After RACH, CORESET and Search Spaces: sketching out the details
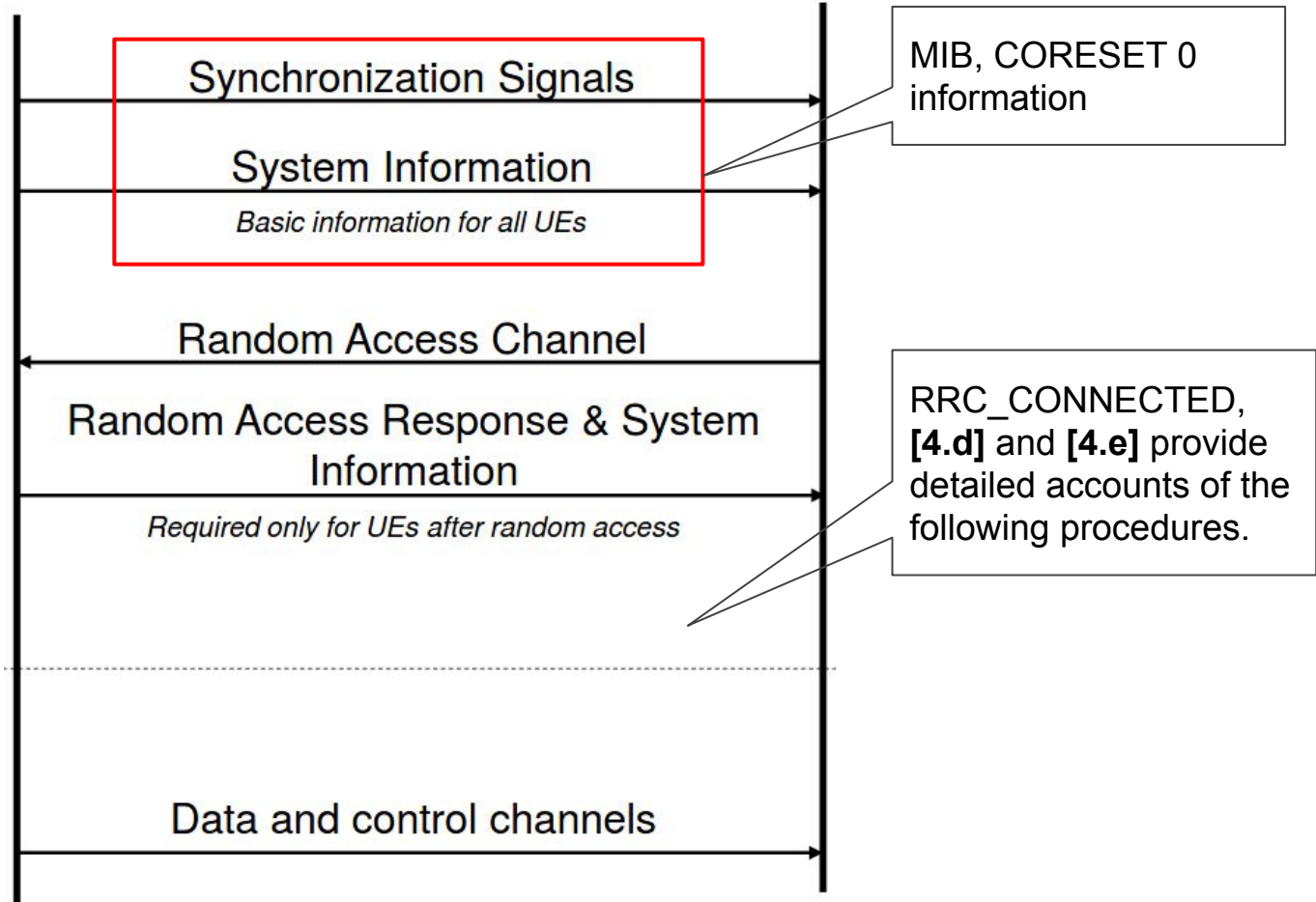
Milind Kumar V (EE16B025)

Summary

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1. UE procedures
   a. RACH and after
2. Search Spaces
   a. Introduction
   b. Obtaining search space information
3. CORESET
   a. Introduction
   b. Obtaining CORESET information
4. Sources

Procedures

The procedures employed by the UE to camp on a cell and obtain data are described the diagram.

Synchronization Signals →	MIB, CORESET 0 information
System Information →	
Basic information for all UEs	
← Random Access Channel	
Random Access Response & System Information →	RRC_CONNECTED, **[4.d]** and **[4.e]** provide detailed accounts of the following procedures.
Required only for UEs after random access	
Data and control channels ↔	

Sequence of steps between UE and BS. [4.a]

Connecting to the Network

———

- UE in RRC_IDLE
- Msg1: Preamble transmission
- Msg2: Random Access Response
- Msg3: RRCSetupRequest
- Msg4: RRCSetup
- UE in RRC_CONNECTED

Next steps [4.d]

- Configure Cell group using ***CellGroupConfig***
- Configure radio bearers using ***RadioBearerConfig***
    - These assist in the transmission of RRC messages
- UE transmits ***RRCSetupComplete*** message

Next steps [4.d]

- A series of messages between 5GC and 5G NodeB necessitate the authentication of UE identity.
- The UE receives and responds to a NAS Identity Request from 5GC using IMEISV which allows the network to provide UE with necessary parameters.
- The gNB issues and UE responds to **_SecurityModeCommand_** which activates AS security.
- The UE receives and responds to **_RRCReconfiguration_** which configures cell groups, radio bearer, etc.
- Finally, uplink and downlink data transfer begins between UE and 5GC.

Search Spaces and CORESETs

- Information regarding CORESET 0 is obtained during the initial part of the steps described above.
- Remaining CORESET information is provided by the means of higher layer (RRC) signalling using
  - The configuration obtained by the steps described previously
  - The IEs described in the subsequent slides

Search Spaces
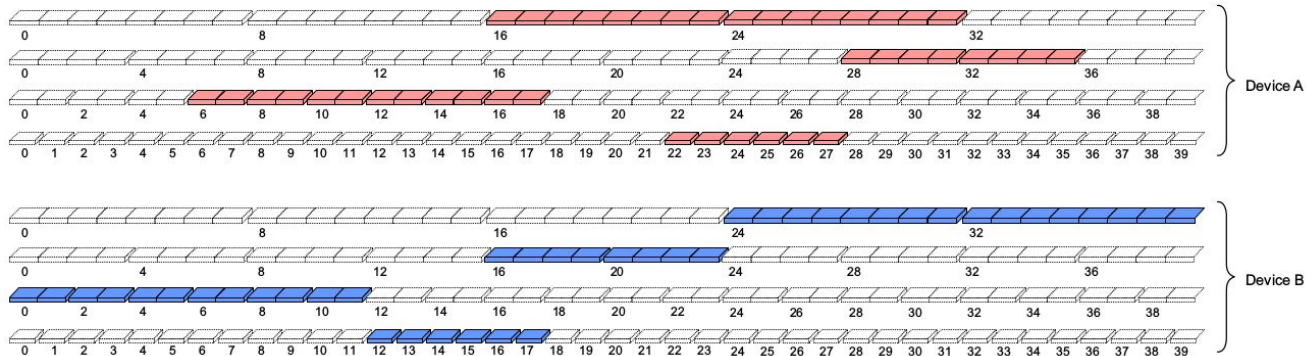
Introduction to Search Spaces

- In NR, downlink control is achieved through PDCCH.
- Payload (actual information) transmitted by PDCCH is called Downlink Control Information (DCI).
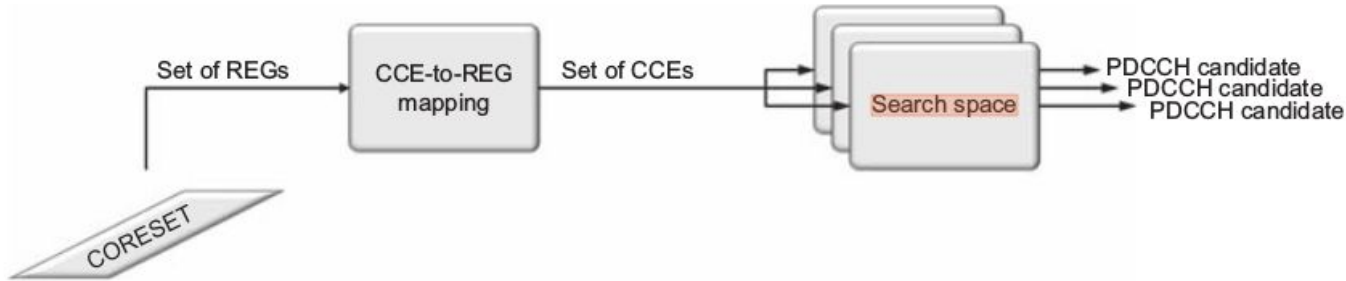
PDCCH processing in NR [1.d]

Introduction to Search Spaces

$---$

- UE uses blind decoding to determine DCI format.
- Search space- used to achieve a tradeoff between device complexity and scheduling restrictions.
- Search space is a set of candidate channels formed by CCEs a given aggregation level.

Configuring search spaces [1.d].

Introduction to Search Spaces

———

- Two types of search spaces
  - Common Search Space (CSS)
  - UE-specific search space (USS)
- CSS- used for broadcast information and before unique identity is assigned.
- USS- PDCCH candidates where network can address a particular device.

Obtaining search space information

———

- Search space information
  - Has multiple use cases (and consequently)
  - Is given by multiple IEs
- Different RNTIs are used for scrambling in different cases.

RNTI	Prefix expansion	Description
SI-RNTI	System Information	Used to decode PDSCH scheduling information from PDCCH
RA-RNTI	Random access	Used (maybe by multiple UEs) to monitor PDCCH during RA process
TC-RNTI	Temporary cell	Used to monitor PDCCH in *contention* based RA procedure
P-RNTI	Paging	Used to receive paging information
INT-RNTI	Interruption	Used to make the UE ignore a PDSCH transmission to meet URLLC needs
SFI-RNTI	Slot format information	Used to determine the structure of information transmitted in a slot
TPC- PUCCH-RNTI	Transmit power control	Used for uplink power control
TPC-SRS-RNTI	TPC-sounding reference signal	Used for uplink power control of UEs with independent control (among others)
C-RNTI	Cell	Unique identification given to a UE to identify allocate resources
MCS-C-RNTI	Modulation coding scheme-cell	Used to indicate alternate MCS table to meet reliability needs
CS-RSNTI	Configured scheduling	Unique to UE and used for scheduling in uplink and downlink

RNTIs used for scrambling CRC of DCI [2.b], [2.c]

Obtaining search space information

— — —

CSS type	RNTI	Usage
Type0-PDCCH	SI-RNTI	SIB decoding
Type0A-PDCCH	SI-RNTI	SIB decoding
Type1-PDCCH	RA-RNTI or TC-RNTI	Msg2, Msg4 decoding in RACH
Type2-PDCCH	P-RNTI	Paging Decoding
Type3-PDCCH	INT-RNTI, SFI-RNTI, TPC-PUSCH-RNTI, TPC-PUCCH-RNTI, TPC-SRS-RNTI, C-RNTI, CS-RNTI	Scheduling, power control, etc.

Details of CSS types

Obtaining Type0-PDCCH CSS information

```
-- ASN1START
-- TAG-MIB-START

MIB ::=                         SEQUENCE {
    systemFrameNumber               BIT STRING (SIZE (6)),
    subCarrierSpacingCommon         ENUMERATED {scs15or60, scs30or120},
    ssb-SubcarrierOffset            INTEGER (0..15),
    dmrs-TypeA-Position             ENUMERATED {pos2, pos3},
    pdcch-ConfigSIB1                PDCCH-ConfigSIB1,
    cellBarred                      ENUMERATED {barred, notBarred},
    intraFreqReselection            ENUMERATED {allowed, notAllowed},
    spare                           BIT STRING (SIZE (1))
}

-- TAG-MIB-STOP
-- ASN1STOP
```

PDCCH-ConfigSIB1 information element

```
-- ASN1START
-- TAG-PDCCH-CONFIGSIB1-START

PDCCH-ConfigSIB1 ::=            SEQUENCE {
    controlResourceSetZero             ControlResourceSetZero,
    searchSpaceZero                    SearchSpaceZero
}

-- TAG-PDCCH-CONFIGSIB1-STOP
-- ASN1STOP
```

PDCCH-ConfigSIB1 field descriptions
controlResourceSetZero   Determines a common ControlResourceSet (CORESET) with ID #0, see TS 38.213 [13], clause 13.
searchSpaceZero   Determines a common search space with ID #0, see TS 38.213 [13], clause 13.

Or…

– – –

PDCCH-ConfigCommon information element

```
-- ASN1START
-- TAG-PDCCH-CONFIGCOMMON-START

PDCCH-ConfigCommon ::=          SEQUENCE {
    controlResourceSetZero          ControlResourceSetZero                              OPTIONAL,   -- Cond InitialBWP-Only
    commonControlResourceSet        ControlResourceSet                                  OPTIONAL,   -- Need R
    searchSpaceZero                 SearchSpaceZero                                     OPTIONAL,   -- Cond InitialBWP-Only
    commonSearchSpaceList           SEQUENCE (SIZE(1..4)) OF SearchSpace                OPTIONAL,   -- Need R
    searchSpaceSIB1                 SearchSpaceId                                       OPTIONAL,   -- Need S
    searchSpaceOtherSystemInformation   SearchSpaceId                                   OPTIONAL,   -- Need S
    pagingSearchSpace               SearchSpaceId                                       OPTIONAL,   -- Need S
    ra-SearchSpace                  SearchSpaceId                                       OPTIONAL,   -- Need S
    ...,
    [[
    firstPDCCH-MonitoringOccasionOfPO   CHOICE {
        sCS15KHZoneT                                    SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..139),
        sCS30KHZoneT-SCS15KHZhalfT                      SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..279),
        sCS60KHZoneT-SCS30KHZhalfT-SCS15KHZquarterT     SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..559),
        sCS120KHZoneT-SCS60KHZhalfT-SCS30KHZquarterT-SCS15KHZoneEighthT   SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..1119),
        sCS120KHZhalfT-SCS60KHZquarterT-SCS30KHZoneEighthT-SCS15KHZoneSixteenthT SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..2239),
        sCS120KHZquarterT-SCS60KHZoneEighthT-SCS30KHZoneSixteenthT   SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..4479),
        sCS120KHZoneEighthT-SCS60KHZoneSixteenthT       SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..8959),
        sCS120KHZoneSixteenthT                          SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..17919)
    }                                                                   OPTIONAL     -- Cond OtherBWP
    ]]
}

-- TAG-PDCCH-CONFIGCOMMON-STOP
-- ASN1STOP
```

The IE BWP-Downlink also gives the search space information when configuring a new bandwidth part.

searchSpaceSIB1
ID of the search space for *SIB1* message. In the initial DL BWP of the UE's PCell, the network sets this field to 0. If the field is absent, the UE does not receive *SIB1* in this BWP. (see TS 38.213 [13], clause 10)

searchSpaceZero
Parameters of the common SearchSpace#0. The values are interpreted like the corresponding bits in *MIB pdcch-ConfigSIB1*. Even though this field is only configured in the initial BWP (BWP#0), *searchSpaceZero* can be used in search spaces configured in other DL BWP(s) than the initial DL BWP if the conditions described in TS 38.213 [13], clause 10, are satisfied.

Obtaining TypeOA-PDCCH CSS information

PDCCH-ConfigCommon information element

```
-- ASN1START
-- TAG-PDCCH-CONFIGCOMMON-START

PDCCH-ConfigCommon ::=            SEQUENCE {
    controlResourceSetZero        ControlResourceSetZero                OPTIONAL,   -- Cond InitialBWP-Only
    commonControlResourceSet      ControlResourceSet                    OPTIONAL,   -- Need R
    searchSpaceZero               SearchSpaceZero                       OPTIONAL,   -- Cond InitialBWP-Only
    commonSearchSpaceList         SEQUENCE (SIZE(1..4)) OF SearchSpace  OPTIONAL,   -- Need R
    searchSpaceSIB1               SearchSpaceId                         OPTIONAL,   -- Need S
    searchSpaceOtherSystemInformation  SearchSpaceId                    OPTIONAL,   -- Need S
    pagingSearchSpace             SearchSpaceId                         OPTIONAL,   -- Need S
    ra-SearchSpace                SearchSpaceId                         OPTIONAL,   -- Need S
    ...,
    [[
    firstPDCCH-MonitoringOccasionOfPO   CHOICE {
        sCS15KHZoneT                                                    SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..139),
        sCS30KHZoneT-SCS15KHZhalfT                                      SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..279),
        sCS60KHZoneT-SCS30KHZhalfT-SCS15KHZquarterT                     SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..559),
        sCS120KHZoneT-SCS60KHZhalfT-SCS30KHZquarterT-SCS15KHZoneEighthT SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..1119),
        sCS120KHZhalfT-SCS60KHZquarterT-SCS30KHZoneEighthT-SCS15KHZoneSixteenthT SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..2239),
        sCS120KHZquarterT-SCS60KHZoneEighthT-SCS30KHZoneSixteenthT      SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..4479),
        sCS120KHZoneEighthT-SCS60KHZoneSixteenthT                       SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..8959),
        sCS120KHZoneSixteenthT                                          SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..17919)
    }                                                                                           OPTIONAL     -- Cond OtherBWP
    ]]
}

-- TAG-PDCCH-CONFIGCOMMON-STOP
-- ASN1STOP
```

searchSpaceOtherSystemInformation
ID of the Search space for other system information, i.e. *SIB2 and beyond* (see TS 38.213 [13], clause 10.1) If the field is absent, the UE does not receive other system information in this BWP.

Obtaining Type1-PDCCH CSS information

--- --- ---

PDCCH-ConfigCommon information element

```
-- ASN1START
-- TAG-PDCCH-CONFIGCOMMON-START

PDCCH-ConfigCommon ::=               SEQUENCE {
    controlResourceSetZero           ControlResourceSetZero                         OPTIONAL,   -- Cond InitialBWP-Only
    commonControlResourceSet         ControlResourceSet                            OPTIONAL,   -- Need R
    searchSpaceZero                  SearchSpaceZero                               OPTIONAL,   -- Cond InitialBWP-Only
    commonSearchSpaceList            SEQUENCE (SIZE(1..4)) OF SearchSpace          OPTIONAL,   -- Need R
    searchSpaceSIB1                  SearchSpaceId                                 OPTIONAL,   -- Need S
    searchSpaceOtherSystemInformation SearchSpaceId                                OPTIONAL,   -- Need S
    pagingSearchSpace                SearchSpaceId                                 OPTIONAL,   -- Need S
    ra-SearchSpace                   SearchSpaceId                                 OPTIONAL,   -- Need S
    ...,
    [[
    firstPDCCH-MonitoringOccasionOfPO  CHOICE {
        sCS15KHZoneT                                                    SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..139),
        sCS30KHZoneT-SCS15KHZhalfT                                      SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..279),
        sCS60KHZoneT-SCS30KHZhalfT-SCS15KHZquarterT                     SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..559),
        sCS120KHZoneT-SCS60KHZhalfT-SCS30KHZquarterT-SCS15KHZoneEighthT SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..1119),
        sCS120KHZhalfT-SCS60KHZquarterT-SCS30KHZoneEighthT-SCS15KHZoneSixteenthT SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..2239),
        sCS120KHZquarterT-SCS60KHZoneEighthT-SCS30KHZoneSixteenthT      SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..4479),
        sCS120KHZoneEighthT-SCS60KHZoneSixteenthT                       SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..8959),
        sCS120KHZoneSixteenthT                                          SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..17919)
    }                                                                                          OPTIONAL    -- Cond OtherBWP
    ]]
}

-- TAG-PDCCH-CONFIGCOMMON-STOP
-- ASN1STOP
```

ra-SearchSpace
ID of the Search space for random access procedure (see TS 38.213 [13], clause 10.1). If the field is absent, the UE does not receive RAR in this BWP. This field is mandatory present in the DL BWP(s) if the conditions described in TS 38.321 [3], subclause 5.15 are met.

Obtaining Type2-PDCCH CSS information

— — —

PDCCH-ConfigCommon information element

```
-- ASN1START
-- TAG-PDCCH-CONFIGCOMMON-START

PDCCH-ConfigCommon ::=              SEQUENCE {
    controlResourceSetZero          ControlResourceSetZero                  OPTIONAL,   -- Cond InitialBWP-Only
    commonControlResourceSet        ControlResourceSet                      OPTIONAL,   -- Need R
    searchSpaceZero                 SearchSpaceZero                         OPTIONAL,   -- Cond InitialBWP-Only
    commonSearchSpaceList           SEQUENCE (SIZE(1..4)) OF SearchSpace    OPTIONAL,   -- Need R
    searchSpaceSIB1                 SearchSpaceId                           OPTIONAL,   -- Need S
    searchSpaceOtherSystemInformation SearchSpaceId                         OPTIONAL,   -- Need S
    pagingSearchSpace               SearchSpaceId                           OPTIONAL,   -- Need S
    ra-SearchSpace                  SearchSpaceId                           OPTIONAL,   -- Need S
    ...,
    [[
    firstPDCCH-MonitoringOccasionOfPO   CHOICE {
        sCS15KHZoneT                                                        SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..139),
        sCS30KHZoneT-SCS15KHZhalfT                                          SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..279),
        sCS60KHZoneT-SCS30KHZhalfT-SCS15KHZquarterT                         SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..559),
        sCS120KHZoneT-SCS60KHZhalfT-SCS30KHZquarterT-SCS15KHZoneEighthT      SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..1119),
        sCS120KHZhalfT-SCS60KHZquarterT-SCS30KHZoneEighthT-SCS15KHZoneSixteenthT SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..2239),
        sCS120KHZquarterT-SCS60KHZoneEighthT-SCS30KHZoneSixteenthT           SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..4479),
        sCS120KHZoneEighthT-SCS60KHZoneSixteenthT                           SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..8959),
        sCS120KHZoneSixteenthT                                              SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..17919)
    }                                                                                   OPTIONAL       -- Cond OtherBWP
    ]]
}

-- TAG-PDCCH-CONFIGCOMMON-STOP
-- ASN1STOP
```

pagingSearchSpace
ID of the Search space for paging (see TS 38.213 [13], clause 10.1). If the field is absent, the UE does not receive paging in this BWP (see TS 38.213 [13], clause 10).

Obtaining Type3-PDCCH CSS information

searchSpacesToAddModList
List of UE specifically configured Search Spaces. The network configures at most 10 Search Spaces per BWP per cell (including UE-specific and common Search Spaces).

PDCCH-Config information element

```
-- ASN1START
-- TAG-PDCCH-CONFIG-START

PDCCH-Config ::=                     SEQUENCE {
    controlResourceSetToAddModList      SEQUENCE(SIZE (1..3)) OF ControlResourceSet      OPTIONAL,   -- Need N
    controlResourceSetToReleaseList     SEQUENCE(SIZE (1..3)) OF ControlResourceSetId    OPTIONAL,   -- Need N
    searchSpacesToAddModList            SEQUENCE(SIZE (1..10)) OF SearchSpace            OPTIONAL,   -- Need N
    searchSpacesToReleaseList           SEQUENCE(SIZE (1..10)) OF SearchSpaceId          OPTIONAL,   -- Need N
    downlinkPreemption                  SetupRelease { DownlinkPreemption }              OPTIONAL,   -- Need M
    tpc-PUSCH                           SetupRelease { PUSCH-TPC-CommandConfig }         OPTIONAL,   -- Need M
    tpc-PUCCH                           SetupRelease { PUCCH-TPC-CommandConfig }         OPTIONAL,   -- Need M
    tpc-SRS                             SetupRelease { SRS-TPC-CommandConfig}            OPTIONAL,   -- Need M
    ...
}

-- TAG-PDCCH-CONFIG-STOP
-- ASN1STOP
```

Obtaining Type3-PDCCH CSS information

SearchSpace information element

```
-- ASN1START
-- TAG-SEARCHSPACE-START

SearchSpace ::=                         SEQUENCE {
    searchSpaceId                           SearchSpaceId,
    controlResourceSetId                    ControlResourceSetId                        OPTIONAL,   -- Cond SetupOnly
    monitoringSlotPeriodicityAndOffset      CHOICE {
        sl1                                     NULL,
        sl2                                     INTEGER (0..1),
        sl4                                     INTEGER (0..3),
        sl5                                     INTEGER (0..4),
        sl8                                     INTEGER (0..7),
        sl10                                    INTEGER (0..9),
        sl16                                    INTEGER (0..15),
        sl20                                    INTEGER (0..19),
        sl40                                    INTEGER (0..39),
        sl80                                    INTEGER (0..79),
        sl160                                   INTEGER (0..159),
        sl320                                   INTEGER (0..319),
        sl640                                   INTEGER (0..639),
        sl1280                                  INTEGER (0..1279),
        sl2560                                  INTEGER (0..2559)
    }                                                                                   OPTIONAL,   -- Cond Setup
    duration                                INTEGER (2..2559)                           OPTIONAL,   -- Need R
    monitoringSymbolsWithinSlot             BIT STRING (SIZE (14))                      OPTIONAL,   -- Cond Setup
    nrofCandidates                          SEQUENCE {
        aggregationLevel1                       ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8},
        aggregationLevel2                       ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8},
        aggregationLevel4                       ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8},
        aggregationLevel8                       ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8},
        aggregationLevel16                      ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8}
    }                                                                                   OPTIONAL,   -- Cond Setup
    searchSpaceType                         CHOICE {
        common                                  SEQUENCE {
            dci-Format0-0-AndFormat1-0                  SEQUENCE {
                ...
            }                                                                           OPTIONAL,   -- Need R
            dci-Format2-0                           SEQUENCE {
                nrofCandidates-SFI                      SEQUENCE {
                    aggregationLevel1                       ENUMERATED {n1, n2}         OPTIONAL,   -- Need R
                    aggregationLevel2                       ENUMERATED {n1, n2}         OPTIONAL,   -- Need R
                    aggregationLevel4                       ENUMERATED {n1, n2}         OPTIONAL,   -- Need R
                    aggregationLevel8                       ENUMERATED {n1, n2}         OPTIONAL,   -- Need R
```

Set to *common*.

Obtaining USS information

SearchSpace information element

```
-- ASN1START
-- TAG-SEARCHSPACE-START

SearchSpace ::=                        SEQUENCE {
    searchSpaceId                          SearchSpaceId,
    controlResourceSetId                   ControlResourceSetId                        OPTIONAL,   -- Cond SetupOnly
    monitoringSlotPeriodicityAndOffset     CHOICE {
        sl1                                    NULL,
        sl2                                    INTEGER (0..1),
        sl4                                    INTEGER (0..3),
        sl5                                    INTEGER (0..4),
        sl8                                    INTEGER (0..7),
        sl10                                   INTEGER (0..9),
        sl16                                   INTEGER (0..15),
        sl20                                   INTEGER (0..19),
        sl40                                   INTEGER (0..39),
        sl80                                   INTEGER (0..79),
        sl160                                  INTEGER (0..159),
        sl320                                  INTEGER (0..319),
        sl640                                  INTEGER (0..639),
        sl1280                                 INTEGER (0..1279),
        sl2560                                 INTEGER (0..2559)
    }                                                                                  OPTIONAL,   -- Cond Setup
    duration                               INTEGER (2..2559)                           OPTIONAL,   -- Need R
    monitoringSymbolsWithinSlot            BIT STRING (SIZE (14))                       OPTIONAL,   -- Cond Setup
    nrofCandidates                         SEQUENCE {
        aggregationLevel1                      ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8},
        aggregationLevel2                      ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8},
        aggregationLevel4                      ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8},
        aggregationLevel8                      ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8},
        aggregationLevel16                     ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8}
    }                                                                                  OPTIONAL,   -- Cond Setup
    searchSpaceType                        CHOICE {
        common                                 SEQUENCE {
            dci-Format0-0-AndFormat1-0             SEQUENCE {
                ...
            }                                                                          OPTIONAL,   -- Need R
            dci-Format2-0                          SEQUENCE {
                nrofCandidates-SFI                     SEQUENCE {
                    aggregationLevel1                      ENUMERATED {n1, n2}         OPTIONAL,   -- Need R
                    aggregationLevel2                      ENUMERATED {n1, n2}         OPTIONAL,   -- Need R
                    aggregationLevel4                      ENUMERATED {n1, n2}         OPTIONAL,   -- Need R
                    aggregationLevel8                      ENUMERATED {n1, n2}         OPTIONAL,   -- Need R
```

- Configured using PDCCH-Config.
- C-RNTI, MCS-C-RNTI, SP-CSI-RNTI and CS-RNTI can be used.

Set to *ue-Specific* in PDCCH-Config IE.

UE behaviour

- If the fields searchSpaceSIB1, searchSpaceOtherSystemInformation, ra-SearchSpace, pagingSearchSpace are not provided to the UE, it does not monitor PDCCH for Type0/0A/1/2-PDCCH CSS set on the DL BWP.

CORESET

Introduction to CORESET

- CORESET- stands for Control Resource Set.
- It is a time-frequency resource in which the device tries to decode candidate control channels using one or more search spaces.[1.d]
- Size and location are configured by network via **higher layer/RRC signalling**.

CORESET and UE

———

- CORESET defined from a UE perspective only. It does not constrain the network (gNB) to transmit control information.
- In a serving cell, a UE may be configured with
  - Up to four bandwidth parts
  - 3 CORESETs per BWP
- Therefore, a total of 12 CORESETs can be configured for a UE on a serving cell.

CORESET and UE

ControlResourceSet information element

```
-- ASN1START
-- TAG-CONTROLRESOURCESET-START

ControlResourceSet ::=              SEQUENCE {
    controlResourceSetId                ControlResourceSetId,

    frequencyDomainResources            BIT STRING (SIZE (45)),
    duration                            INTEGER (1..maxCoReSetDuration),
    cce-REG-MappingType                 CHOICE {
        interleaved                         SEQUENCE {
            reg-BundleSize                      ENUMERATED {n2, n3, n6},
            interleaverSize                     ENUMERATED {n2, n3, n6},
            shiftIndex                          INTEGER(0..maxNrofPhysicalResourceBlocks-1)      OPTIONAL -- Need S
        },
        nonInterleaved                      NULL
    },
    precoderGranularity                 ENUMERATED {sameAsREG-bundle, allContiguousRBs},
    tci-StatesPDCCH-ToAddList           SEQUENCE(SIZE (1..maxNrofTCI-StatesPDCCH)) OF TCI-StateId OPTIONAL, -- Cond NotSIB1-initialBWP
    tci-StatesPDCCH-ToReleaseList       SEQUENCE(SIZE (1..maxNrofTCI-StatesPDCCH)) OF TCI-StateId OPTIONAL, -- Cond NotSIB1-initialBWP
    tci-PresentInDCI                        ENUMERATED {enabled}                            OPTIONAL, -- Need S
    pdcch-DMRS-ScramblingID                 INTEGER (0..65535)                              OPTIONAL, -- Need S
    ...
}

-- TAG-CONTROLRESOURCESET-STOP
-- ASN1STOP
```

ControlResourceSetId information element

```
-- ASN1START
-- TAG-CONTROLRESOURCESETID-START

ControlResourceSetId ::=            INTEGER (0..maxNrofControlResourceSets-1)

-- TAG-CONTROLRESOURCESETID-STOP
-- ASN1STOP
```

CORESET and UE

– Multiplicity and type constraint definitions

```
maxNrofControlResourceSets-1           INTEGER ::= 11        -- Max number of CoReSets configurable on a serving cell minus 1
```

- Therefore, CORESETs #(0-11) can be configured for the UE.
- The CORESET can occur at any part of the slot.
- The CORESET can occur anywhere in the frequency range of the carrier.
- The UE handles only those CORESETs which lie in the active bandwidth part.
- CORESET 0 is configured differently from the remaining CORESETs.

Indicating CORESET parameters to UE

___

● The CORESETs are configured as REGs in the frequency
  domain and using 1-3 OFDM symbols in the time domain.

Parameter	Description
$N_{RB}^{CORESET}$	Number of RBs in frequency domain
$N_{symb}^{CORESET}$	Number of symbols in time domain in a CORESET. This can be 1 or 2 or 3, but 3 is possible only when DL-DMRS-typeA-pos = 3
$N_{REG}^{CORESET}$	Number of REGs in a CORESET
L	REG Bundle size

CORESET Parameters when configured by ControlResourceSet IE

Indicating CORESET parameters to UE

— — —

ControlResourceSet information element

```
-- ASN1START
-- TAG-CONTROLRESOURCESET-START

ControlResourceSet ::=              SEQUENCE {
    controlResourceSetId            ControlResourceSetId,

    frequencyDomainResources        BIT STRING (SIZE (45)),
    duration                        INTEGER (1..maxCoReSetDuration),
    cce-REG-MappingType             CHOICE {
        interleaved                     SEQUENCE {
            reg-BundleSize                  ENUMERATED {n2, n3, n6},
            interleaverSize                 ENUMERATED {n2, n3, n6},
            shiftIndex                      INTEGER(0..maxNrofPhysicalResourceBlocks-1)        OPTIONAL -- Need S
        },
        nonInterleaved                  NULL
    },
    precoderGranularity             ENUMERATED {sameAsREG-bundle, allContiguousRBs},
    tci-StatesPDCCH-ToAddList       SEQUENCE(SIZE (1..maxNrofTCI-StatesPDCCH)) OF TCI-StateId OPTIONAL, -- Cond NotSIB1-initialBWP
    tci-StatesPDCCH-ToReleaseList   SEQUENCE(SIZE (1..maxNrofTCI-StatesPDCCH)) OF TCI-StateId OPTIONAL, -- Cond NotSIB1-initialBWP
    tci-PresentInDCI                    ENUMERATED {enabled}                                 OPTIONAL, -- Need S
    pdcch-DMRS-ScramblingID             INTEGER (0..65535)                                   OPTIONAL, -- Need S
    ...
}

-- TAG-CONTROLRESOURCESET-STOP
-- ASN1STOP
```

$N_{RB}^{CORESET}$

$N_{symb}^{CORESET}$

L

Again, these are for CORESETs which are configured by RRC signalling.

Indicating CORESETs to UE

— — —

Common CORESETs can be configured via PDCCH-ConfigCommon IE i.e via RRC signalling.

PDCCH-ConfigCommon information element

```
-- ASN1START
-- TAG-PDCCH-CONFIGCOMMON-START

PDCCH-ConfigCommon ::=           SEQUENCE {
    controlResourceSetZero       ControlResourceSetZero            OPTIONAL,  -- Cond InitialBWP-Only
    commonControlResourceSet     ControlResourceSet                OPTIONAL,  -- Need R
    searchSpaceZero              SearchSpaceZero                   OPTIONAL,  -- Cond InitialBWP-Only
    commonSearchSpaceList        SEQUENCE (SIZE(1..4)) OF SearchSpace   OPTIONAL,  -- Need R
    searchSpaceSIB1              SearchSpaceId                     OPTIONAL,  -- Need S
    searchSpaceOtherSystemInformation  SearchSpaceId               OPTIONAL,  -- Need S
```

PDCCH-ConfigCommon field descriptions

commonControlResourceSet
An additional common control resource set which may be configured and used for any common or UE-specific search space. If the network configures this field, it uses a *ControlResourceSetId* other than 0 for this *ControlResourceSet*. The network configures the *commonControlResourceSet* in *SIB1* so that it is contained in the bandwidth of CORESET#0.

Indicating CORESETs to UE

— — —

UE specific CORESETs can be configured via PDCCH-Config IE again via RRC signalling.

PDCCH-Config information element

```
-- ASN1START
-- TAG-PDCCH-CONFIG-START

PDCCH-Config ::=                    SEQUENCE {
    controlResourceSetToAddModList      SEQUENCE(SIZE (1..3)) OF ControlResourceSet                OPTIONAL,   -- Need N
```

PDCCH-Config field descriptions
controlResourceSetToAddModList
List of UE specifically configured Control Resource Sets (CORESETs) to be used by the UE. The network configures at most 3 CORESETs per BWP per cell (including UE-specific and common CORESETs). In case network reconfigures control resource set with the same *ControlResourceSetId* as used for *commonControlResourceSet* configured via *PDCCH-ConfigCommon*, the configuration from *PDCCH-Config* always takes precedence and should not be updated by the UE based on *servingCellConfigCommon*.

Indicating CORESET 0 parameters to UE

- CORESET 0 is configured by *ControlResourceSetZero* IE.

Parameter	Description
$N_{RB}^{CORESET}$	Number of RBs in frequency domain. Obtained from TS 38.213 (Tables 13-1 to 13-10).
$N_{symb}^{CORESET}$	Number of symbols in time domain in a CORESET. This can be 1 or 2 or 3, but 3 is possible only when DL-DMRS-typeA-pos = 3. Obtained from TS 38.213 (Tables 13-1 to 13-10).
L	REG Bundle size

CORESET Parameters when configured by ControlResourceSet IE

ControlResourceSetZero information element

```
-- ASN1START
-- TAG-CONTROLRESOURCESETZERO-START

ControlResourceSetZero ::=                INTEGER (0..15)

-- TAG-CONTROLRESOURCESETZERO-STOP
-- ASN1STOP
```

Indicating CORESET 0 to UE

_ _ _

- CORESET 0 information is obtained from SS/PBCH transmission.
- In MIB, ssb-SubcarrierOffset gives k_{SSB}.
- k_{SSB} <= 23 (FR1) and k_{SSB}<=11 (FR2) indicate the presence of CORESET 0.

PDCCH-ConfigSIB1 information element

```
-- ASN1START
-- TAG-PDCCH-CONFIGSIB1-START

PDCCH-ConfigSIB1 ::=                  SEQUENCE {
    controlResourceSetZero              ControlResourceSetZero,
    searchSpaceZero                     SearchSpaceZero
}

-- TAG-PDCCH-CONFIGSIB1-STOP
-- ASN1STOP
```

PDCCH-ConfigSIB1 field descriptions
controlResourceSetZero
Determines a common ControlResourceSet (CORESET) with ID #0, see TS 38.213 [13], clause 13.
searchSpaceZero
Determines a common search space with ID #0, see TS 38.213 [13], clause 13.

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   c. http://howltestuffworks.blogspot.com/2019/09/rntis-in-5g-nr.html
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Thank you!