Physical DL Control Channel
“Resource Allocation”

Optimization

Technology

Mohamed Eladawi

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What is the primary function of PDCCH?

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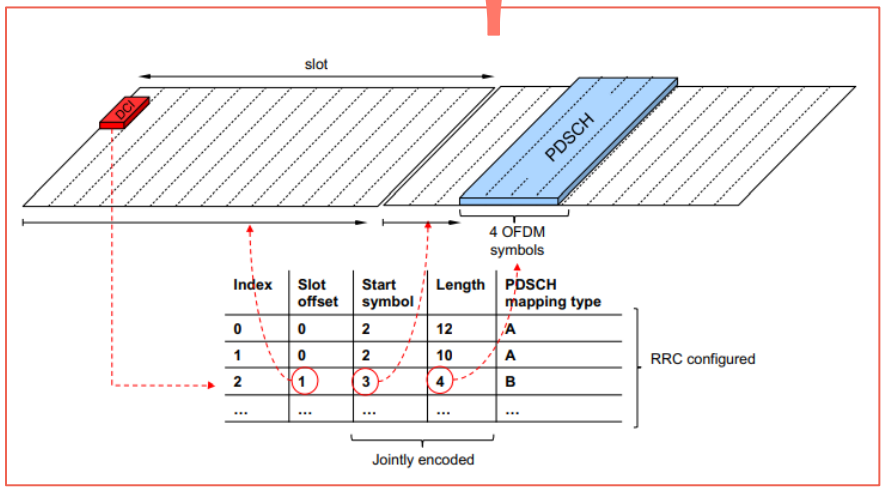
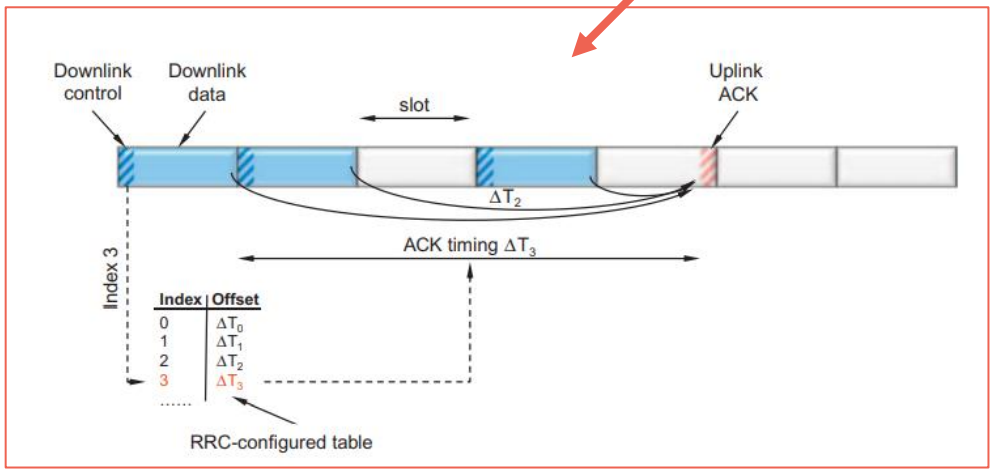
DCI
Main Contents

- **Frequency domain Resource Assignment**
  - Set of Resource Blocks for PDSCH or PUSCH
- **Time domain Resource Assignment**
  - 1- Starting Symbol
  - 2- Number of allocated Symbols
  - 3- Slot Offset
- **Modulation and Coding Scheme**
  - Define which MCS Table to be used
  - Example: 64QAM / 256QAM
- **HARQ**
  - 1-HARQ feedback timing
  - 2-Hybrid-ARQ process number
- **PUCCH-related information**
  - 1-PUCCH power Control
  - 2-PUCCH resource indicator





Differences between 4G & 5G PDCCH

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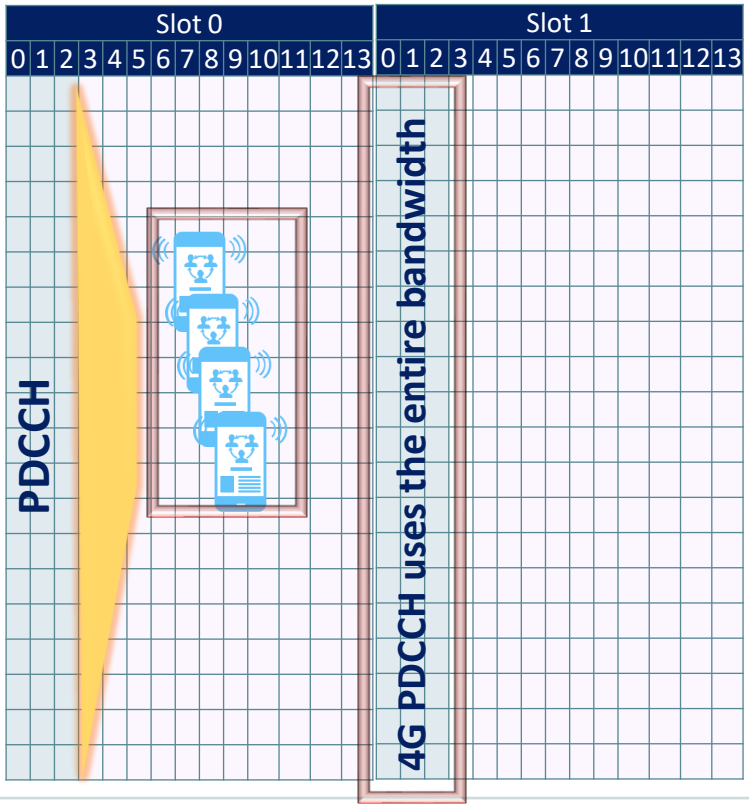
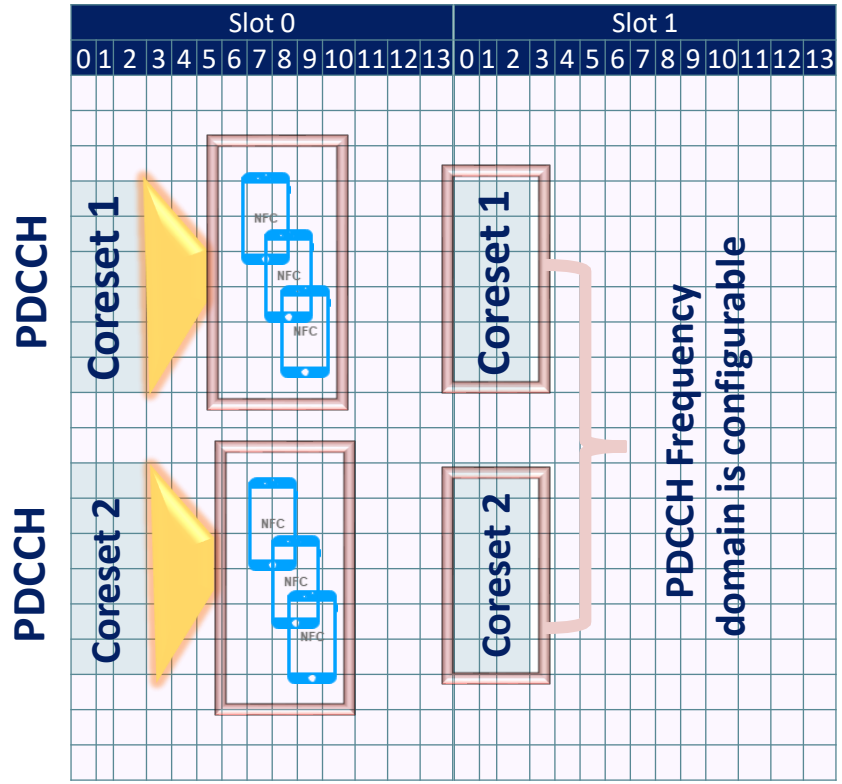
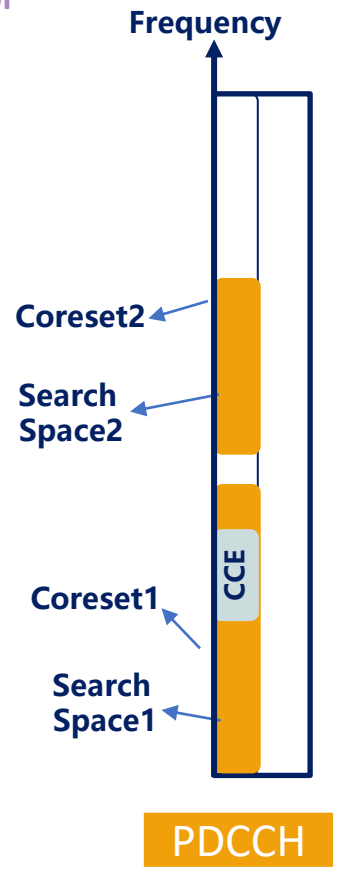
In general, NR PDCCH provides the same functions as LTE PDCCH; however, Some new aspects related to PDCCH have been introduced in 5G, such as CORESET, which will be introduced in detail in the following sections.

In LTE, PDCCH control channels are always distributed across the entire system bandwidth.



NR PDCCHs are designed to transmit in a configurable control resource set (Called CORESET).





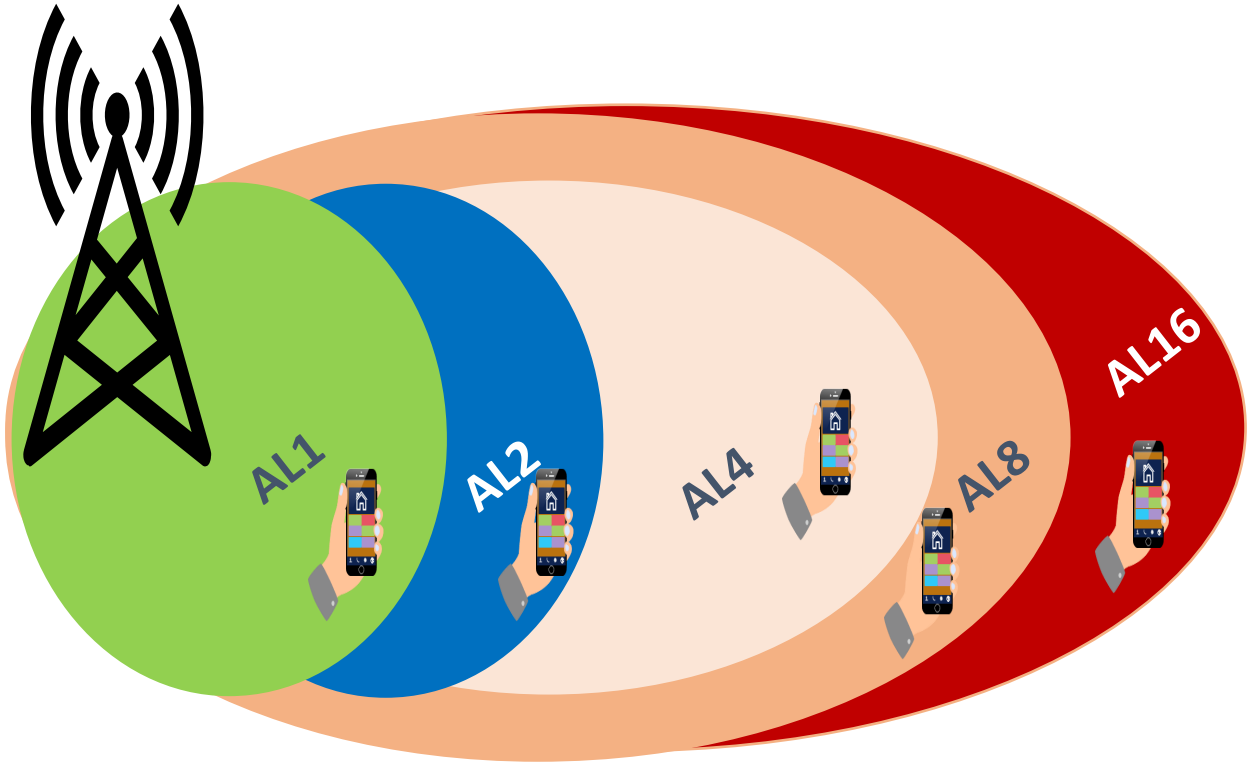
The time domain is configurable in both 4G & 5G: first 1~3 OFDM symbols of each slot.

PDCCH Resources

1 CCE = 6 REG & 1 REG = 1Resource block

Aggregation Level	CCE	Resource Element Groups(REG)	Resource Elements
1	1	6	72
2	2	12	144
4	4	24	288
8	8	48	576
16	16	96	1152

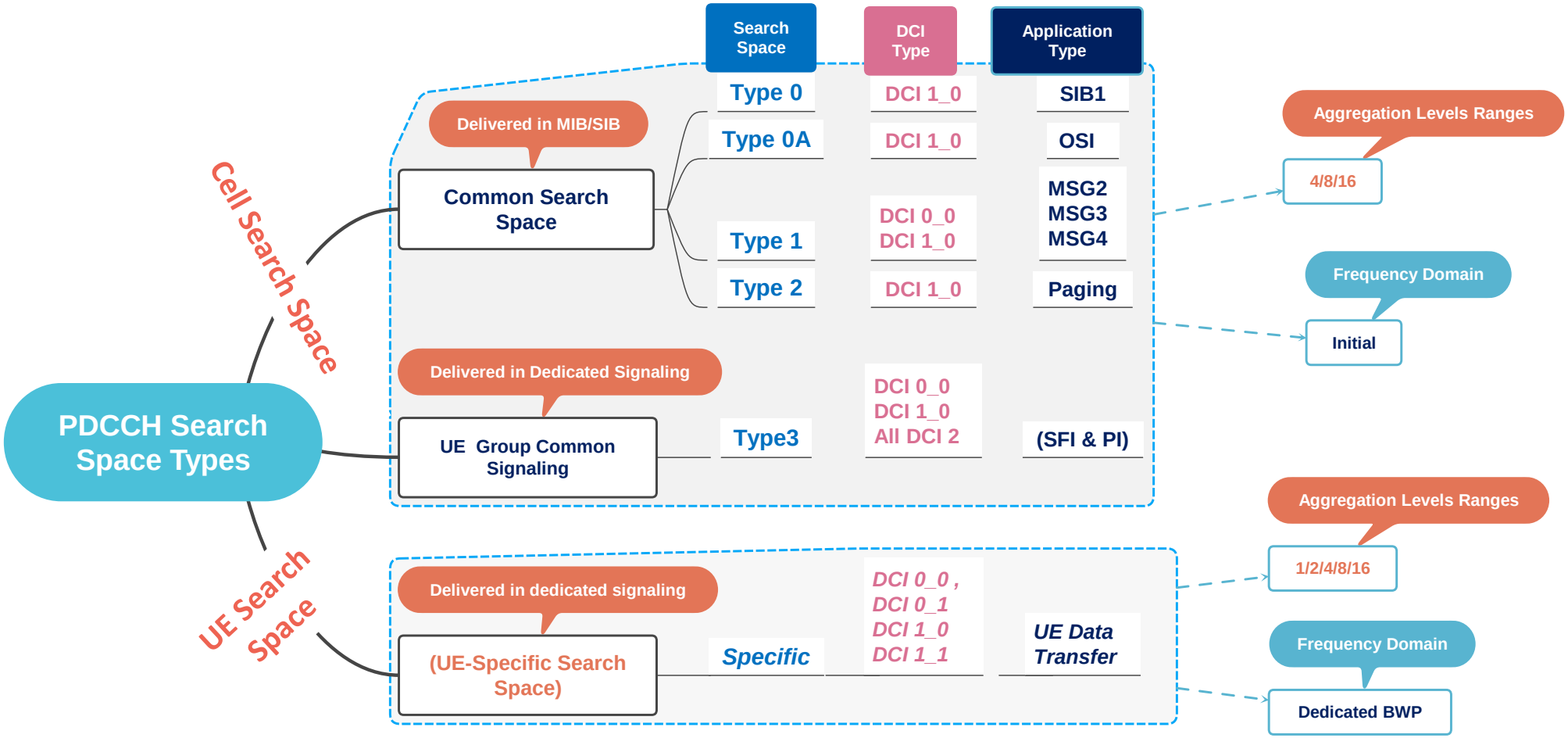
The Higher Aggregation Level → The Worst the Coverage



*CCE: Control channel elements

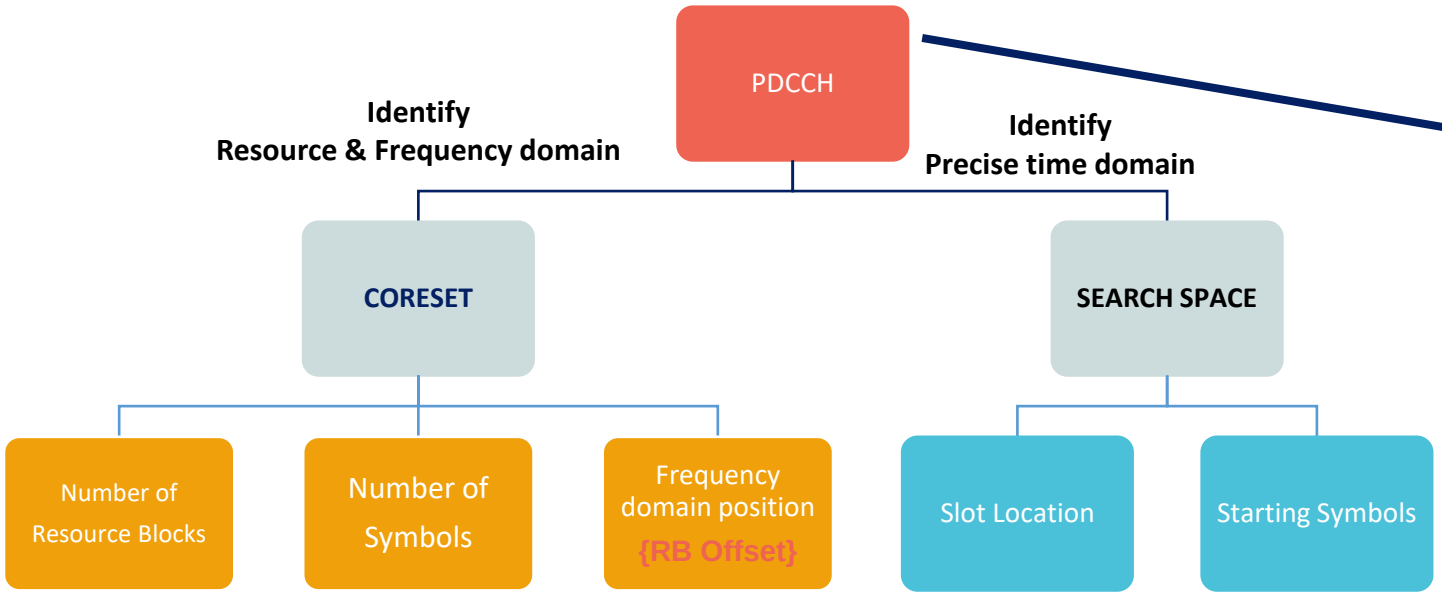
Search Space Types mapping into DCI different Types and Application

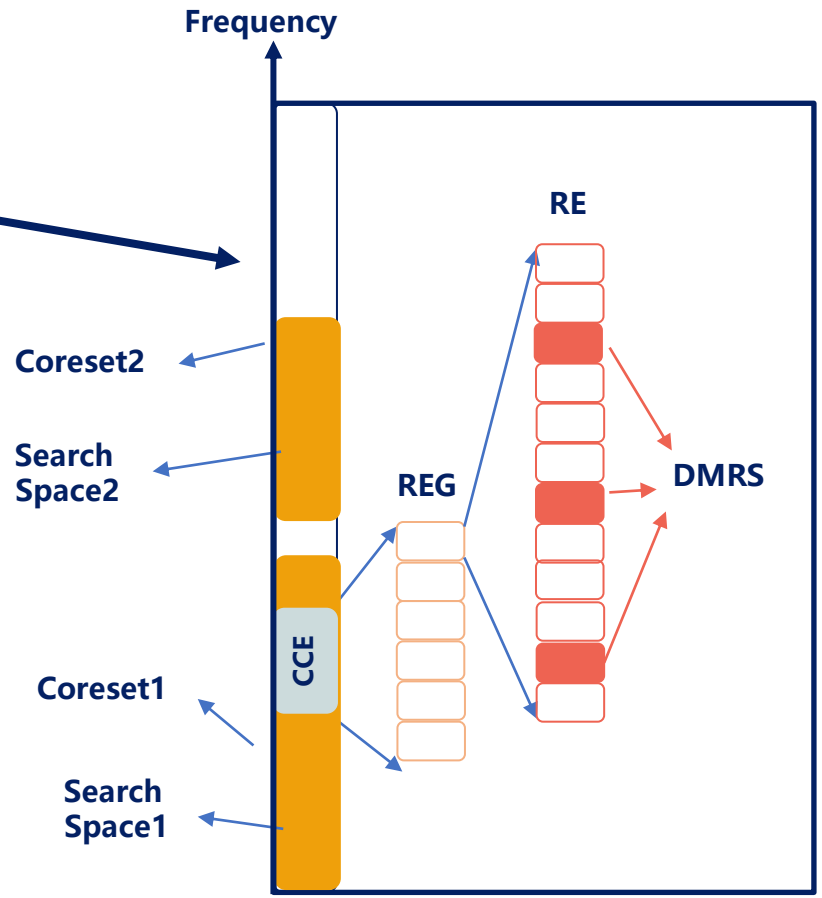
UE Scans Search Space to be able to deduce the required DCI Format and application type; the following figure covers the details regarding Search Spaces types, mapping with DCI Format and application type, required aggregation levels range, and Messages carrying Search Space resources.



CORESET & SEARCH SPACE Main functions

- gNB transmits PDCCH using resource elements belonging to a Control Resource Set(CORESET).
- A Search Space uses CORESET to define the specific Resource Blocks and Symbols where the UE attempts to decode the PDCCH.
- The Frequency & Time domain position of the PDCCH is identified by CORESET & SEARCH SPACE(Information included in MIB)





- a Maximum of 3 CORESET can be configured for an active downlink Bandwidth Part.
- The Precise timing of CORESET is defined within the Search Space Set configuration to allow Multiple Search Space Sets to re-use the same CORESET but with different timings.

Frequency Domain Resource Allocation(SIB1)

gNB transmits core information element inside MIB message which is used as a pointer within 3GPP Specified tables to identify Frequency & Time domain Positions.

(1) MIB Message and 3GPP Specified table

MIB

PDCCH-Config

ControlResourceSetZero (0)

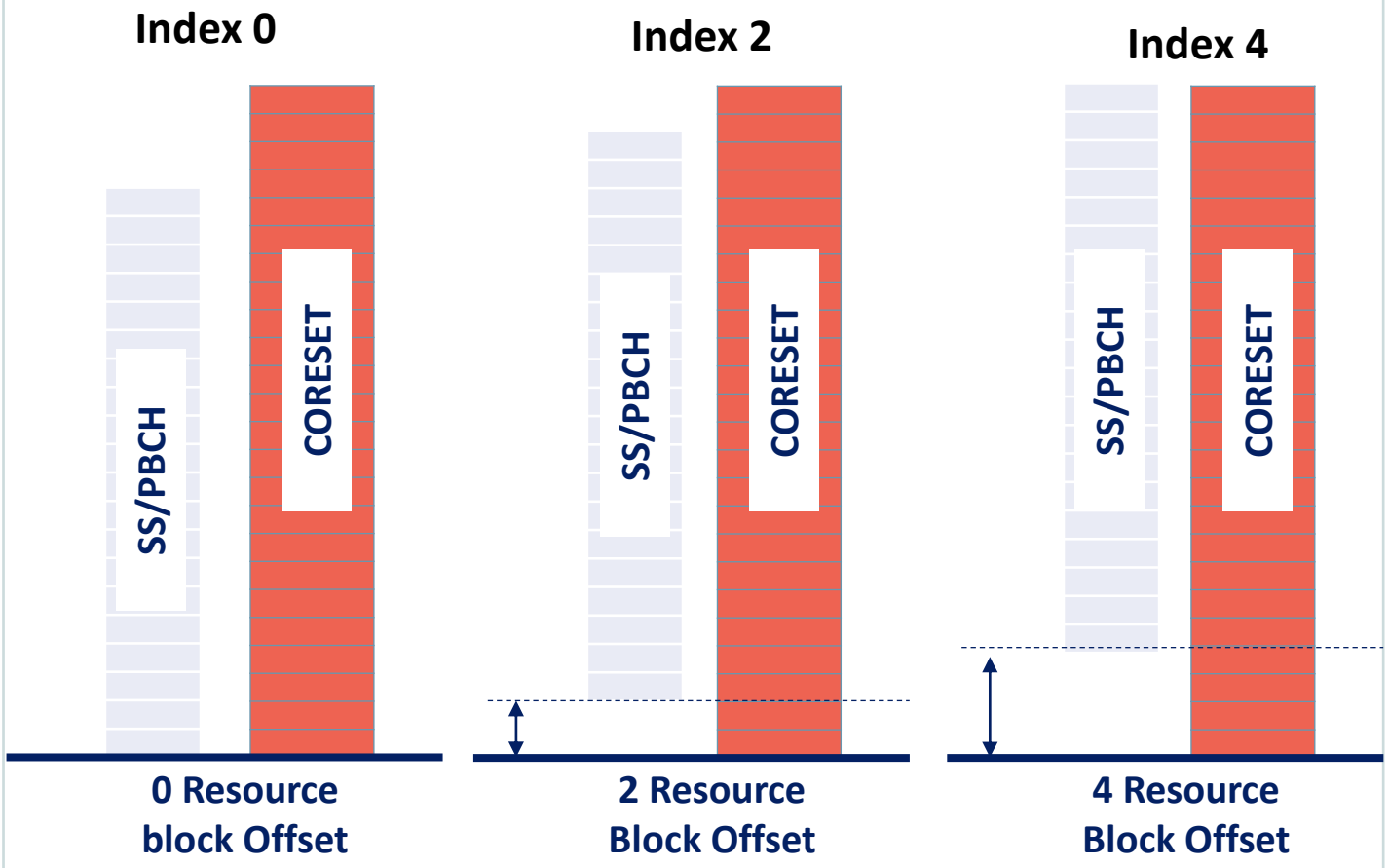
{SS/PBCH block, PDCCH} =SCS is {30, 30} kHz

Index	Multiplexing pattern	Number of Resource Blocks	Number of Symbols	Resource Block Offset
0	1	24	2	0
1	1	24	2	1
2	1	24	2	2
3	1	24	2	3
4	1	24	2	4
5	1	24	3	0
6	1	24	3	1
7	1	24	3	2
8	1	24	3	3
9	1	24	3	4
10	1	48	1	12
11	1	48	1	14
12	1	48	1	16
13	1	48	2	12
14	1	48	2	14

***Table 13-4: 3GPP 38213-h40**

(2) Illustration for Locating CORESET Frequency Position

Configured according to channel Bandwidth and specific combination of SS/PBCH & PDCCH SCS



Time Domain Resource Allocation (SIB1) :

gNB transmits core information element inside MIB message called SEARCHSPACEZero which is used as a pointer within 3GPP Specified tables to identify Frequency & Time domain Positions

0 =2 Means start Slot will be 2 as the offset is given relative to start of the frame
M = 1: Means we will have one Search space per slot in the first SSB Transmission

MIB
PDCCH-Config
SEARCHSpaceZero: (2)

***3GPP Table for FR 1 & Pattern 1**

Index	O	Number of search space sets per slot	M	First symbol index
0	0	1	1	0
2	2	1	1	0
4	5	1	1	0
6	7	1	1	0
8	0	1	2	0
9	5	1	2	0

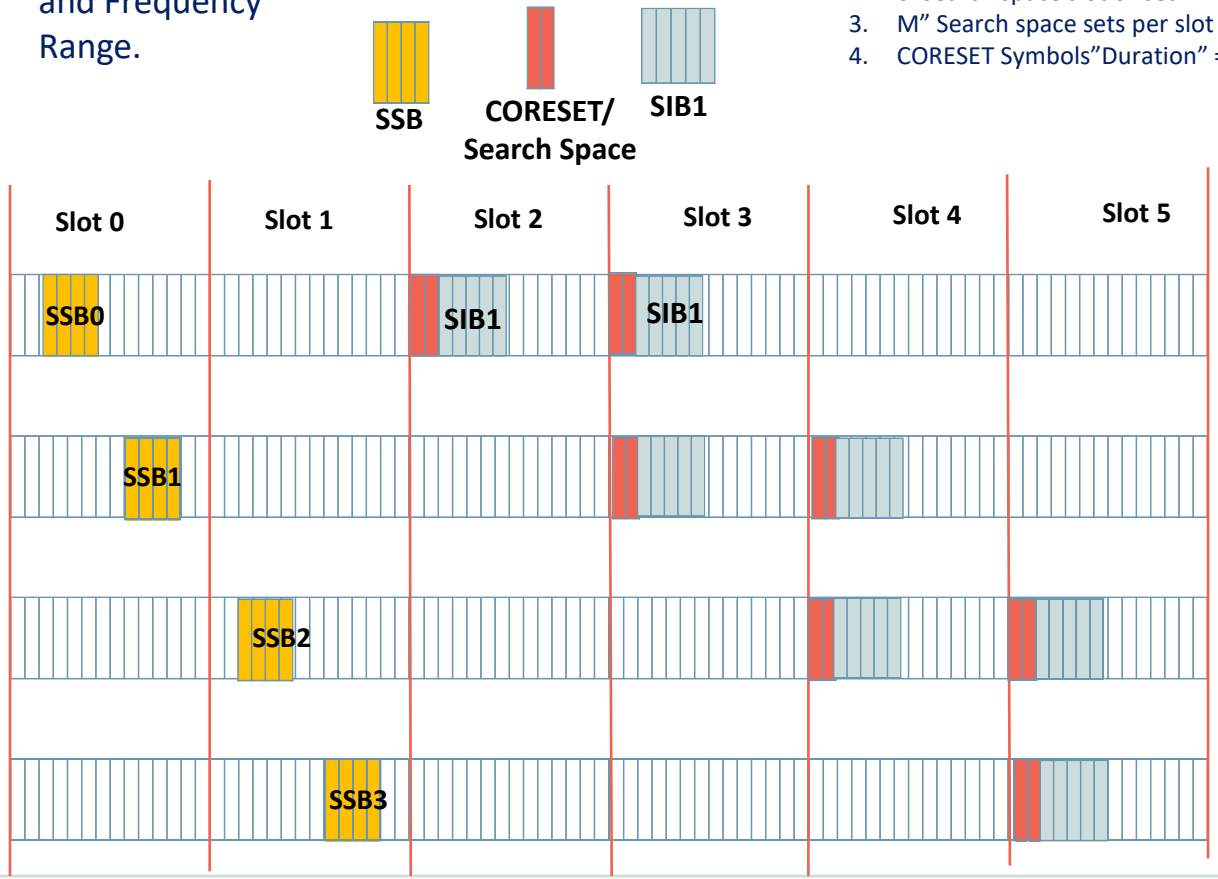
***Table 13-11: 3GPP 38213-h40**

(2) Illustration for Locating CORESET/Search Space Time

Configured according a Specific pattern and Frequency Range.

Assumptions Used

1. 4 SSBs starting duration 2,8,16,22
2. 0"Search space slot offset" = 2
3. M" Search space sets per slot = 1
4. CORESET Symbols"Duration" = 2



***FR1 is always using Multiplexing pattern 1**

Steps followed by the UE to deduce DCI information:

1. **Find CORESET Resources**
2. **Search Space Blind detection for PDCCH**
3. **CCE Allocation** "CCE-to-REG mapping"
4. **Identify DCI Type "Resource Allocation"**

MIB

```
.....mib
    ..........systemFrameNumber:000111(07)
    ..........subCarrierSpacingCommon:scs30or120 (1)
    ..........ssb-SubcarrierOffset:0x2 (2)
    ..........dmrs-TypeA-Position:pos2 (0)
..........pdcch-ConfigSIB1
     ..........controlResourceSetZero:0xa (10)
     ..........searchSpaceZero:0x4 (4)
     ..........cellBarred:notBarred (1)
     ..........intraFreqReselection:allowed (0)
```

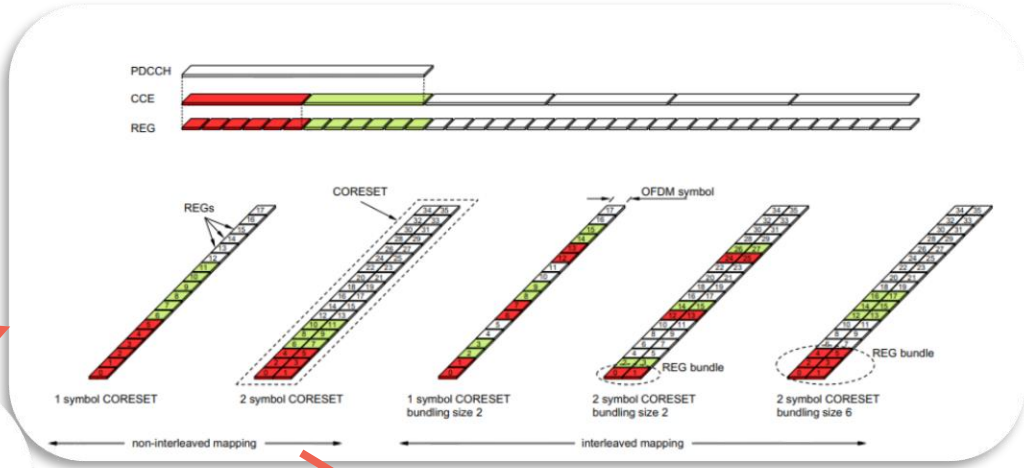
SIB1

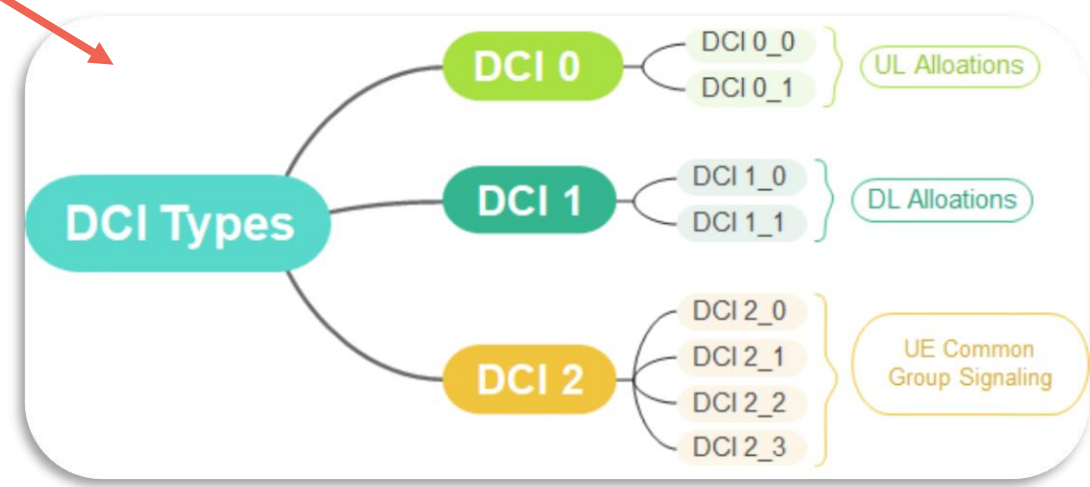
```
.....initialDownlinkBWP
    .....genericParameters
        .....locationAndBandwidth:0x70cb (28875)
        .....subcarrierSpacing:kHz30 (1)

    .....pdcch-ConfigCommon

        .....controlResourceSetZero:0xa (10)
        .....searchSpaceZero:0x4 (4)

    .....commonSearchSpaceList
    .....SearchSpace
    .....searchSpaceId:0x1 (1)
    .....controlResourceSetId:0x0 (0)
    .....monitoringSlotPeriodicityAndOffset
    .....monitoringSymbolsWithinSlot:10000000000000(20 00)
    .....nrofCandidates
        .....aggregationLevel1:n0 (0)
        .....aggregationLevel2:n0 (0)
        .....aggregationLevel4:n4 (4)
        .....aggregationLevel8:n2 (2)
        .....aggregationLevel16:n1 (1)
    .....searchSpaceType
        .....common
            .....dci-Format0-0-AndFormat1-0
```

identifies the (CORESET) that the Search Space Set is mapped onto

Specifies the starting symbol (s) for the Search Space Set

This provides the Base Station with the flexibility to focus the UE blind decoding attempts upon the most appropriate aggregation levels.





PDCCH Beamforming Feature

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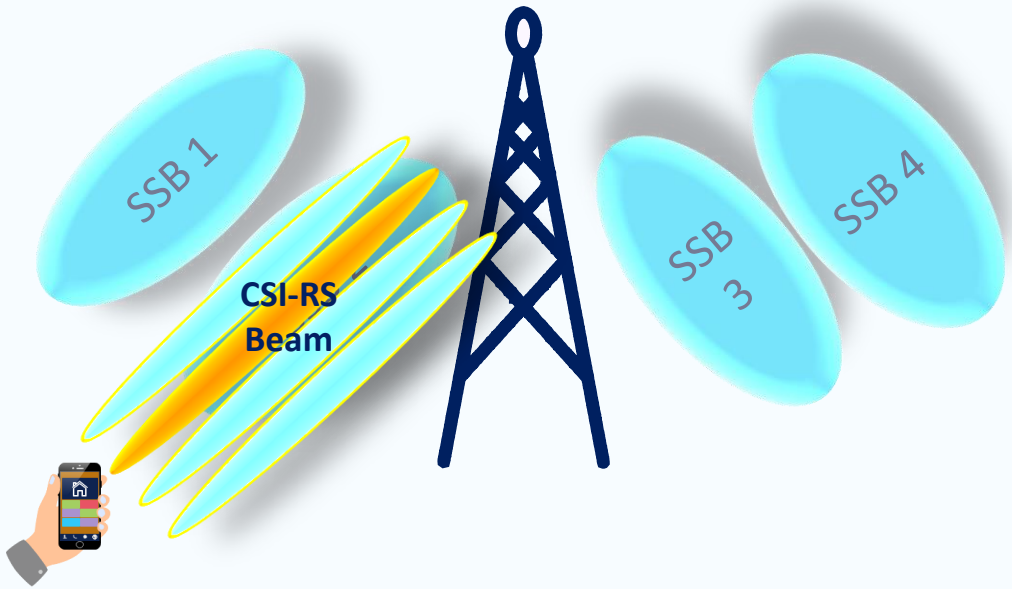
PDCCH Transmission to allocated resources for paging

Common Beamforming

PDCCH Transmission to allocated resources data transfer



User Beamforming

PDCCH Resource mapping from BTS Side

- PDCCH occupies a specific number of CCEs and is mapped onto a specific search space according to the content of the DCI; each Search space is mapped onto a specific CORESET. The CORESET defines a set of RBs and the number of symbols

Downlink Control Information(DCI)

Format 0_0, Format 0_1 — UL Allocations

Format 1_0, Format 1_1 — DL Allocations

Format 2_0, Format 2_1, Format 2_2, Format 2_3 — UE Common Group Signaling

The UE deduces which DCI is being received by using a combination of the following:

- PDCCH Search Space Set
- RNTI Type
- DCI Payload Size
- DCI Information

Example: If UE Scans Type2 Common Search space, this means DCI format 1_0 is used because format 1_0 is used to provide Paging messages resource allocations.

PDCCH(Resources)

(Aggregation Levels)

1 CCE = 72 RE
2 CCE = 144 RE
4 CCE = 288 RE
8 CCE = 576 RE
16 CCE = 1152 RE

CCE — Control channel elemets
RE — Resource elements

1 CCE = 6 REG & 1 REG = 1Resource block

Aggregation Level	CCE	Resource Element Groups(REG)	Resource Elements
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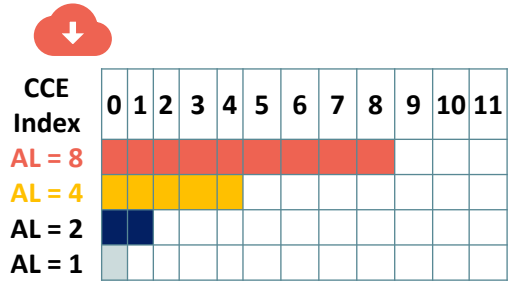

Search Space Sets

(Common):

Type 0/0A : SIB1/Other SIB
Type 1 : MSG2/MSG4
Type 2 : Paging
Type 3 : UE Group/Specific signaling(SFI,PI)

(UE Specific):

User-level data scheduling, power control, and schedule for a group of users

- A search space uses a CORESET to define the specific resource blocks and symbols where the UE attempts to decode the PDCCH
- There are two types of search space
- Common and UE Specific search space sets each are using with a specific application and specific RNTI

CORESET

- Resource Blocks & Symbols
- CCE to REG Mapping

REG : Resource element group