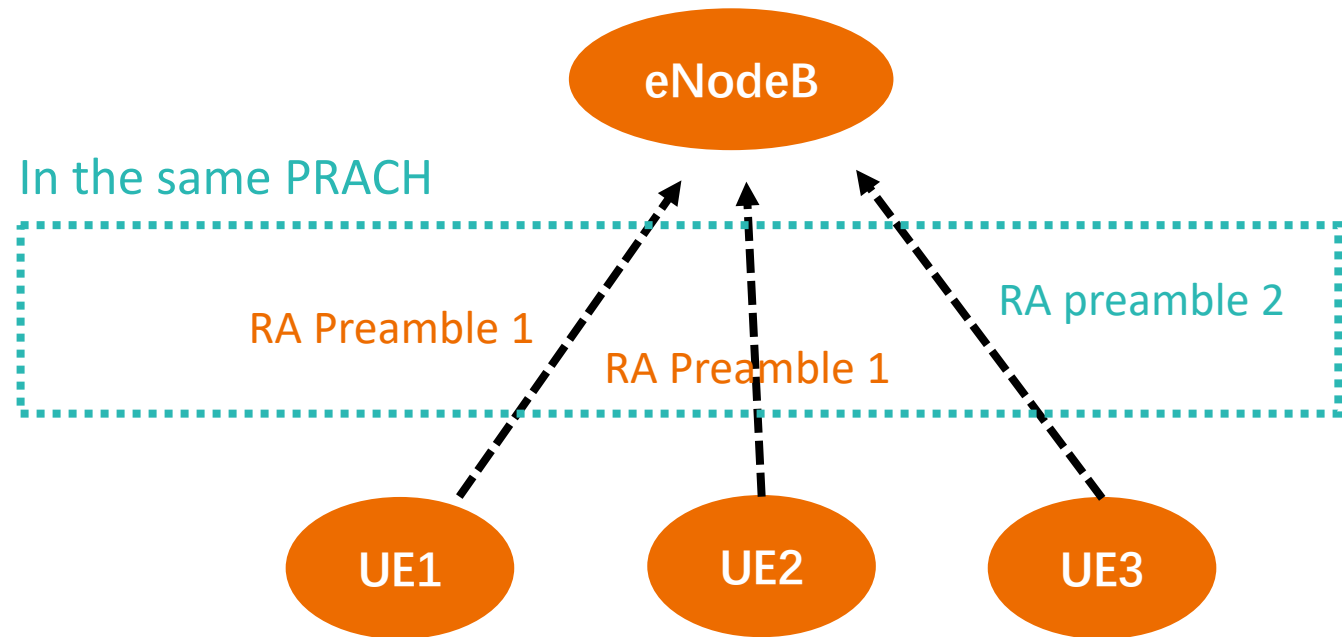
< 36.211 Table 5.7.1-1: Random access preamble parameters >

# Up to Now

- If multiple UEs transmit in different PRACHs or with different preambles in the same PRACHs
- The BS can differentiate them (Contention Solved)
- If multiple UEs transmit with the same preamble in the same PRACH
- The BS can detect this preamble, but not sure on the UE number (Contention Unsolved)

# Message 1: Preamble Transmission

- All UEs randomly select one preamble
- UE1 collides with UE2, UE3 can be differentiated from UE1 and UE2, thanks to the orthogonality of preambles
- For eNB, it sees two different preambles

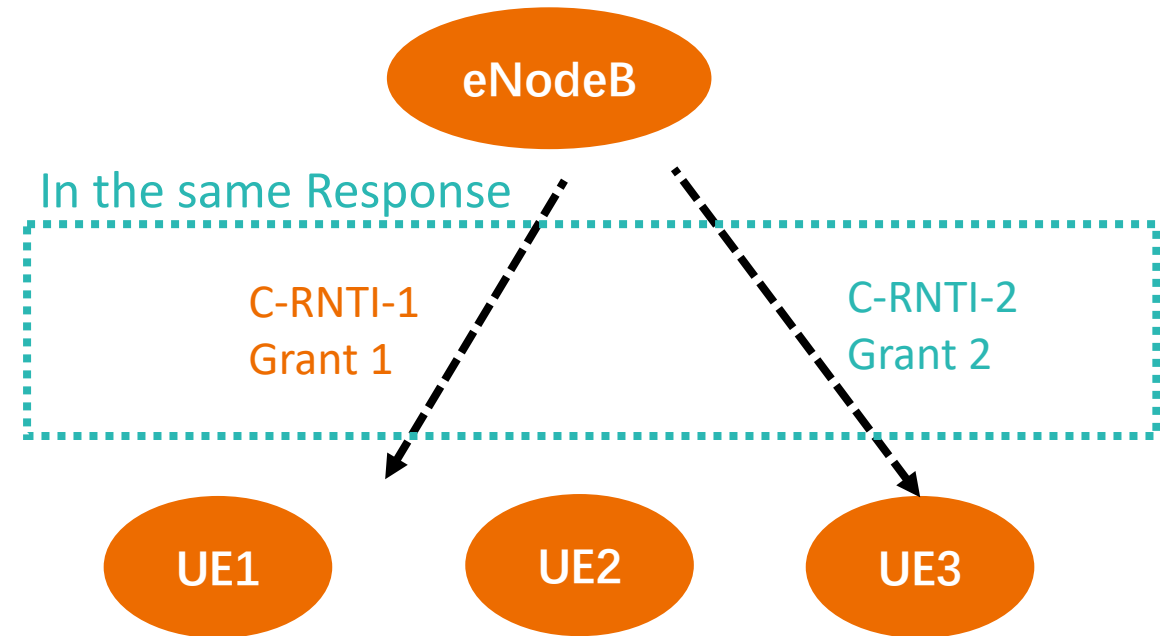


# RA-RNTI

- The BS gives the UE or (UEs) in the same PRACH one RA-RNTI, for downlink transmission indication
- UE1, 2 and 3 are assigned with same RA-RNTI, say RA-RNTI-1
- The RA-RNTI associated with the PRACH is computed as (TS 36.321, 5.1.4):  
$$\text{RA-RNTI} = 1 + t\_id + 10 * f\_id$$
- Where  $t\_id$  is the index of the first subframe of the specified PRACH ( $0 \leq t\_id < 10$ ), and  $f\_id$  is the index of the specified PRACH within that subframe, in ascending order of frequency domain ( $0 \leq f\_id < 6$ ). For FDD,  $f\_id$  is fixed as 0.
- In our previous FDD example, RA-RNTI = 2

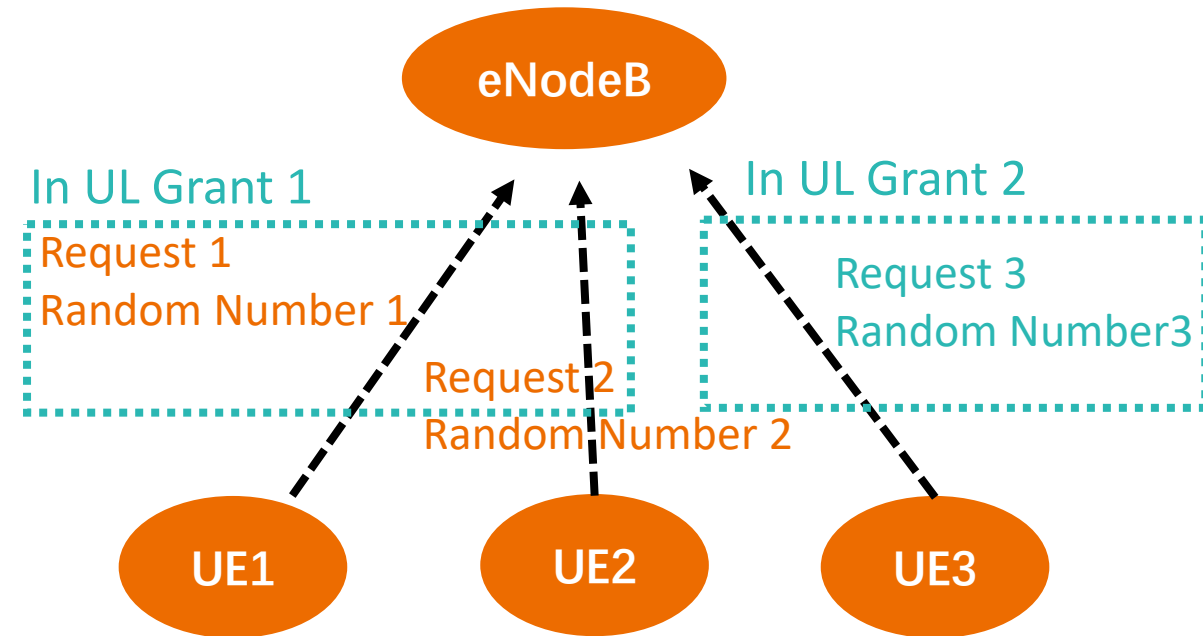
# Message 2: RA Response

- eNodeB sees two preambles, it assigns **temporary C-RNTIs** to both
- eNodeB sends **one RA response** in **PDSCH** indicating the reception of the previous PRACH
- The **DCI** is masked by **RA-RNTI-1**
- In the response, **Preamble 1 and 2** are assigned with **C-RNTI-1** and **C-RNTI-2**, each with uplink resource grant, say **UL Grant 1** and **Grant 2**.



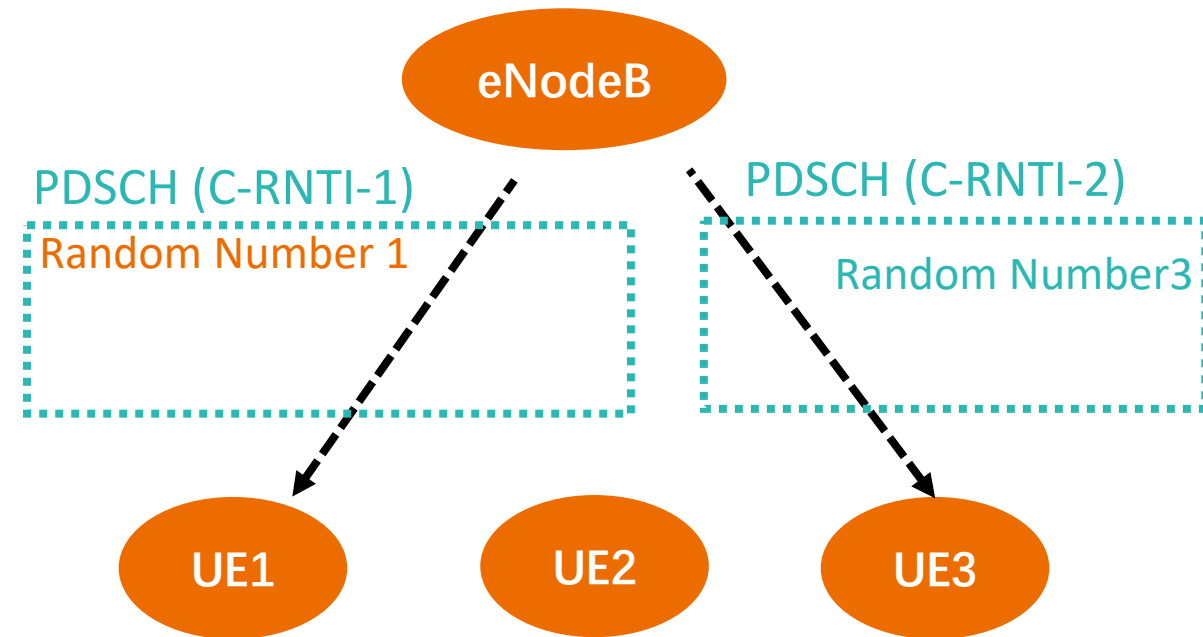
# Message 3: RRC Connection Request

- All UEs send RRC connect request message + local random number
- UE3 sends request in dedicated UL grant, successful reception
- UE1 and UE2's requests collide



# Message 4: RRC Connection Setup

- eNodeB replies with RRC connection setup message, including the received random number
- In the RRC connection setup message, if Random Number 1 is received, UE2 detects its failure in contention.



# Homework

## Assignment 6