**MAC**

RRC is in control of the MAC configuration.

**MAC Entities:**

The MAC entity of the UE handles the following transport channels:

* Broadcast Channel (BCH)
* Downlink Shared Channel(s) (DL-SCH)
* Paging Channel (PCH)
* Uplink Shared Channel(s) (UL-SCH)
* Random Access Channel(s) (RACH).

When the UE is configured with SCG, two MAC entities are configured to the UE: one for the MCG and one for the SCG.

When the UE is configured with DAPS handover, two MAC entities are used by the UE: one for the source cell (source MAC entity) and one for the target cell (target MAC entity).

**Services:**

**Services provided to upper layers**

The MAC sublayer provides the following services to upper layers:

* Data transfer
* Radio resource allocation.

**Services expected from physical layer**

The MAC sublayer expects the following services from the physical layer:

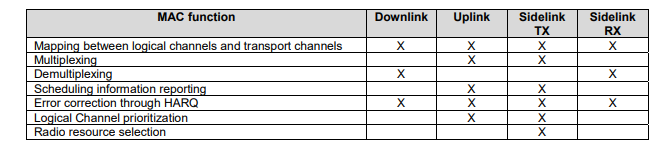
* Data transfer services
* Signalling of HARQ feedback
* Signalling of Scheduling Request
* Measurements (e.g. Channel Quality Indication (CQI)).

**Functions**

The MAC sublayer supports the following functions:

* Mapping between logical channels and transport channels
* Multiplexing of MAC SDUs from one or different logical channels onto transport blocks (TB) to be delivered to the physical layer on transport channels
* Demultiplexing of MAC SDUs to one or different logical channels from transport blocks (TB) delivered from the physical layer on transport channels
* Scheduling information reporting
* Error correction through HARQ
* Logical channel prioritization
* Priority handling between overlapping resources of one UE
* Radio resource selection.

The relevance of MAC functions for uplink, downlink, and sidelink is indicated below

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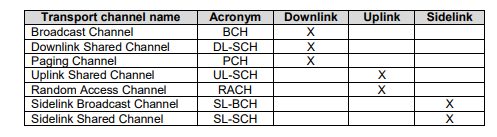
**Channel structure**

The MAC sublayer operates on the channels defined below;

transport channels are SAPs between MAC and Layer 1, logical channels are SAPs between MAC and RLC.

**Transport Channels:**

The MAC sublayer uses the transport channels listed in below table.

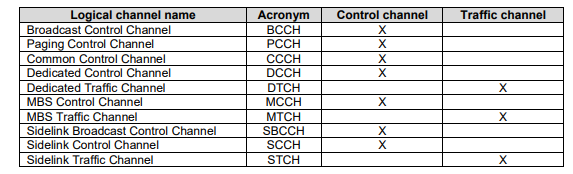
****

**Logical Channels:**

The MAC sublayer provides data transfer services on logical channels. To accommodate different kinds of data transfer services, multiple types of logical channels are defined i.e. each supporting transfer of a particular type of information.

Each logical channel type is defined by what type of information is transferred.

The MAC sublayer provides the control and traffic channels listed in Table

****

**MAC Control Elements (CEs):**

**Buffer Status Report MAC CEs:**

Buffer Status Report (BSR) MAC CEs consist of either

* Short BSR format (fixed size); or
* Extended Short BSR format (fixed size); or
* Long BSR format (variable size); or
* Extended Long BSR format (variable size); or
* Short Truncated BSR format (fixed size); or
* Extended Short Truncated BSR format (fixed size); or
* Long Truncated BSR format (variable size); or
* Extended Long Truncated BSR format (variable size).

Pre-emptive BSR MAC CE consists of:

* Pre-emptive BSR format (variable size); or
* Extended Pre-emptive BSR format (variable size).

**C-RNTI MAC CE:**

The C-RNTI MAC CE is identified by MAC subheader with LCID

It has a fixed size and consists of a single field

* C-RNTI: This field contains the C-RNTI of the MAC entity. The length of the field is 16 bits.

**UE Contention Resolution Identity MAC CE:**

The UE Contention Resolution Identity MAC CE is identified by MAC subheader with LCID.

It has a fixed 48-bit size and consists of a single field .

* UE Contention Resolution Identity: This field contains the UL CCCH SDU. If the UL CCCH SDU is longer than 48 bits, this field contains the first 48 bits of the UL CCCH SDU.

**Timing Advance Command MAC CE:**

The Timing Advance Command MAC CE is identified by MAC subheader with LCID.

It has a fixed size and consists of a single octet

* TAG Identity (TAG ID): This field indicates the TAG Identity of the addressed TAG. The TAG containing the SpCell has the TAG Identity 0. The length of the field is 2 bits;
* Timing Advance Command: This field indicates the index value TA (0, 1, 2… 63) used to control the amount of timing adjustment that MAC entity has to apply . The length of the field is 6 bits.

**Absolute Timing Advance Command MAC CE:**

The Absolute Timing Advance Command MAC CE is identified by MAC subheader with eLCID.

It has a fixed size and consists of two octets.

* Timing Advance Command: This field indicates the index value TA used to control the amount of timing adjustment that the MAC entity has to apply in TS 38.213 [6]. The size of the field is 12 bits.
* R: Reserved bit, set to 0.

**DRX Command MAC CE:**

The DRX Command MAC CE is identified by a MAC subheader with LCID .

It has a fixed size of zero bits.

**Long DRX Command MAC CE**:

The Long DRX Command MAC CE is identified by a MAC subheader with LCID.

It has a fixed size of zero bits.

**Configured Grant Confirmation MAC CE**:

The Configured Grant Confirmation MAC CE is identified by a MAC subheader with LCID.

It has a fixed size of zero bits.

**Single Entry PHR MAC CE**:

The Single Entry PHR MAC CE is identified by a MAC subheader with LCID.

It has a fixed size and consists of two octets:

* R: Reserved bit, set to 0;
* Power Headroom (PH): This field indicates the power headroom level. The length of the field is 6 bits. The reported PH and the corresponding power headroom levels.
* P: If mpe-Reporting-FR2 is configured and the Serving Cell operates on FR2, the MAC entity shall set this field to 0 if the applied P-MPR value, to meet MPE requirements, is less than P- MPR\_00 and to 1 otherwise. If mpe-Reporting-FR2 is not configured or the Serving Cell operates on FR1, this field indicates whether power backoff is applied due to power management.The MAC entity shall set the P field to 1 if the corresponding PCMAX,f,c field would have had a different value if no power backoff due to power management had been applied;
* PCMAX,f,c: This field indicates the PCMAX,f,c (as specified in TS 38.213 [6]) used for calculation of the preceding PH field. The reported PCMAX,f,c and the corresponding nominal UE transmit power levels .
* MPE: If mpe-Reporting-FR2 is configured, and the Serving Cell operates on FR2, and if the P field is set to 1, this field indicates the applied power backoff to meet MPE requirements. This field indicates an index and the corresponding measured values of P-MPR levels in dB. The length of the field is 2 bits. If mpe-Reporting-FR2 is not configured, or if the Serving Cell operates on FR1, or if the P field is set to 0, R bits are present instead.

**Multiple Entry PHR MAC CE:**

The Multiple Entry PHR MAC CE is identified by a MAC subheader with LCID

The presence of Type 2 PH field for SpCell of the other MAC entity is configured by phr-Type2OtherCell with value true.

A single octet bitmap is used for indicating the presence of PH per Serving Cell when the highest ServCellIndex of Serving Cell with configured uplink is less than 8, otherwise four octets are used.

The PHR MAC CEs are defined as follows

* Ci: This field indicates the presence of a PH field for the Serving Cell with ServCellIndex i. The Ci field set to 1 indicates that a PH field for the Serving Cell with ServCellIndex i is reported. The Ci field set to 0 indicates that a PH field for the Serving Cell with ServCellIndex i is not reported
* R: Reserved bit, set to 0;
* V: This field indicates if the PH value is based on a real transmission or a reference format. For Type 1 PH, the V field set to 0 indicates real transmission on PUSCH and the V field set to 1 indicates that a PUSCH reference format is used. For Type 2 PH, the V field set to 0 indicates real transmission on PUCCH and the V field set to 1 indicates that a PUCCH reference format is used. For Type 3 PH, the V field set to 0 indicates real transmission on SRS and the V field set to 1 indicates that an SRS reference format is used. Furthermore, for Type 1, Type 2, and Type 3 PH, the V field set to 0 indicates the presence of the octet containing the associated PCMAX,f,c field and the MPE field, and the V field set to 1 indicates that the octet containing the associated PCMAX,f,c field and the MPE field is omitted;
* Power Headroom (PH): This field indicates the power headroom level. The length of the field is 6 bits. The reported PH and the corresponding power headroom levels are shown in Table 6.1.3.8-1 (the corresponding measured values in dB for the NR Serving Cell are specified in TS 38.133 [11] while the corresponding measured values in dB for the E-UTRA Serving Cell are specified in TS 36.133 [12]);

**SCell Activation/Deactivation MAC CEs:**

The SCell Activation/Deactivation MAC CE of one octet is identified by a MAC subheader with LCID as specified in Table 6.2.1-1. It has a fixed size and consists of a single octet containing seven C-fields and one R-field. The SCell Activation/Deactivation MAC CE with one octet is defined as follows (Figure 6.1.3.10-1).

The SCell Activation/Deactivation MAC CE of four octets is identified by a MAC subheader with LCID as specified in Table 6.2.1-1. It has a fixed size and consists of four octets containing 31 C-fields and one R-field. The SCell Activation/Deactivation MAC CE of four octets is defined as follows (Figure 6.1.3.10-2).

* Ci: If there is an SCell configured for the MAC entity with SCellIndex i as specified in TS 38.331 [5], this field indicates the activation/deactivation status of the SCell with SCellIndex i, else the MAC entity shall ignore the Ci field. The Ci field is set to 1 to indicate that the SCell with SCellIndex i shall be activated. The Ci field is set to 0 to indicate that the SCell with SCellIndex i shall be deactivated;
* R: Reserved bit, set to 0

**Duplication Activation/Deactivation MAC CE:**

The Duplication Activation/Deactivation MAC CE of one octet is identified by a MAC subheader with LCID as specified in Table 6.2.1-1. It has a fixed size and consists of a single octet containing eight D-fields. The Duplication Activation/Deactivation MAC CE is defined, for a MAC entity, as follows (Figure 6.1.3.11-1).

- Di: This field indicates the activation/deactivation status of the PDCP duplication of DRB i where i is the ascending order of the DRB ID among the DRBs configured with PDCP duplication and with RLC entity(ies) associated with this MAC entity. The Di field is set to 1 to indicate that the PDCP duplication of DRB i shall be activated. The Di field is set to 0 to indicate that the PDCP duplication of DRB i shall be deactivated.

**SP CSI-RS/CSI-IM Resource Set Activation/Deactivation MAC CE:**

The SP CSI-RS/CSI-IM Resource Set Activation/Deactivation MAC CE is identified by a MAC subheader with LCID as specified in Table 6.2.1-1. It has a variable size and consists of the following fields:

* A/D: This field indicates whether to activate or deactivate indicated SP CSI-RS and CSI-IM resource set(s). The field is set to 1 to indicate activation, otherwise it indicates deactivation;
* Serving Cell ID: This field indicates the identity of the Serving Cell for which the MAC CE applies. The length of the field is 5 bits;
* BWP ID: This field indicates a DL BWP for which the MAC CE applies as the codepoint of the DCI bandwidth part indicator field as specified in TS 38.212 [9]. The length of the BWP ID field is 2 bits;
* SP CSI-RS resource set ID: This field contains an index of NZP-CSI-RS-ResourceSet containing Semi Persistent NZP CSI-RS resources, as specified in TS 38.331 [5], indicating the Semi Persistent NZP CSI-RS resource set, which shall be activated or deactivated. The length of the field is 6 bits;
* IM: This field indicates the presence of the octet containing SP CSI-IM resource set ID field. If the IM field is set to 1, the octet containing SP CSI-IM resource set ID field is present. If IM field is set to 0, the octet containing SP CSI-IM resource set ID field is not present;
* SP CSI-IM resource set ID: This field contains an index of CSI-IM-ResourceSet containing Semi Persistent CSIIM resources, as specified in TS 38.331 [5], indicating the Semi Persistent CSI-IM resource set, which shall be activated or deactivated. The length of the field is 6 bits;
* TCI State IDi: This field contains TCI-StateId, as specified in TS 38.331 [5], of a TCI State, which is used as QCL source for the resource within the Semi Persistent NZP CSI-RS resource set indicated by SP CSI-RS resource set ID field. TCI State ID0 indicates TCI State for the first resource within the set, TCI State ID1 for the second one and so on. The length of the field is 7 bits. If the A/D field is set to 0, the octets containing TCI State ID field(s) are not present;
* R: Reserved bit, set to 0.

**Aperiodic CSI Trigger State Subselection MAC CE:**

The Aperiodic CSI Trigger State Subselection MAC CE is identified by a MAC subheader with LCID as specified in Table 6.2.1-1. It has a variable size consisting of following fields:

* Serving Cell ID: This field indicates the identity of the Serving Cell for which the MAC CE applies. The length of the field is 5 bits;
* BWP ID: This field indicates a DL BWP for which the MAC CE applies as the codepoint of the DCI bandwidth part indicator field as specified in TS 38.212 [9]. The length of the BWP ID field is 2 bits;
* Ti: This field indicates the selection status of the Aperiodic Trigger States configured within aperiodicTriggerStateList, as specified in TS 38.331 [5]. T0 refers to the first trigger state within the list, T1 to the second one and so on. If the list does not contain entry with index i, MAC entity shall ignore the Ti field. The Ti field is set to 1 to indicate that the Aperiodic Trigger State i shall be mapped to the codepoint of the DCI CSI request field, as specified in TS 38.214 [7]. The codepoint to which the Aperiodic Trigger State is mapped is determined by its ordinal position among all the Aperiodic Trigger States with Ti field set to 1, i.e. the first Aperiodic Trigger State with Ti field set to 1 shall be mapped to the codepoint value 1, second Aperiodic Trigger State with Ti field set to 1 shall be mapped to the codepoint value 2 and so on. The maximum number of mapped Aperiodic Trigger States is 63;
* R: Reserved bit, set to 0.

**TCI States Activation/Deactivation for UE-specific PDSCH MAC CE:**

The TCI States Activation/Deactivation for UE-specific PDSCH MAC CE is identified by a MAC subheader with LCID as specified in Table 6.2.1-1. It has a variable size consisting of following fields:

* Serving Cell ID: This field indicates the identity of the Serving Cell for which the MAC CE applies. The length of the field is 5 bits. If the indicated Serving Cell is configured as part of a simultaneousTCI-UpdateList1 or simultaneousTCI-UpdateList2 as specified in TS 38.331 [5], this MAC CE applies to all the Serving Cells configured in the set simultaneousTCI-UpdateList1 or simultaneousTCI-UpdateList2, respectively;
* BWP ID: This field indicates a DL BWP for which the MAC CE applies as the codepoint of the DCI bandwidth part indicator field as specified in TS 38.212 [9]. The length of the BWP ID field is 2 bits. This field is ignored if this MAC CE applies to a set of Serving Cells;
* Ti: If there is a TCI state with TCI-StateId i as specified in TS 38.331 [5], this field indicates the activation/deactivation status of the TCI state with TCI-StateId i, otherwise MAC entity shall ignore the Ti field. The Ti field is set to 1 to indicate that the TCI state with TCI-StateId i shall be activated and mapped to the codepoint of the DCI Transmission Configuration Indication field, as specified in TS 38.214 [7]. The Ti field is set to 0 to indicate that the TCI state with TCI-StateId i shall be deactivated and is not mapped to the codepoint of the DCI Transmission Configuration Indication field. The codepoint to which the TCI State is mapped is determined by its ordinal position among all the TCI States with Ti field set to 1, i.e. the first TCI State with Ti field set to 1 shall be mapped to the codepoint value 0, second TCI State with Ti field set to 1 shall be mapped to the codepoint value 1 and so on. The maximum number of activated TCI states is 8. The activated TCI states can be associated with at most one PCI different from the Serving Cell PCI at a time;
* CORESET Pool ID: This field indicates that mapping between the activated TCI states and the codepoint of the DCI Transmission Configuration Indication set by field Ti is specific to the ControlResourceSetId configured with CORESET Pool ID as specified in TS 38.331 [5]. This field set to 1 indicates that this MAC CE shall be applied for the DL transmission scheduled by CORESET with the CORESET pool ID equal to 1, otherwise, this MAC CE shall be applied for the DL transmission scheduled by CORESET pool ID equal to 0. If the coresetPoolIndex is not configured for any CORESET, MAC entity shall ignore the CORESET Pool ID field in this MAC CE when receiving the MAC CE. If the Serving Cell in the MAC CE is configured in a cell list that contains more than one Serving Cell, the CORSET Pool ID field shall be ignored when receiving the MAC CE.

**TCI State Indication for UE-specific PDCCH MAC CE:**

The TCI State Indication for UE-specific PDCCH MAC CE is identified by a MAC subheader with LCID as specified in Table 6.2.1-1. It has a fixed size of 16 bits with following fields:

* Serving Cell ID: This field indicates the identity of the Serving Cell for which the MAC CE applies. The length of the field is 5 bits. If the indicated Serving Cell is configured as part of a simultaneousTCI-UpdateList1 or simultaneousTCI-UpdateList2 as specified in TS 38.331 [5], this MAC CE applies to all theServing Cells in the set simultaneousTCI-UpdateList1 or simultaneousTCI-UpdateList2, respectively;
* CORESET ID: This field indicates a Control Resource Set identified with ControlResourceSetId as specified in TS 38.331 [5], for which the TCI State is being indicated. In case the value of the field is 0, the field refers to the Control Resource Set configured by controlResourceSetZero as specified in TS 38.331 [5]. The length of the field is 4 bits;
* TCI State ID: This field indicates the TCI state identified by TCI-StateId as specified in TS 38.331 [5] applicable to the Control Resource Set identified by CORESET ID field. If the field of CORESET ID is set to 0, this field indicates a TCI-StateId for a TCI state of the first 64 TCI-states configured by tci-StatesToAddModList and tciStatesToReleaseList in the PDSCH-Config in the active BWP. If the field of CORESET ID is set to the other value than 0, this field indicates a TCI-StateId configured by tci-StatesPDCCH-ToAddList and tciStatesPDCCH-ToReleaseList in the controlResourceSet identified by the indicated CORESET ID. The length of the field is 7 bits.

**SP CSI reporting on PUCCH Activation/Deactivation MAC CE:**

The SP CSI reporting on PUCCH Activation/Deactivation MAC CE is identified by a MAC subheader with LCID as specified in Table 6.2.1-1. It has a fixed size of 16 bits with following fields:

* Serving Cell ID: This field indicates the identity of the Serving Cell for which the MAC CE applies. The length of the field is 5 bits;
* BWP ID: This field indicates a UL BWP for which the MAC CE applies as the codepoint of the DCI bandwidth part indicator field as specified in TS 38.212 [9]. The length of the BWP ID field is 2 bits;
* Si: This field indicates the activation/deactivation status of the Semi-Persistent CSI report configuration within csi-ReportConfigToAddModList, as specified in TS 38.331 [5]. S0 refers to the report configuration which includes PUCCH resources for SP CSI reporting in the indicated BWP and has the lowest CSI-ReportConfigId within the list with type set to semiPersistentOnPUCCH, S1 to the report configuration which includes PUCCH resources for SP CSI reporting in the indicated BWP and has the second lowest CSI-ReportConfigId and so on. If the number of report configurations within the list with type set to semiPersistentOnPUCCH in the indicated BWP is less than i + 1, MAC entity shall ignore the Si field. The Si field is set to 1 to indicate that the corresponding Semi-Persistent CSI report configuration shall be activated. The Si field is set to 0 to indicate that the corresponding Semi-Persistent CSI report configuration i shall be deactivated;
* R: Reserved bit, set to 0.

**SP SRS Activation/Deactivation MAC CE:**

The SP SRS Activation/Deactivation MAC CE is identified by a MAC subheader with LCID as specified in Table 6.2.1-1. It has a variable size with following fields:

* A/D: This field indicates whether to activate or deactivate indicated SP SRS resource set. The field is set to 1 to indicate activation, otherwise it indicates deactivation;

**Editor's note:** FFS if Upon reception of a MAC CE to activate an SP SRS resource set for antenna switching, the UE considers any previously activated SP SRS resource set for antenna switching as deactivated.

* SRS Resource Set's Cell ID: This field indicates the identity of the Serving Cell, which contains activated/deactivated SP SRS Resource Set. If the C field is set to 0, this field also indicates the identity of the Serving Cell which contains all resources indicated by the Resource IDi fields. The length of the field is 5 bits;
* SRS Resource Set's BWP ID: This field indicates a UL BWP as the codepoint of the DCI bandwidth part indicator field as specified in TS 38.212 [9], which contains activated/deactivated SP SRS Resource Set. If the C field is set to 0, this field also indicates the identity of the BWP which contains all resources indicated by the Resource IDi fields. The length of the field is 2 bits;
* C: This field indicates whether the octets containing Resource Serving Cell ID field(s) and Resource BWP ID field(s) are present. If this field is set to 1, the octets containing Resource Serving Cell ID field(s) and Resource BWP ID field(s) are present, otherwise they are not present;
* SUL: This field indicates whether the MAC CE applies to the NUL carrier or SUL carrier configuration. This field is set to 1 to indicate that it applies to the SUL carrier configuration, and it is set to 0 to indicate that it applies to the NUL carrier configuration;
* SP SRS Resource Set ID: This field indicates the SP SRS Resource Set ID identified by SRS-ResourceSetId as specified in TS 38.331 [5], which is to be activated or deactivated. The length of the field is 4 bits;
* Fi: This field indicates the type of a resource used as a spatial relationship for SRS resource within SP SRS Resource Set indicated with SP SRS Resource Set ID field. F0 refers to the first SRS resource within the resource set, F1 to the second one and so on. The field is set to 1 to indicate NZP CSI-RS resource index is used, and it is set to 0 to indicate either SSB index or SRS resource index is used. The length of the field is 1 bit. This field is only present if MAC CE is used for activation, i.e. the A/D field is set to 1;
* Resource IDi: This field contains an identifier of the resource used for spatial relationship derivation for SRS resource i. Resource ID0 refers to the first SRS resource within the resource set, Resource ID1 to the second one and so on. If Fi is set to 0, and the first bit of this field is set to 1, the remainder of this field contains SSB-Index as specified in TS 38.331 [5]. If Fi is set to 0, and the first bit of this field is set to 0, the remainder of this field contains SRS-ResourceId as specified in TS 38.331 [5]. The length of the field is 7 bits. This field is only present if MAC CE is used for activation, i.e. the A/D field is set to 1;
* Resource Serving Cell IDi: This field indicates the identity of the Serving Cell on which the resource used for spatial relationship derivation for SRS resource i is located. The length of the field is 5 bits;
* Resource BWP IDi: This field indicates a UL BWP as the codepoint of the DCI bandwidth part indicator field as specified in TS 38.212 [9], on which the resource used for spatial relationship derivation for SRS resource i is located. The length of the field is 2 bits;
* R: Reserved bit, set to 0.

**PUCCH spatial relation Activation/Deactivation MAC CE:**

The PUCCH spatial relation Activation/Deactivation MAC CE is identified by a MAC subheader with LCID as specified in Table 6.2.1-1. It has a fixed size of 24 bits with following fields:

* Serving Cell ID: This field indicates the identity of the Serving Cell for which the MAC CE applies. The length of the field is 5 bits;
* BWP ID: This field indicates a UL BWP for which the MAC CE applies as the codepoint of the DCI bandwidth part indicator field as specified in TS 38.212 [9]. The length of the BWP ID field is 2 bits;
* PUCCH Resource ID: This field contains an identifier of the PUCCH resource ID identified by PUCCHResourceId as specified in TS 38.331 [5]. The length of the field is 7 bits;
* Si: If, in PUCCH-Config in which the PUCCH Resource ID is configured, there is a PUCCH Spatial Relation Info with PUCCH-SpatialRelationInfoId as specified in TS 38.331 [5], configured for the uplink bandwidth part indicated by BWP ID field, Si indicates the activation status of PUCCH Spatial Relation Info with PUCCHSpatialRelationInfoId equal to i + 1, otherwise MAC entity shall ignore this field. The Si field is set to 1 to indicate PUCCH Spatial Relation Info with PUCCH-SpatialRelationInfoId equal to i + 1 shall be activated. The Si field is set to 0 to indicate PUCCH Spatial Relation Info with PUCCH-SpatialRelationInfoId equal to i + 1 shall be deactivated. Only a single PUCCH Spatial Relation Info can be active for a PUCCH Resource at a time;
* R: Reserved bit, set to 0.

**SP ZP CSI-RS Resource Set Activation/Deactivation MAC CE:**

The SP ZP CSI-RS Resource Set Activation/Deactivation MAC CE is identified by a MAC subheader with LCID as specified in Table 6.2.1-1. It has a fixed size of 16 bits with following fields:

* A/D: This field indicates whether to activate or deactivate indicated SP ZP CSI-RS resource set. The field is set to 1 to indicate activation, otherwise it indicates deactivation;
* Serving Cell ID: This field indicates the identity of the Serving Cell for which the MAC CE applies. The length of the field is 5 bits;
* BWP ID: This field indicates a DL BWP for which the MAC CE applies as the codepoint value of the DCI bandwidth part indicator field as specified in TS 38.212 [9]. The length of the BWP ID field is 2 bits;
* SP ZP CSI-RS resource set ID: This field contains an index of sp-ZP-CSI-RS-ResourceSetsToAddModList, as specified in TS 38.331 [5], indicating the Semi Persistent ZP CSI-RS resource set, which shall be activated or deactivated. The length of the field is 4 bits;
* R: Reserved bit, set to 0.

**Recommended bit rate MAC CE:**

The Recommended bit rate MAC CE is identified by a MAC subheader with LCID as specified in Tables 6.2.1-1 and 6.2.1-2 for bit rate recommendation message from the gNB to the UE and bit rate recommendation query message from the UE to the gNB, respectively. It has a fixed size and consists of two octets defined as follows (Figure 6.1.3.20-1):

* LCID: This field indicates the identity of the logical channel for which the recommended bit rate or the recommended bit rate query is applicable. The length of the field is 6 bits;
* Uplink/Downlink (UL/DL): This field indicates whether the recommended bit rate or the recommended bit rate query applies to uplink or downlink. The length of the field is 1 bit. The UL/DL field set to 0 indicates downlink. The UL/DL field set to 1 indicates uplink;
* Bit Rate: This field indicates an index to Table 6.1.3.20-1. The length of the field is 6 bits. For bit rate recommendation the value indicates the recommended bit rate. For bit rate recommendation query the value indicates the desired bit rate;
* X: Bit rate multiplier. For UEs supporting recommended bit rate multiplier, when bitRateMultiplier is configured for the logical channel indicated by LCID field, X field set to 1 indicates the actual value of bit rate is the value corresponding to the index indicated by the Bit Rate field multiplied by bitRateMultiplier as specified in TS 38.331 [5].
* R: reserved bit, set to 0.

**Timing Delta MAC CE:**

The Timing Delta MAC CE is identified by MAC subheader with eLCID as specified in Table 6.2.1-1b. It has a fixed size and consists of two octets defined as follows (Figure 6.1.3.21-1):

* R: Reserved bit, set to 0;
* Tdelta: This field indicates the value (0,1,…,2047) used to control the amount of timing adjustment that MAC entity indicates (as specified in TS 38.213 [6]). The length of the field is 11 bits.

**Guard Symbols MAC CEs:**

The Guard Symbols MAC CEs (i.e. Provided Guard Symbols MAC CE and Desired Guard Symbols MAC CE) for Case-1 timing mode are identified by the MAC subheader with eLCID as specified in Table 6.2.1-1b for DL-SCH and in Table 6.2.1-2b for UL-SCH. It has fixed size and consists of four octets defined as follows (Figure 6.1.3.22-1):

* R: Reserved bit, set to 0;
* Serving Cell ID: This field indicates the identity of the Serving Cell for which the MAC CE applies. The length of the field is 5 bits;
* Sub-carrier spacing (SCS): This field indicates the subcarrier spacing used as reference for the guard spacing. The length of this field is 2bits. The values for the SCS field are shown in Table 6.1.3.22-2;
* Number of Guard Symbols (NmbGSi): This field indicates the number of guard symbols for the switching scenario shown in Table 5.18.19-1. The number of guard symbols can take values within the range of 0 to 4. Higher values 5 to 7 are reserved.

**BFR MAC CEs:**

The MAC CEs for BFR consists of either:

* BFR MAC CE; or
* Truncated BFR MAC CE.

For Truncated BFR MAC CE, a single octet bitmap is used for the following cases, otherwise four octets are used:

* The highest ServCellIndex of this MAC entity's SCell for which beam failure is detected and the evaluation of the candidate beams according to the requirements as specified in TS 38.133 [11] has been completed is less than 8; or
* Beam failure is detected for SpCell (as specified in Clause 5.17) and the SpCell is to be indicated in a Truncated BFR MAC CE and the UL-SCH resources available for transmission cannot accommodate the Truncated BFR MAC CE with the four octets bitmap plus its subheader as a result of LCP.

The fields in the BFR MAC CEs are defined as follows:

* SP: This field indicates beam failure detection (as specified in clause 5.17) for the SpCell of this MAC entity. The SP field is set to 1 to indicate that beam failure is detected for SpCell only when BFR MAC CE or Truncated BFR MAC CE is to be included into a MAC PDU as part of Random Access Procedure (as specified in 5.1.3a and 5.1.4), otherwise, it is set to 0;
* Ci (BFR MAC CE): This field indicates beam failure detection (as specified in clause 5.17) and the presence of an octet containing the AC field for the SCell with ServCellIndex i as specified in TS 38.331 [5]. The Ci field set to 1 indicates that beam failure is detected, the evaluation of the candidate beams according to the requirements as specified in TS 38.133 [11] has been completed, and the octet containing the AC field is present for the SCell with ServCellIndex i. The Ci field set to 0 indicates that the beam failure is either not detected or the beam failure is detected but the evaluation of the candidate beams according to the requirements as specified in TS 38.133 [11] has not been completed, and the octet containing the AC field is not present for the SCell with ServCellIndex i. The octets containing the AC field are present in ascending order based on the ServCellIndex;
* Ci (Truncated BFR MAC CE): This field indicates beam failure detection (as specified in clause 5.17) for the SCell with ServCellIndex i as specified in TS 38.331 [5]. The Ci field set to 1 indicates that beam failure is detected, the evaluation of the candidate beams according to the requirements as specified in TS 38.133 [11] has been completed, and the octet containing the AC field for the SCell with ServCellIndex i may be present. The Ci field set to 0 indicates that the beam failure is either not detected or the beam failure is detected but the evaluation of the candidate beams according to the requirements as specified in TS 38.133 [11] has not been completed, and the octet containing the AC field is not present for the SCell with ServCellIndex i. The octets containing the AC field, if present, are included in ascending order based on the ServCellIndex. The number of octets containing the AC field included is maximised, while not exceeding the available grant size;

**NOTE:** The number of the octets containing the AC field in the Truncated BFR MAC CE can be zero.

* AC: This field indicates the presence of the Candidate RS ID field in this octet. If at least one of the SSBs with SS-RSRP above rsrp-ThresholdBFR amongst the SSBs in candidateBeamRSSCellList or the CSI-RSs with CSIRSRP above rsrp-ThresholdBFR amongst the CSI-RSs in candidateBeamRSSCellList is available, the AC field is set to 1; otherwise, it is set to 0. If the AC field set to 1, the Candidate RS ID field is present. If the AC field set to 0, R bits are present instead;
* Candidate RS ID: This field is set to the index of an SSB with SS-RSRP above rsrp-ThresholdBFR amongst the SSBs in candidateBeamRSSCellList or to the index of a CSI-RS with CSI-RSRP above rsrp-ThresholdBFR amongst the CSI-RSs in candidateBeamRSSCellList. Index of an SSB or CSI-RS is the index of an entry in candidateBeamRSSCellList corresponding to the SSB or CSI-RS. Index 0 corresponds to the first entry in the candidateBeamRSSCellList, index 1 corresponds to the second entry in the list and so on. The length of this field is 6 bits.
* R: Reserved bit, set to 0.

**Enhanced TCI States Activation/Deactivation for UE-specific PDSCH MAC CE:**

The Enhanced TCI States Activation/Deactivation for UE-specific PDSCH MAC CE is identified by a MAC PDU subheader with eLCID as specified in Table 6.2.1-1b. It has a variable size consisting of following fields:

* Serving Cell ID: This field indicates the identity of the Serving Cell for which the MAC CE applies. The length of the field is 5 bits. If the indicated Serving Cell is configured as part of a simultaneousTCI-UpdateList1 or simultaneousTCI-UpdateList2 as specified in TS 38.331 [5], this MAC CE applies to all the Serving Cells configured in the set simultaneousTCI-UpdateList1 or simultaneousTCI-UpdateList2, respectively;
* BWP ID: This field indicates a DL BWP for which the MAC CE applies as the codepoint of the DCI bandwidth part indicator field as specified in TS 38.212 [9]. The length of the BWP ID field is 2 bits;
* Ci: This field indicates whether the octet containing TCI state IDi,2 is present. If this field is set to 1, the octet containing TCI state IDi,2 is present. If this field is set to 0, the octet containing TCI state IDi,2 is not present;
* TCI state IDi,j: This field indicates the TCI state identified by TCI-StateId as specified in TS 38.331 [5], where i is the index of the codepoint of the DCI Transmission configuration indication field as specified in TS 38.212 [9] and TCI state IDi,j denotes the jth TCI state indicated for the ith codepoint in the DCI Transmission Configuration Indication field. The TCI codepoint to which the TCI States are mapped is determined by its ordinal position among all the TCI codepoints with sets of TCI state IDi,j fields, i.e. the first TCI codepoint with TCI state ID0,1 and TCI state ID0,2 shall be mapped to the codepoint value 0, the second TCI codepoint with TCI state ID1,1 and TCI state ID1,2 shall be mapped to the codepoint value 1 and so on. The TCI state IDi,2 is optional based on the indication of the Ci field. The maximum number of activated TCI codepoint is 8 and the maximum number of TCI states mapped to a TCI codepoint is 2.
* R: Reserved bit, set to 0.

**Enhanced PUCCH Spatial Relation Activation/Deactivation MAC CE:**

The Enhanced PUCCH Spatial Relation Activation/Deactivation MAC CE is identified by a MAC subheader with eLCID as specified in Table 6.2.1-1b. It has a variable size with following fields:

* Serving Cell ID: This field indicates the identity of the Serving Cell for which the MAC CE applies. The length of the field is 5 bits;
* BWP ID: This field indicates a UL BWP for which the MAC CE applies as the codepoint of the DCI bandwidth part indicator field as specified in TS 38.212 [9]. The length of the BWP ID field is 2 bits;
* PUCCH Resource ID: This field contains an identifier of the PUCCH resource ID identified by PUCCHResourceId as specified in TS 38.331 [5], which is to be activated with a spatial relation indicated by Spatial Relation Info ID field in the subsequent octet. The length of the field is 7 bits. If the indicated PUCCH Resource ID is included in a PUCCH Resource Group (configured via resourceGroupToAddModList as specified in TS 38.331 [5]) of the indicated UL BWP, no other PUCCH Resources within the same PUCCH Resource group are indicated in the MAC CE, and this MAC CE applies to all the PUCCH Resources in the PUCCH Resource group;
* Spatial Relation Info ID: This field contains PUCCH-SpatialRelationInfoId – 1 where PUCCHSpatialRelationInfoId is the identifier of the PUCCH Spatial Relation Info in PUCCH-Config in which the PUCCH Resource ID is configured, as specified in TS 38.331 [5]. The length of the field is 6 bits;
* R: Reserved bit, set to 0.

**Enhanced SP/AP SRS Spatial Relation Indication MAC CE:**

The Enhanced SP/AP SRS Spatial Relation Indication MAC CE is identified by a MAC subheader with eLCID as specified in Table 6.2.1-1b. It has a variable size with following fields:

* A/D: This field indicates whether to activate or deactivate indicated SP SRS resource set. The field is set to 1 to indicate activation, otherwise it indicates deactivation. If the indicated SRS resource set ID is for the AP SRS resource set, MAC entity shall ignore this field;

**Editor's note**: FFS if Upon reception of a MAC CE to activate an SP SRS resource set for antenna switching, the UE considers any previously activated SP SRS resource set for antenna switching as deactivated.

* SRS Resource Set's Cell ID: This field indicates the identity of the Serving Cell, which contains the indicated SP/AP SRS Resource Set. If the C field is set to 0, this field also indicates the identity of the Serving Cell which contains all resources indicated by the Resource IDi fields. The length of the field is 5 bits;
* SRS Resource Set's BWP ID: This field indicates a UL BWP as the codepoint of the DCI bandwidth part indicator field as specified in TS 38.212 [9], which contains the indicated SP/AP SRS Resource Set. If the C field is set to 0, this field also indicates the identity of the BWP which contains all resources indicated by the Resource IDi fields. The length of the field is 2 bits;
* C: This field indicates whether the octets containing Resource Serving Cell ID field(s) and Resource BWP ID field(s) are present. If this field is set to 1, Resource Serving Cell ID field(s) and Resource BWP ID field(s) are present, otherwise they are not present so MAC entity shall ignore Resource Serving Cell ID field(s) and Resource BWP ID field(s);
* SUL: This field indicates whether the MAC CE applies to the NUL carrier or SUL carrier configuration. This field is set to 1 to indicate that it applies to the SUL carrier configuration, and it is set to 0 to indicate that it applies to the NUL carrier configuration;
* SRS Resource Set ID: This field indicates the SP/AP SRS Resource Set ID identified by SRS-ResourceSetId as specified in TS 38.331 [5]. The length of the field is 4 bits;
* Fi: This field indicates the type of a resource used as a spatial relationship for SRS resource within SP/AP SRS Resource Set indicated with SP/AP SRS Resource Set ID field. F0 refers to the first SRS resource within the resource set, F1 to the second one and so on. The field is set to 1 to indicate NZP CSI-RS resource index is used, and it is set to 0 to indicate either SSB index or SRS resource index is used. The length of the field is 1 bit. This field is only present if MAC CE is used for activation of SP SRS resource set, i.e. the A/D field is set to 1, or for AP SRS resource set;
* Resource Serving Cell IDi: This field indicates the identity of the Serving Cell on which the resource used for spatial relationship derivation for SRS resource i is located. The length of the field is 5 bits;
* Resource BWP IDi: This field indicates a UL BWP as the codepoint of the DCI bandwidth part indicator field as specified in TS 38.212 [9], on which the resource used for spatial relationship derivation for SRS resource i is located. The length of the field is 2 bits;
* Resource IDi: This field contains an identifier of the resource used for spatial relationship derivation for SRS resource i. Resource ID0 refers to the first SRS resource within the resource set, Resource ID1 to the second one and so on. If Fi is set to 0, the first bit of this field is always set to 0. If Fi is set to 0, and the second bit of this field is set to 1, the remainder of this field contains SSB-Index as specified in TS 38.331 [5]. If Fi is set to 0, and the second bit of this field is set to 0, the remainder of this field contains SRS-ResourceId as specified in TS 38.331 [5]. The length of the field is 8 bits. This field is only present if MAC CE is used for activation of SP SRS resource set, i.e. the A/D field is set to 1, or for AP SRS resource set;
* R: Reserved bit, set to 0.

**SRS Pathloss Reference RS Update MAC CE:**

The SRS Pathloss Reference RS Update MAC CE is identified by a MAC subheader with eLCID as specified in Table 6.2.1-1b. It has a fixed size of 24 bits:

* Serving Cell ID: This field indicates the identity of the Serving Cell, which contains activated SRS Resource Set. The length of the field is 5 bits;
* BWP ID: This field indicates a UL BWP as the codepoint of the DCI bandwidth part indicator field as specified in TS 38.212 [9], which contains activated SRS Resource Set. The length of the field is 2 bits;
* SRS Resource Set ID: This field indicates the SRS Resource Set ID identified by SRS-ResourceSetId as specified in TS 38.331 [5]. The length of the field is 4 bits;
* Pathloss Reference RS ID: This field indicates the Pathloss Reference RS ID identified by srsPathlossReferenceRS-Id as specified in TS 38.331 [5]. It updates the pathloss reference RS for a SRS-resource set indicated by SRS Resource Set ID field. The length of the field is 6 bits;
* R: Reserved bit, set to 0.

**PUSCH Pathloss Reference RS Update MAC CE:**

The PUSCH Pathloss Reference RS Update MAC CE is identified by a MAC subheader with eLCID as specified in Table 6.2.1-1b. It has a variable size and consists of the following fields:

* Serving Cell ID: This field indicates the identity of the Serving Cell, which contains activated PUSCH Pathloss Reference RS. The length of the field is 5 bits;
* BWP ID: This field indicates a UL BWP as the codepoint of the DCI bandwidth part indicator field as specified in TS 38.212 [9], which contains activated PUSCH Pathloss Reference RS. The length of the field is 2 bits;
* T: If the UE is configured with two SRS resources sets for codebook or non-codebook, as specified in TS 38.331 [5], in the indicated bandwidth part of the indicated Serving Cell, if this field is set to 0, SRI ID(s) to be updated are the ones associated with the first SRS resource set, and if is set to 1 the SRI ID(s) to be updated are the ones associated with the second SRS resource set. Otherwise, this field is a reserved bit set to 0;
* PUSCH Pathloss Reference RS ID: This field indicates the PUSCH Pathloss Reference RS ID identified by PUSCH-PathlossReferenceRS-Id as specified in TS 38.331 [5], which is to be updated in the SRI PUSCH power control mappings indicated by SRI ID fields indicated in the same MAC CE. The length of the field is 6 bits;
* C: This field indicates the presence of the additional SRI ID in the last octet of this MAC CE. If this field is set to 1, two SRI ID(s) are present in the last octet. Otherwise only one SRI ID (i.e. the first SRI ID) is present in the last octet;
* SRI ID: This field indicates the SRI PUSCH power control ID identified by sri-PUSCH-PowerControlId as specified in TS 38.331 [5]. The length of the field is 4 bits;
* R: Reserved bit, set to 0.