

LTE Aperiodic CSI Reporting for Carrier Aggregation

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When eNodeB wants to know how good UE receives DL signal of the serving cell, it sends CSI request to the UE. In return, the UE sends CSI report back to the eNodeB containing CQI, RI and PMI characteristics of the serving cell as perceived by this particular UE at this particular point in time and space.

There are a few very basic questions that can be asked w.r.t. this process:

1. How does eNodeB request the UE to send a CSI report?
2. When does the UE have to send CSI report upon receiving CSI request?
3. In case of carrier aggregation, how does UE know which component carriers the eNodeB wants to receive CSI report for? Does eNodeB specify this somehow?
4. How many component carriers can be reported at one go, i.e. in one CSI report?

Let's answer these question.

According to *3GPP TS 36.213 Physical layer procedures*, specifically to *7.2.1 Aperiodic CSI Reporting using PUSCH*, A UE shall perform aperiodic CSI reporting using the PUSCH in subframe ***n+k*** on serving cell , upon decoding in subframe ***n*** either:

- an uplink DCI format, or
- a Random Access Response Grant,

for serving cell if the respective CSI request field is set to trigger a report and is not reserved. If the CSI request field is 1 bit, a report is triggered for serving cell if the CSI request field is set to '1'. If the CSI request field size is 2 bits, a report is triggered according to the value in Table 7.2.1-1A corresponding to aperiodic CSI reporting:

Table 7.2.1-1A: CSI Request field for PDCCH with uplink DCI format in UE specific search space

Value of CSI request field	Description
'00'	No aperiodic CSI report is triggered
'01'	Aperiodic CSI report is triggered for serving cell c
'10'	Aperiodic CSI report is triggered for a 1st set of serving cells configured by higher layers
'11'	Aperiodic CSI report is triggered for a 2nd set of serving cells configured by higher layers

When the CSI request field from an uplink DCI format is set to trigger a report, for FDD ***k=4***, and for TDD UL/DL configuration 1-6, k is given in Table 8-2:

Table 8-2 *k* for TDD configurations 0-6

TDD UL/DL Configuration	subframe number *n*									
	0	1	2	3	4	5	6	7	8	9
0	4	6				4	6			
1		6			4		6			4
2				4					4	
3	4								4	4

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4									4	4
5									4	
6	7	7				7	7			5

Two questions have been already answered:

1. UL DCI (DCI 0) contains a special CSAI Request field and that is how eNodeB requests the UE to send a CSI report: 0 (or 00) - eNodeB doesn't need any CSI report, 1 (or 01) - it requests a CSI report fro PCell.
2. Upon receiving CSI request from eNodeB, UE must send CSI report in 4 subframes in case of FDD primary cell and in mostly the same 4 subframes in case of TDD primary cell, however other values are possible subject to ***n*** and TDD UL/DL Configuration.

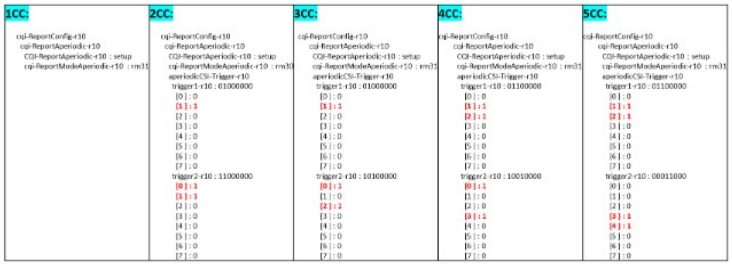
And now more interesting part - how does it all work in case of DL carrier aggregation with multiple component carriers?

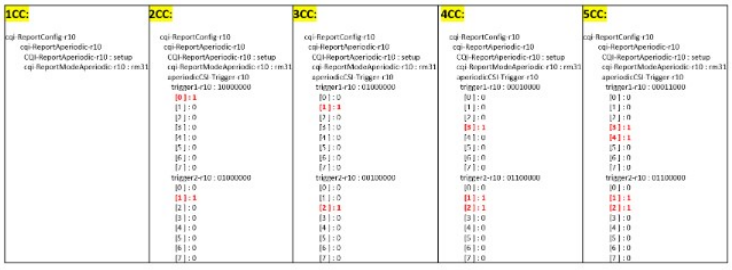
To this end, *3GPP TS 36.213* allows for special values of CSI request field - values 10 and 11. According to Table 7.2.1-1A, either value requests aperiodic CSI report a set of component carriers and there are two sets possible. That is exactly the way to operators to allocate component carriers per either set and request CSI for a several component carriers in this way. Which component carrier belongs to which set (Set1 or Set2) is configured by higher layers, specifically by the *aperiodicCSI-Trigger* field of RRC Connection Reconfiguration message. According to *3GPP TS 36.331 Radio Resource Control (RRC)*, *aperiodicCSI-Trigger* indicates for which serving cell(s) the aperiodic CSI report is triggered when one or more SCells are configured. ***trigger1*** corresponds to the CSI request field 10 and ***trigger2*** corresponds to the CSI request field 11. The leftmost bit, bit 0 in the bit string corresponds to the cell with ServCellIndex=0 and bit 1 in the bit string corresponds to the cell with ServCellIndex=1 etc. Each bit has either value 0 (means no aperiodic CSI report is triggered) or value 1 (means the aperiodic CSI report is triggered). At most 5 bits can be set to value 1 in the bit string.

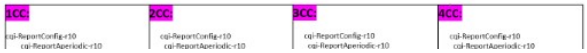
Now we have another question answered - at most 5 bits can be set to value 1 in the bit string, which means CSI of maximum 5 component carriers can be requested/reported by means of one trigger set. Truth be told, in real life commercial networks you will never find more than s 1's per trigger set, and in overwhelming majority of cases 2 1's is the maximum, which is totally sufficient to cover 5CC carrier aggregation case.

Below you can see three examples from three different networks of how component carriers, or to be correct their corresponding *sCellIndex* are included in either *trigger1* or *trigger2* set. It is totally up to RAN infrastructure vendor which component carriers to include in either trigger set.

click on image to enlarge







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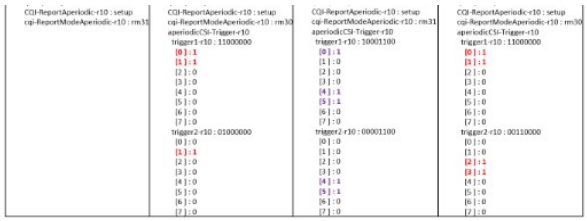
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Please pay attention that position in the bit string does not automatically implies the number of component carriers in the carrier aggregation. It just equals to the *sCellIndex-r10* value of the corresponding SCell of the *sCellToAddModList-r10* field of the *RRC Connection Reconfiguration* message. To stress this point, please pay attention to the 3CC case of the "purple" operator - even though there are 1's in the bit string corresponding to *sCellIndex* 4 and 5, it doesn't automatically mean that 6CC CA with indexes 0, 1, 2, 3, 4 and 5 is configured currently in this UE. It only means that eNodeB, due to one reason or another, decided to allocated sCellIndex 4 and 5 to the SCell_1 and SCell_2 (PCell has always index 0) of 3CC CA configuration. What really reflects the total number of component carriers configured in carrier aggregation, is the sum of unique positions in the bit string with value 1: in this particular case they are 0, 4 and 5, i.e. this is a 3CC CA case.

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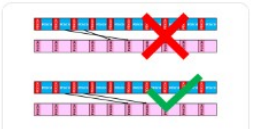
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