Random Access of Cellular Systems

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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)**

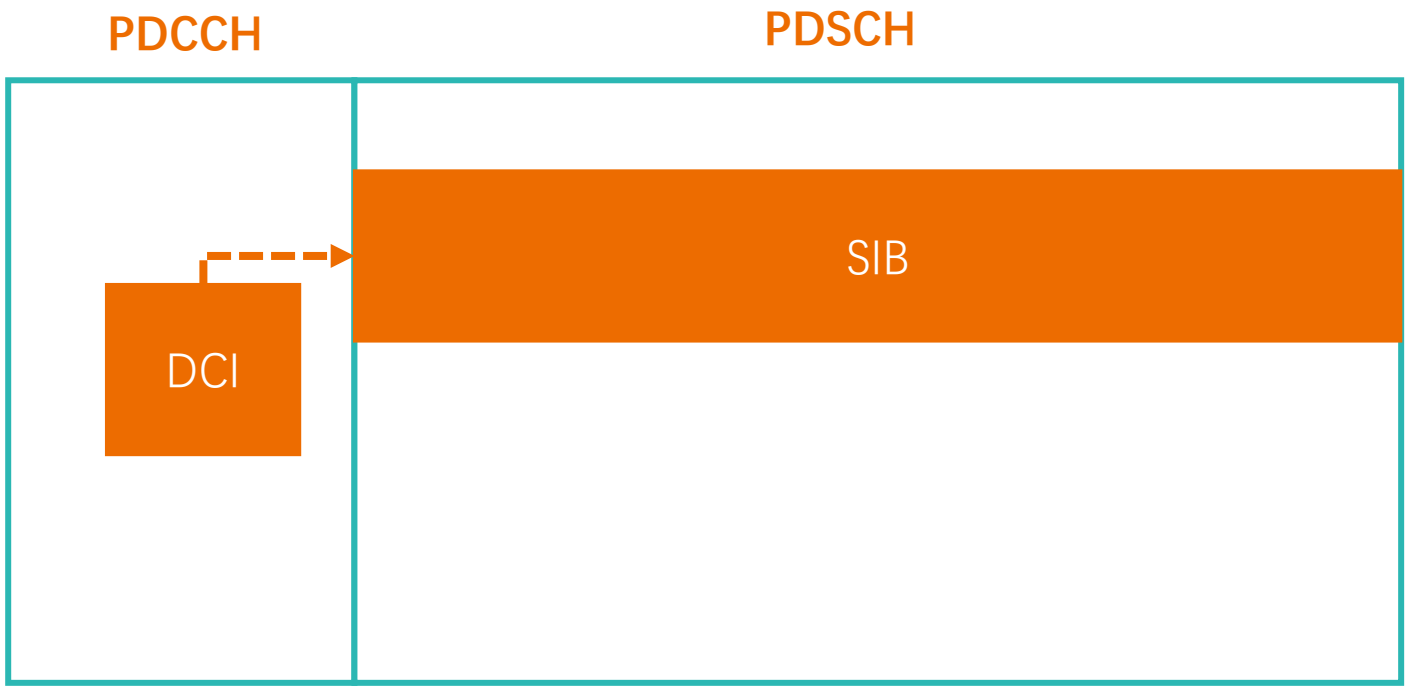
36.321-c70 Table 7.1-1: RNTI values

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.

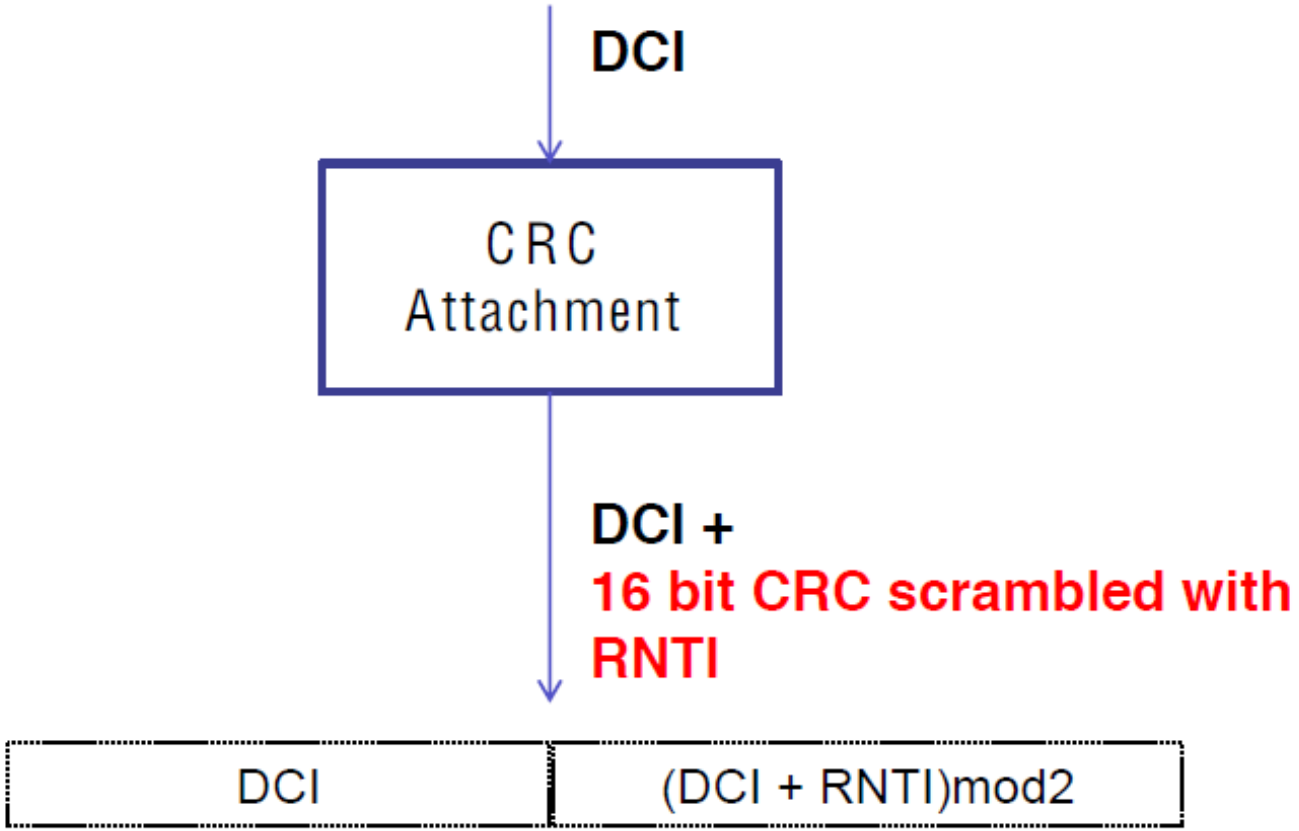
SIB (TS36.331)

- SIB is sent by PDSCH



Recap: Whose PDCCH?

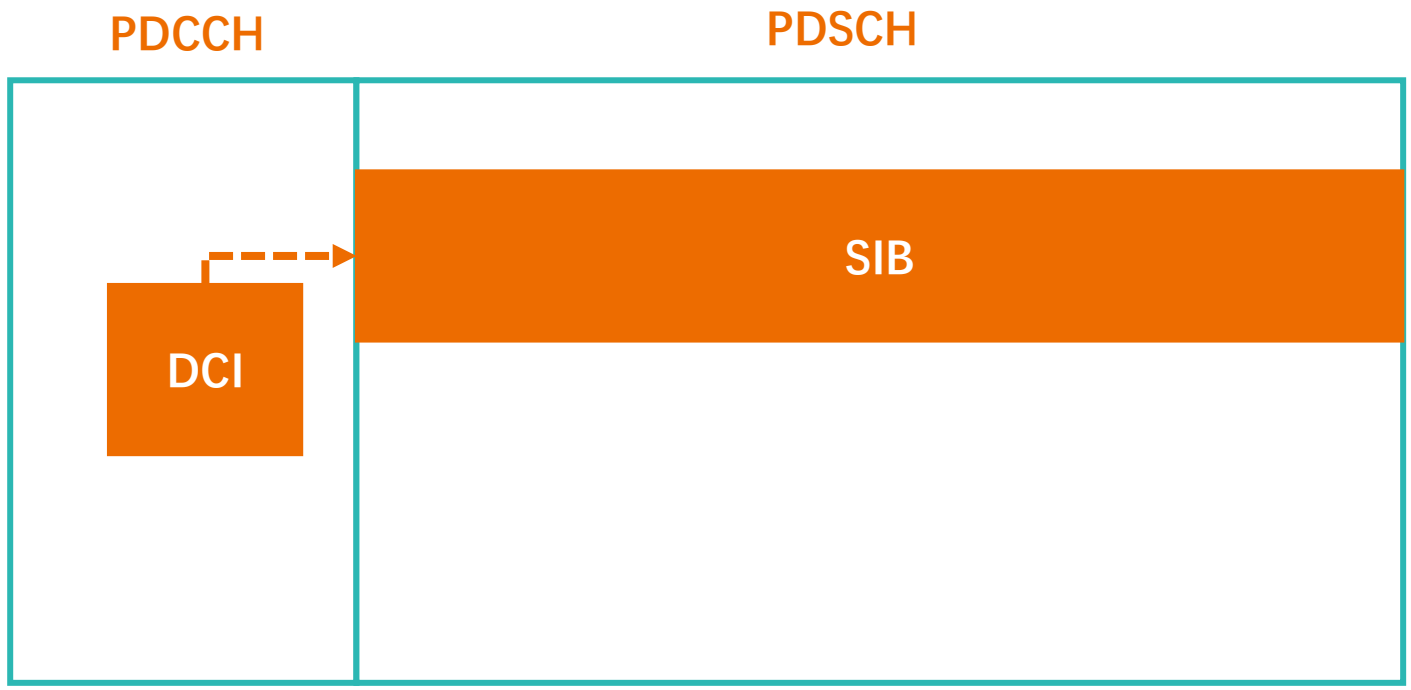
✓ With RNTI (Radio Network Temporary Identifier) : User Identification



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

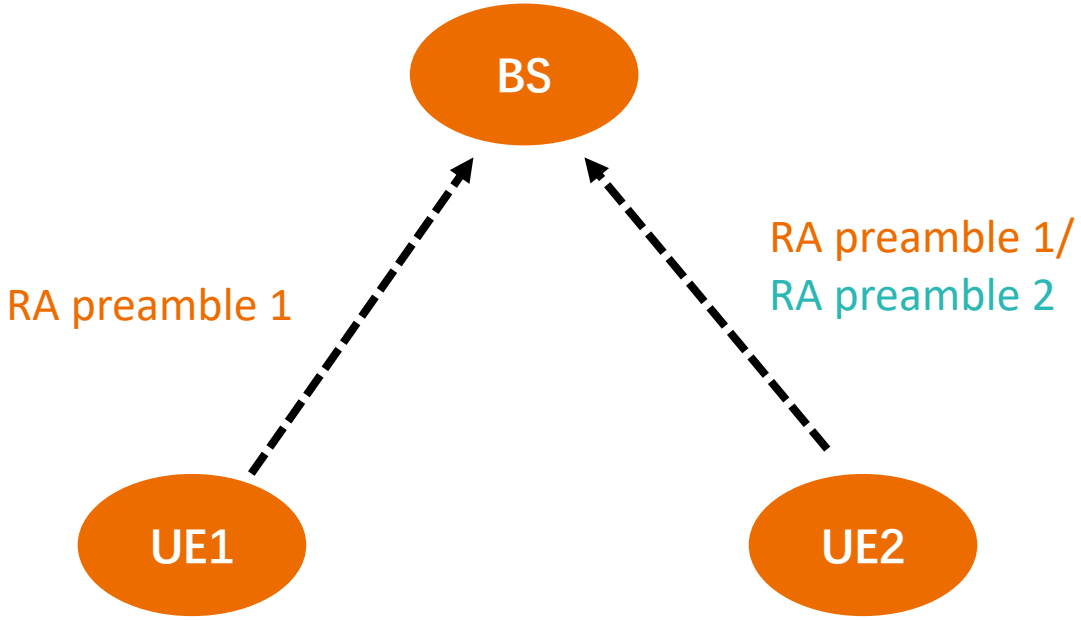
- In IEEE802.11, the access requests of multiple STAs can be resolved via **CSMA/CA** mechanism.
  - Contention is resolved via **random backoff**.

- 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

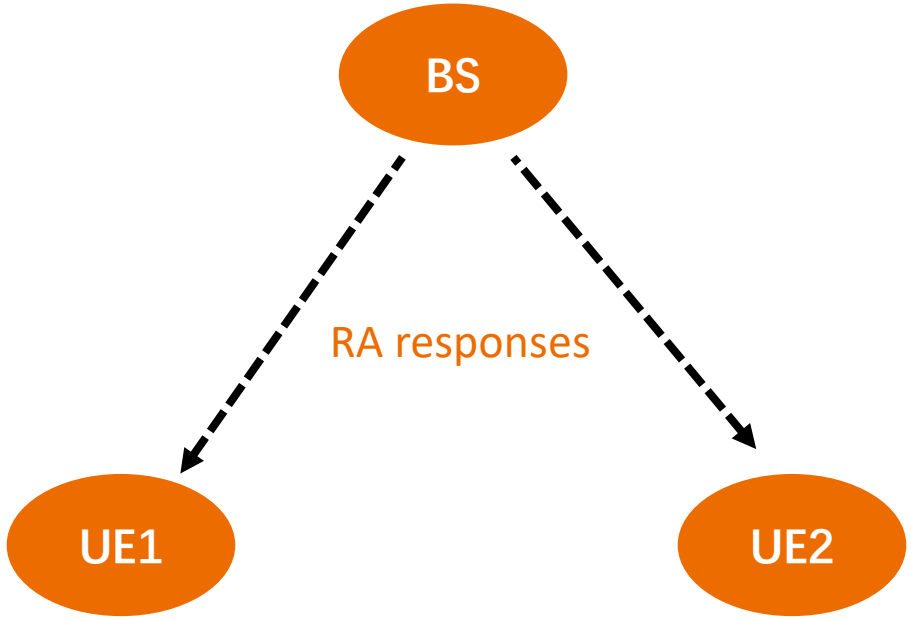
- UEs transmits RA preambles to BS in PRACH
- UEs are separated via different preambles and transmission time-frequency
- But collision is still possible



Random Access

- Contention-based RA is necessary for one mobile device just powered on

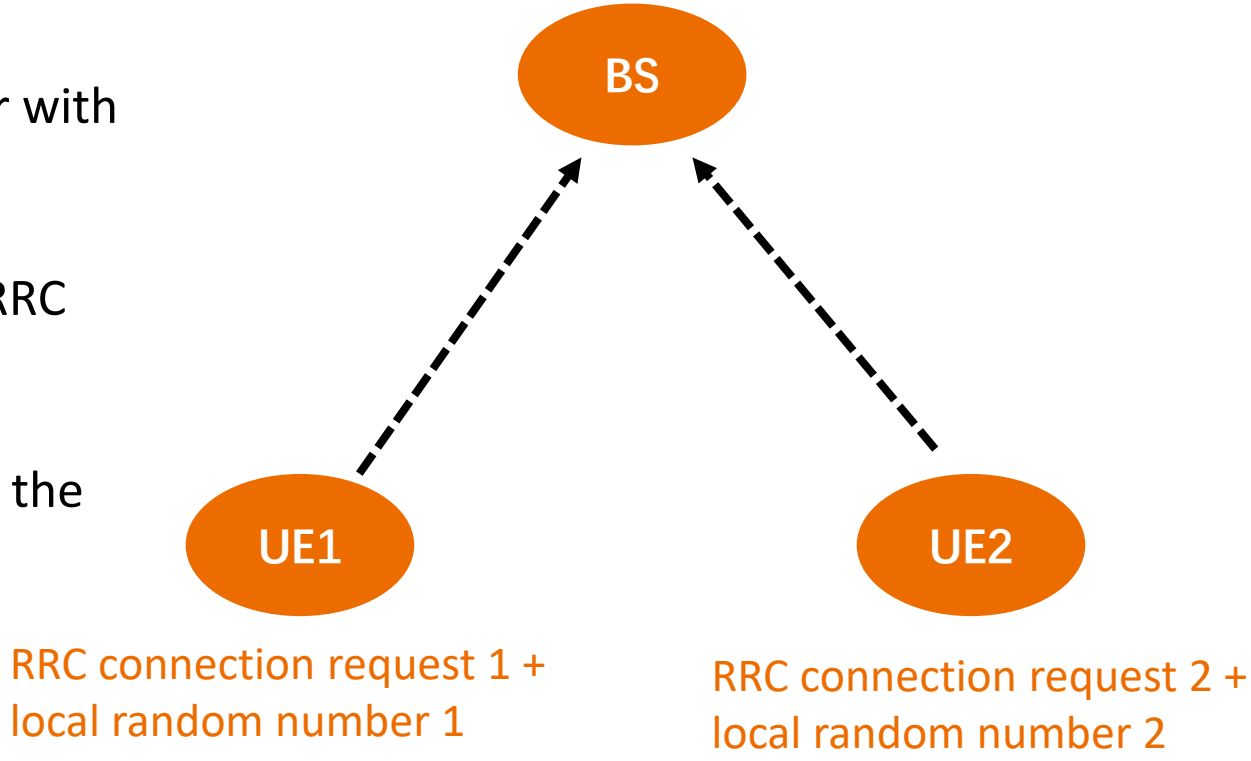
- BS replies with RA responses, indicating the UL transmission opportunities for further handshaking
- If two UEs can be separated, the following random access has no problem
- Otherwise, contention is still unsolved



Random Access

- Contention-based RA is necessary for one mobile device just powered on

- UEs transmits 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)
            preamblesGroupAConfig
               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
```

TS 36.211

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

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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 1st subframe

BS broadcasts SIB2 periodically:

```
sib2
   radioResourceConfigCommon
      rach-ConfigCommon
         preambleInfo
            numberOfRA-Preambles: n52 (12)
            preamblesGroupAConfig
               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
```

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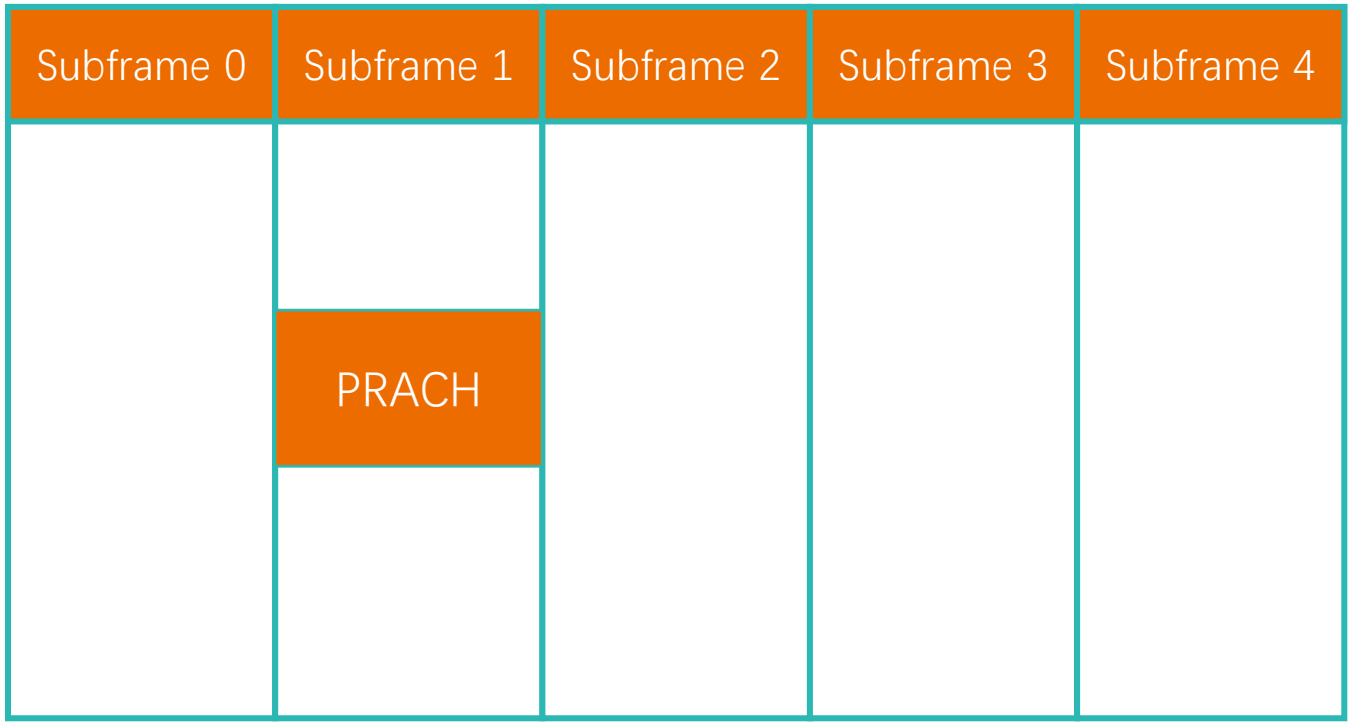
Exact Location of PRACH

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



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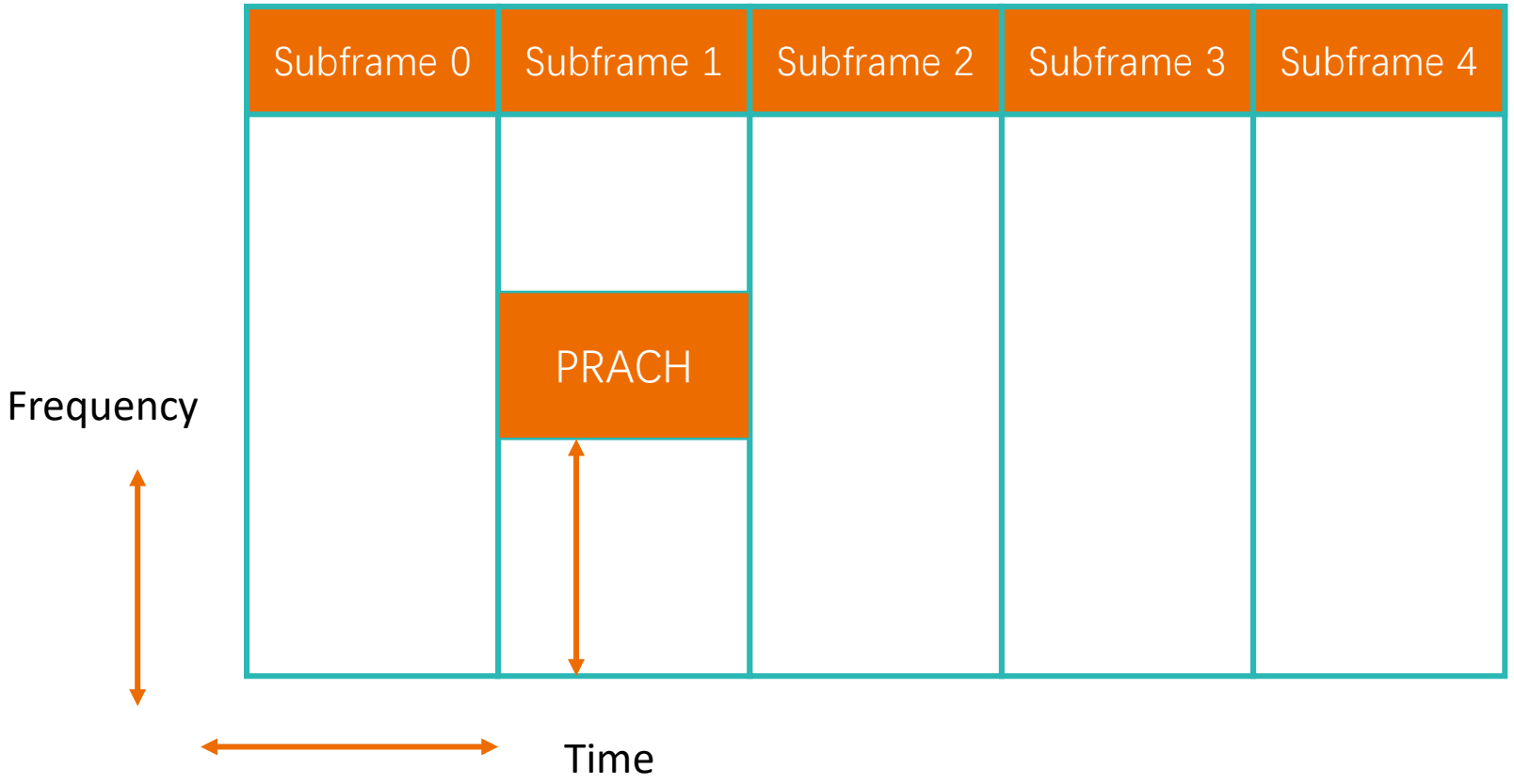

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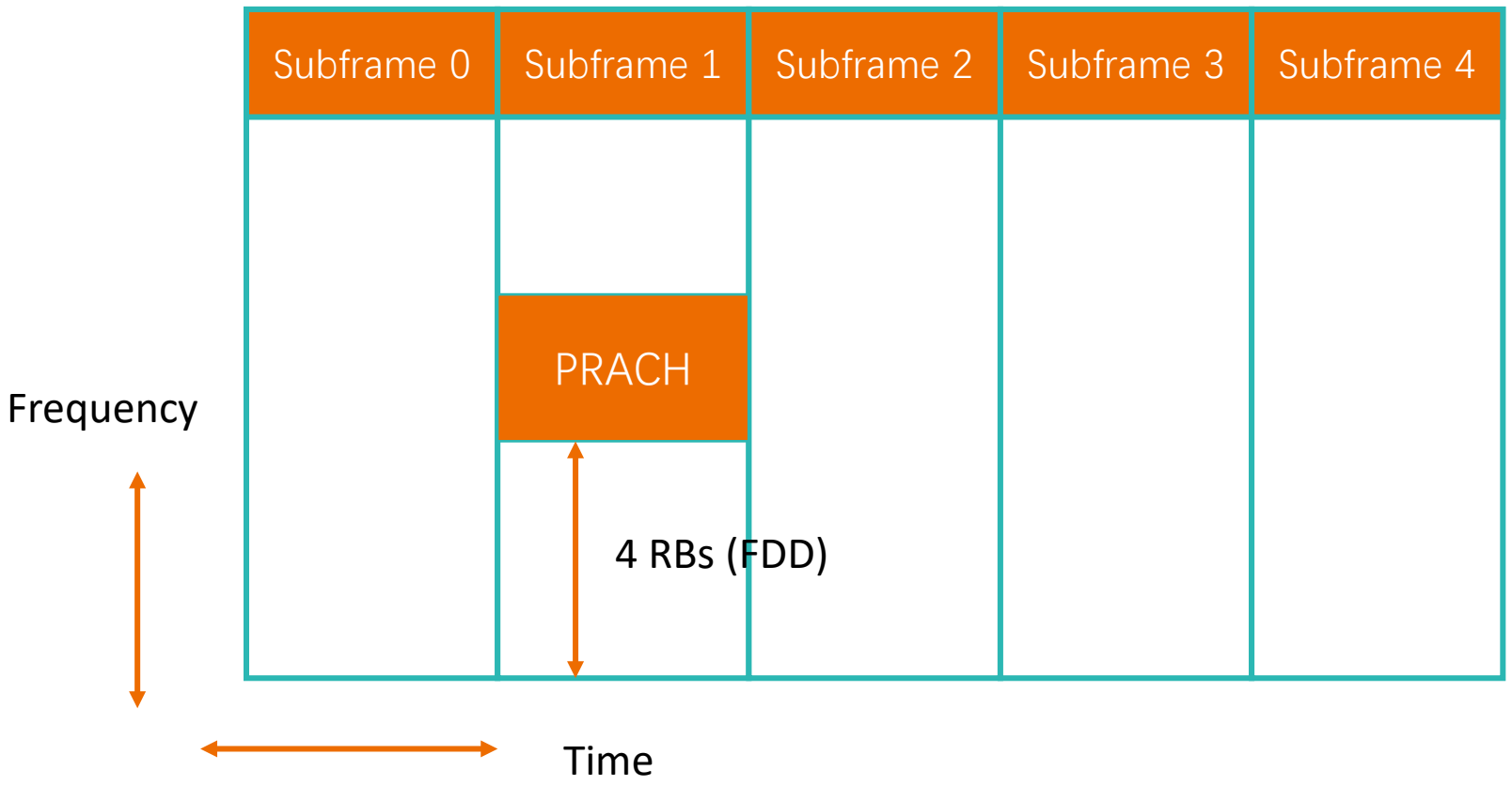


```
sib2
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      rach-ConfigCommon
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            preambleInitialReceivedTargetPower: dBm-104 (8)
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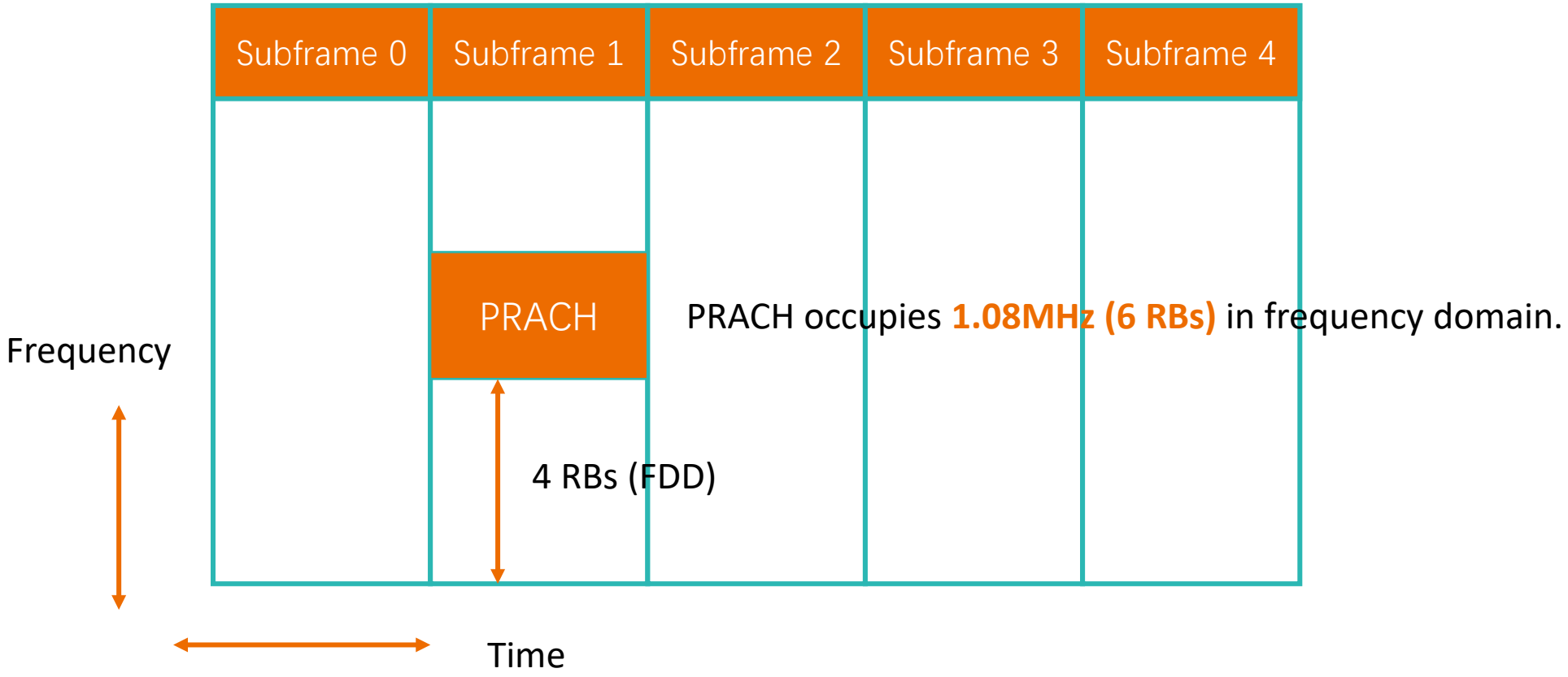

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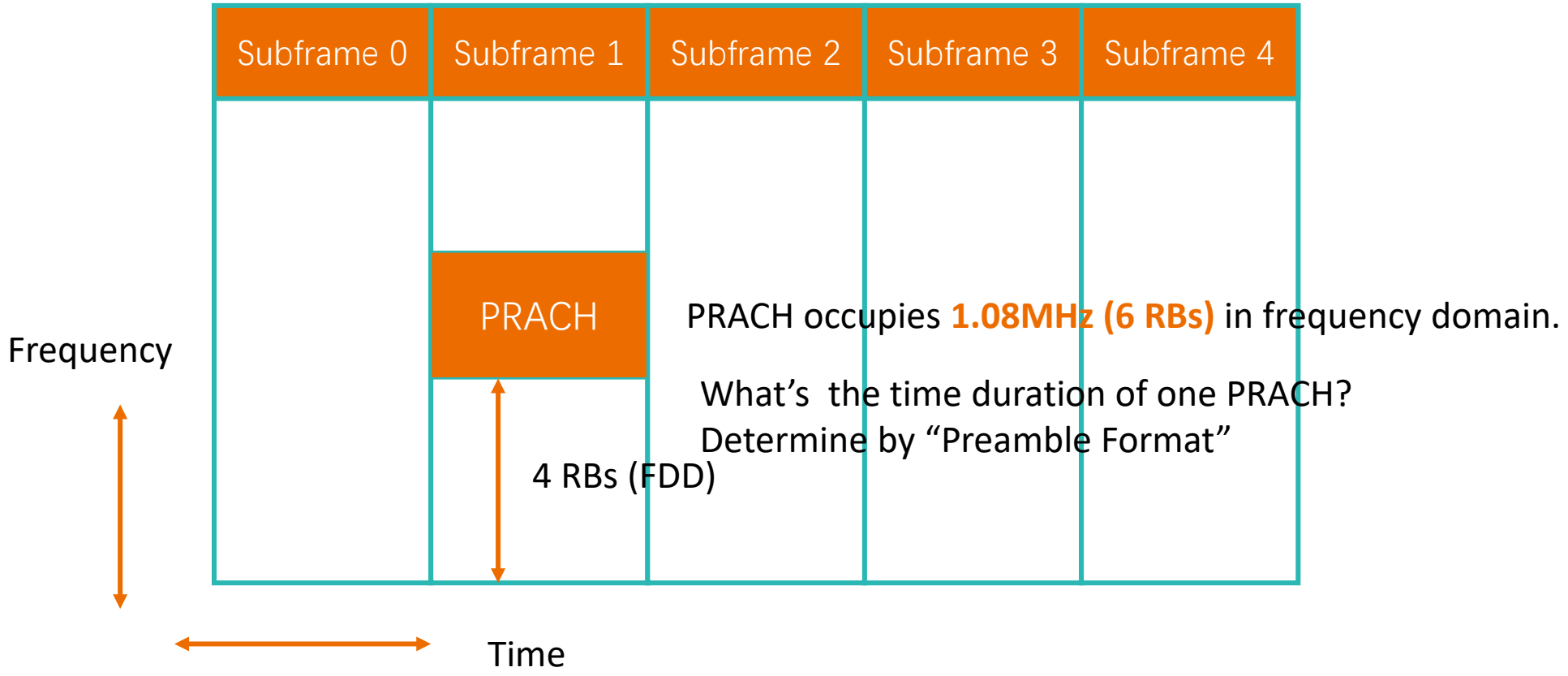
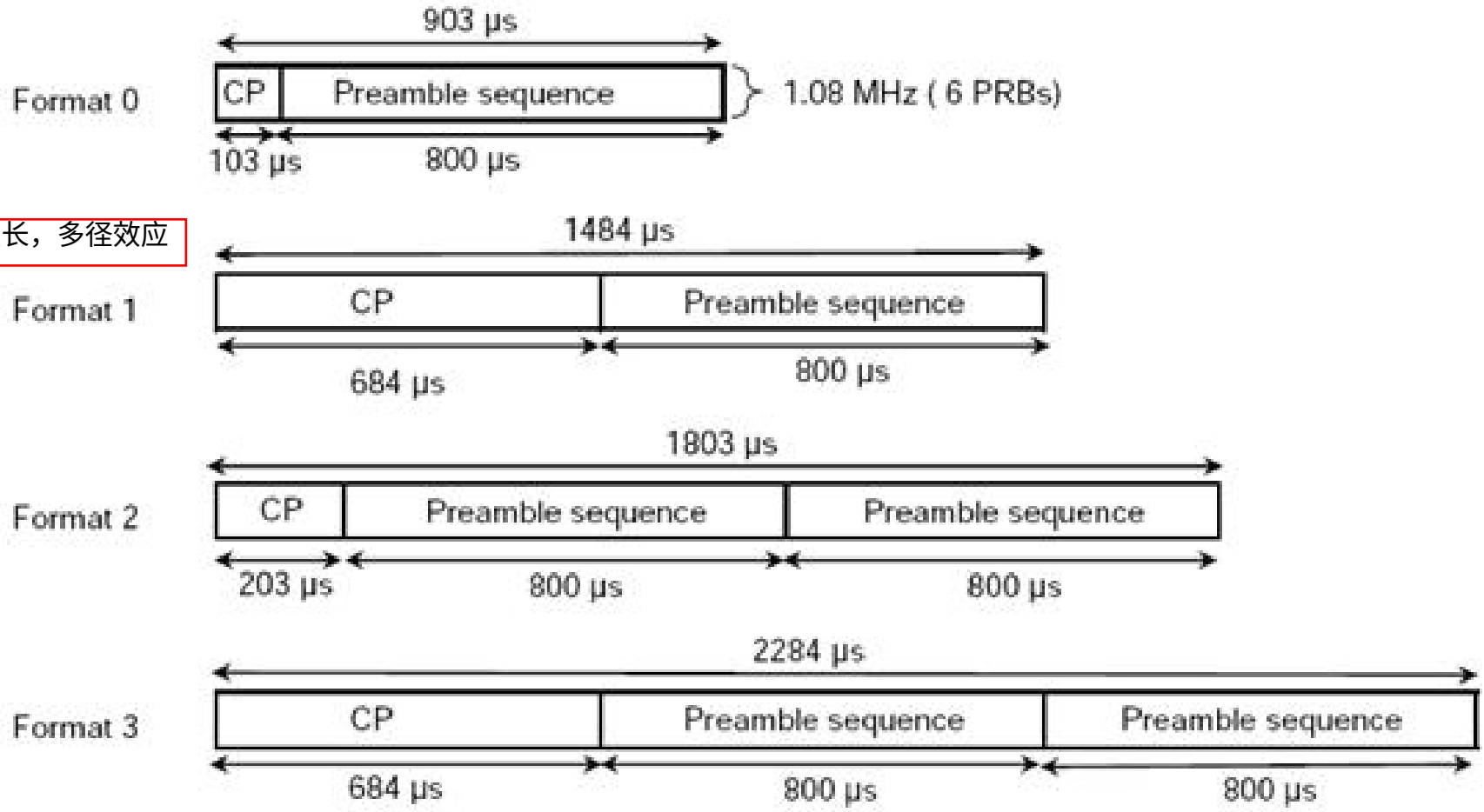


PRACH occupies **1.08MHz (6 RBs)** in frequency domain.

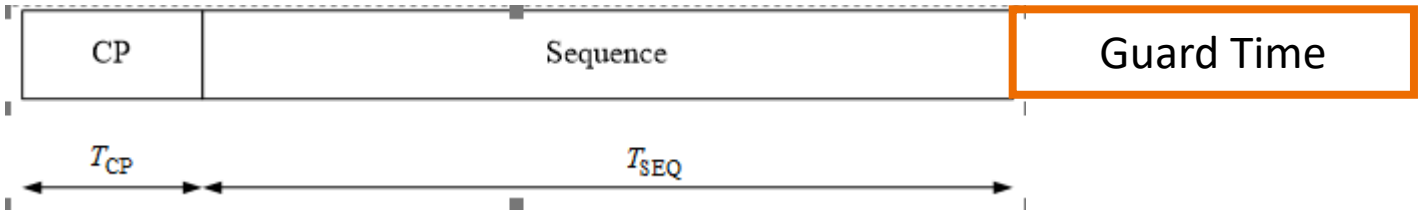
What's the time duration of one PRACH?
Determine by "Preamble Format"

Preamble Formats



Preamble Formats

- Preamble is transmitted in PRACH

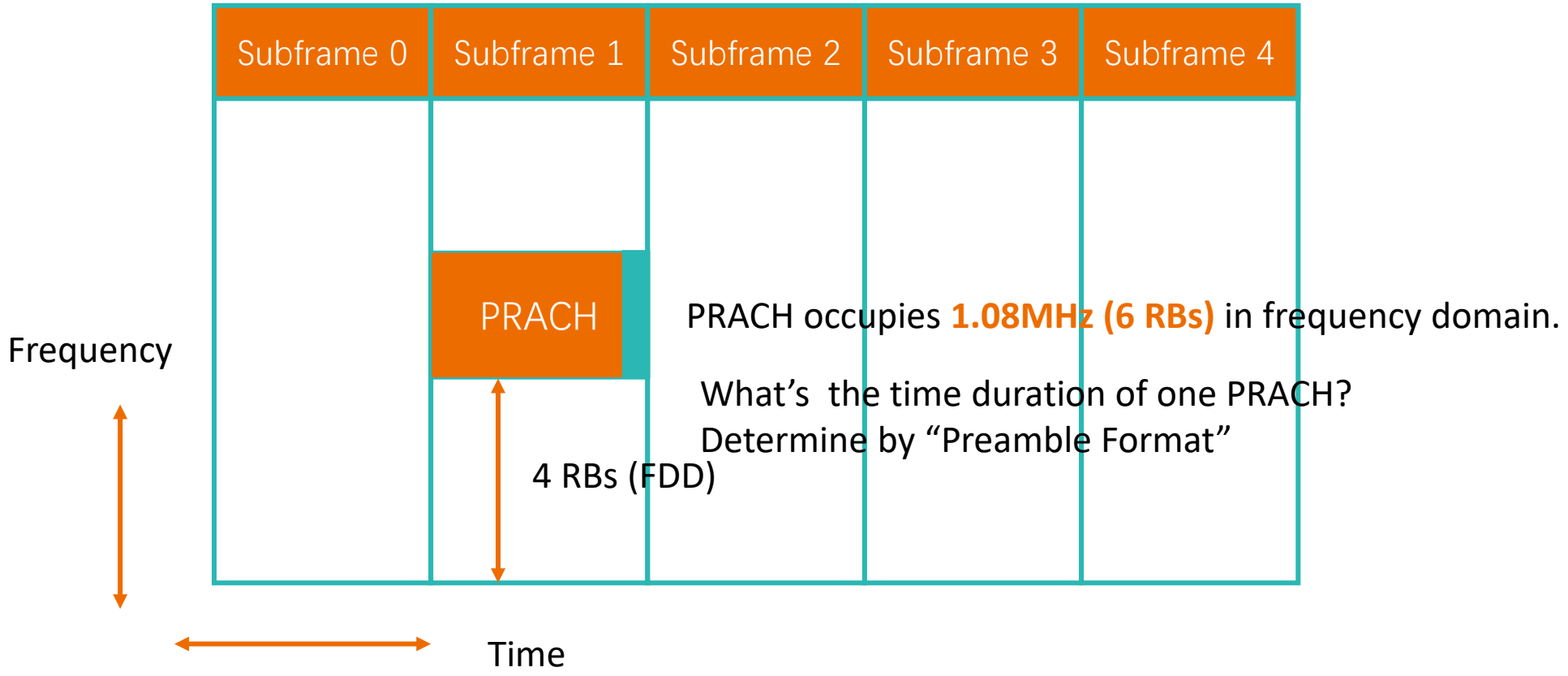


占据多少个subframe　剩余时间，不用了

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



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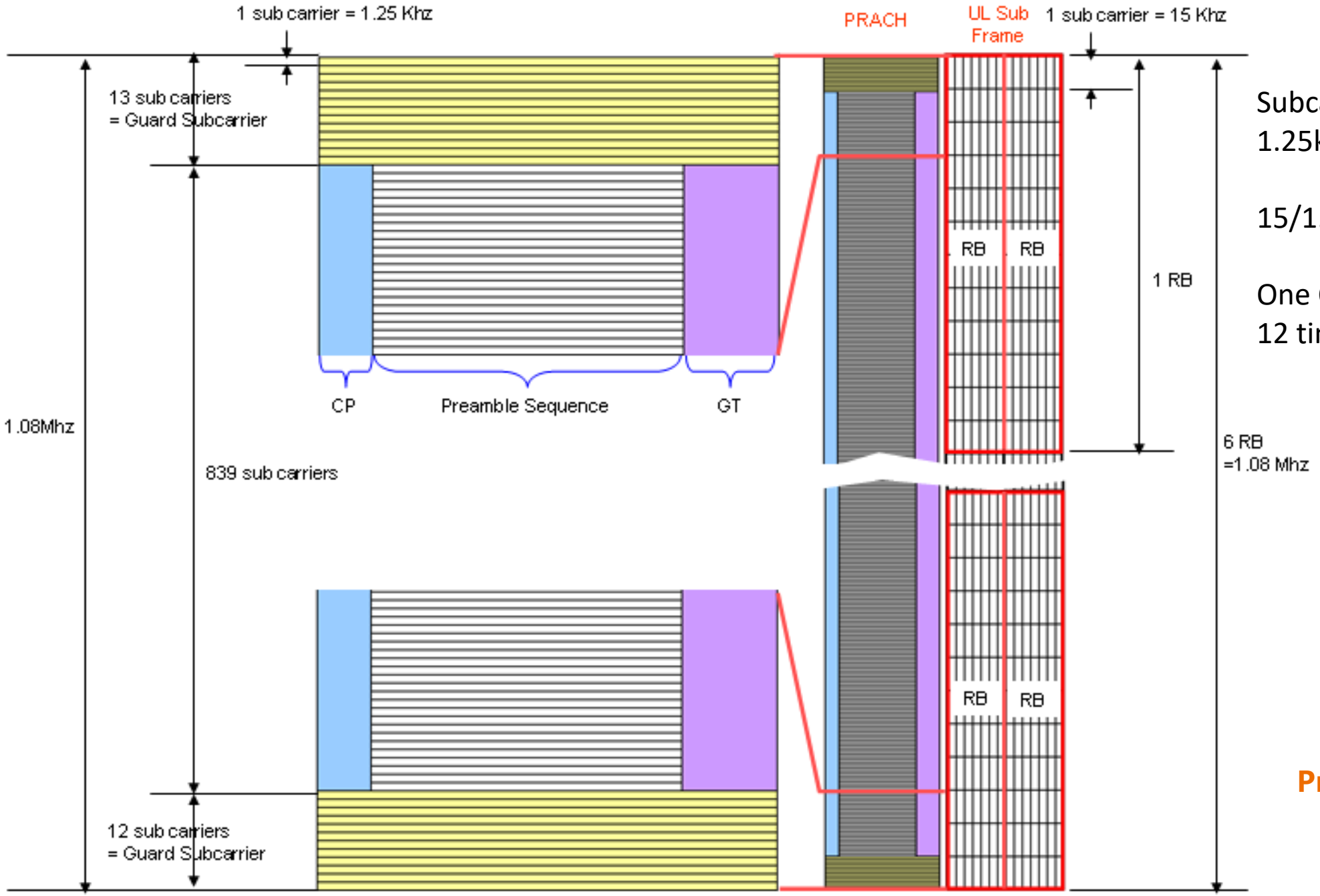


Subcarrier spacing for PRACH = 1.25khz

15/1.25 = 12

One OFDM symbol for PRACH is 12 times longer

Preamble Format 0

Baseband Signal Generation

Preamble format	N_{ZC}
0 – 3	839
4	139

PRACH Sequence in Time Domain

Zaddoff Chu Sequence

$$K = \Delta f / \Delta f_{RA}$$

$$k_0 = n_{PRB}^{RA} N_{sc}^{RB} - N_{RB}^{UL} N_{sc}^{RB} / 2$$

$$s(t) = \beta_{PRACH} \sum_{k=0}^{N_{ZC}-1} \left[\sum_{n=0}^{N_{ZC}-1} x_{u,v}(n) \cdot e^{-j\frac{2\pi nk}{N_{ZC}}} \right] \cdot e^{j2\pi(k+\varphi+K(k_0+1/2))\Delta f_{RA}(t-T_{CP})}$$

$$0 \le t < T_{SEQ} + T_{CP}$$

DFT of Zadoff-Chu sequences (64 Choices)

Preamble format	T_{CP}	T_{SEQ}
0	$3168 \cdot T_s$	$24576 \cdot T_s$
1	$21024 \cdot T_s$	$24576 \cdot T_s$
2	$6240 \cdot T_s$	$2 \cdot 24576 \cdot T_s$
3	$21024 \cdot T_s$	$2 \cdot 24576 \cdot T_s$
4*	$448 \cdot T_s$	$4096 \cdot T_s$

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

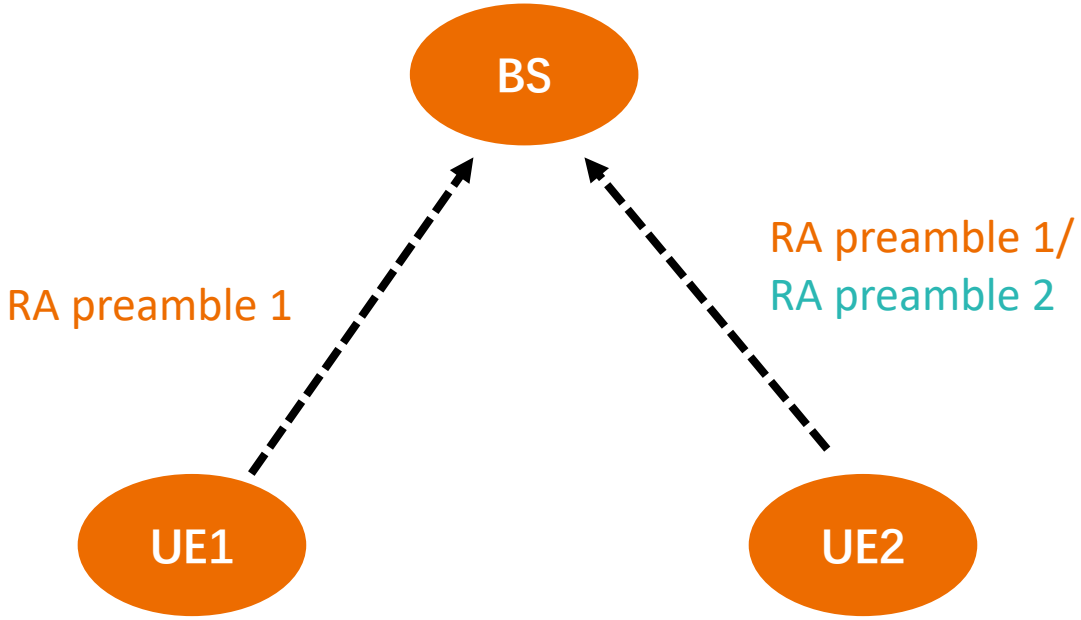
Preamble format	Δf_{RA}	φ
0 – 3	1250 Hz	7
4	7500 Hz	2

36.211 Table 5.7.3-1: Random access baseband parameters

Recap: Random Access

- Contention-based RA is necessary for one mobile device just powered on

- UEs transmits RA preambles to BS in PRACH
- UEs are separated via different preambles and transmission time-frequency
- But collision is still possible



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)

当基站和用户都算出来RNTI后，基站给每一个prem分配后续的空间（时频资源）

RA-RNTI

代表了全部用户的信息，也可以是某一组特定用户的信息

- The BS gives the UE or (UEs) in the same PRACH one RA-RNTI, for downlink transmission indication

subframe的index

- The RA-RNTI associated with the PRACH is computed as (TS 36.321, 5.1.4):

  RA-RNTI = 1 + t_id + 10 * f_id

- Where t_id is the index of the first subframe of the specified PRACH ($0 \le t\_id < 10$), and f_id is the index of the specified PRACH within that subframe, in ascending order of frequency domain ($0 \le f\_id < 6$). For FDD, f_id is fixed as 0.

- In our previous FDD example, RA-RNTI = 2