

Ex. 1031

Carrier Aggregation explained

Dec 11,2022

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Carrier aggregation is used in LTE-Advanced in order to increase the bandwidth, and thereby increase the bitrate. Since it is important to keep backward compatibility with R8 and R9 UEs the aggregation is based on R8/R9 carriers. Carrier aggregation can be used for both FDD and TDD, see figure 1 for an example where FDD is used.

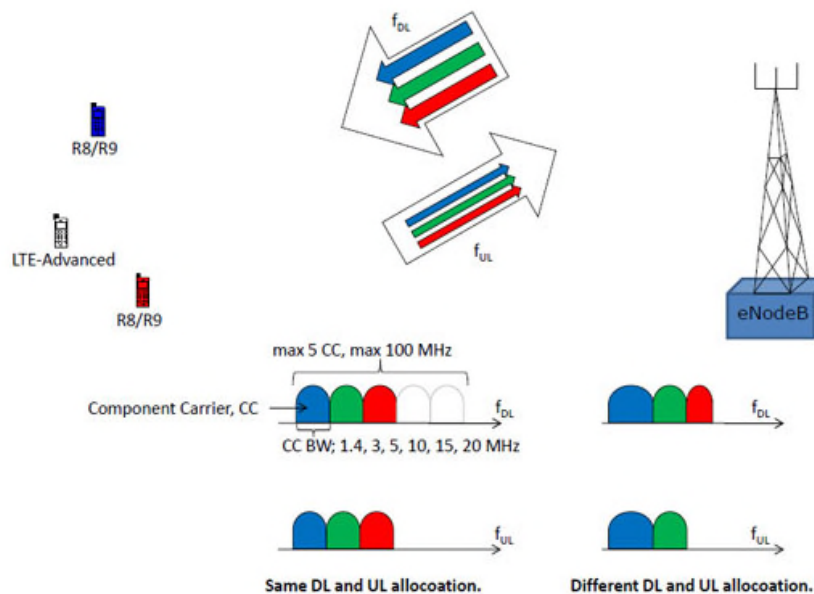


Figure 1. Carrier Aggregation (FDD); The LTE-Advanced UE can be allocated DL and UL resources on the aggregated resource consisting of two or more Component Carriers (CC), the R8/R9 UEs can be allocated resources on any ONE of the CCs. The CCs can be of different bandwidths.

Each aggregated carrier is referred to as a component carrier, CC. The component carrier can have 1.4, 3, 5, 10, 15 or 20 MHz

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and a maximum of five component carriers can be aggregated, hence the maximum aggregated bandwidth is 100 MHz. In FDD the number of aggregated carriers can be different in DL and UL, see figure 1. However, the number of UL component carriers is always equal to or lower than the number of DL component carriers. The individual component carriers can also be of different bandwidths. For TDD the number of CCs as well as the bandwidths of each CC will normally be the same for DL and UL.

The easiest way to arrange aggregation would be to use contiguous component carriers within the same operating frequency band (as defined for LTE), so called intra-band contiguous. This might not always be possible, due to operator frequency allocation scenarios. For non-contiguous allocation it could either be intra-band, i.e. the component carriers belong to the same operating frequency band, but have a gap, or gaps, in between, or it could be inter-band, in which case the component carriers belong to different operating frequency bands, see figure 2.

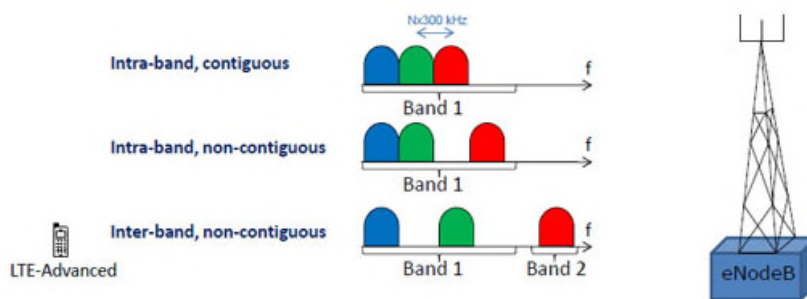


Figure 2. Carrier Aggregation; Intra-band and inter-band aggregation alternatives. The spacing between the centre frequencies of two contiguous CCs is $N \times 300$ kHz, $N = \text{integer}$. For non-contiguous cases the CCs are separated by one, or more, frequency gap(s).

For practical reasons CA is initially specified for only a few combinations of E-UTRA operating bands and number of CCs. To specify different CA combinations some new definitions are used:

- Aggregated Transmission Bandwidth Configuration (ATBC): total number of aggregated physical resource blocks (PRB).
- CA bandwidth class: indicates a combination of maximum ATBC and maximum number of CCs. In R10 and R11 three classes are defined:

Class A: $\text{ATBC} \leq 100$, maximum number of CC = 1

Class B: $ATBC \leq 100$, maximum number of CC = 2

Class C: $100 < ATBC \leq 200$, maximum number of CC = 2

- CA configuration: indicates a combination of E-UTRA operating band(s) and CA bandwidth class(es), to exemplify the configuration CA_1C indicates intra-band contiguous CA on E-UTRA operating band 1 and CA bandwidth class C, CA_1A_1A, indicates intra-band non-contiguous CA on band 1 with a one CC on each side of the intra-band gap, finally CA_1A-5B indicates inter-band CA, on operating band 1 with bandwidth class A and operating band 5 with bandwidth class B.

In R10 three CA configurations are defined, see table 1.

Type of CA and duplex type	CA configuration	Maximum aggregated bandwidth (MHz)	Max number of CC
Intra-band contiguous FDD	CA_1C	40	2
Intra-band contiguous TDD	CA_40C	40	2
Inter-band FDD	CA_1A_5A	20	1 + 1

Table 1. CA configurations defined for R10

In R11 a large number of additional CA configurations are defined, see table 2. The maximum aggregated bandwidth is still 40 MHz and maximum number of CC is 2. Note also that for both R10 and R11 any UL CC will have the same bandwidth as the corresponding DL CC. Also for inter-band CA there will only be ONE UL CC, i.e. no UL CA.

Type of CA and duplex type	CA configuration	Maximum aggregated bandwidth (MHz)	Max number of CC
Intra-band contiguous FDD	CA_1C	40	2
	CA_7C	40	2
Intra-band contiguous	CA_38C	40	2

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TDD	CA_40C	20	2
	CA_41C	40	2
	CA_1A_5A	20	1 + 1
	CA_1A_18A	35	1 + 1
	CA_1A_19A	35	1 + 1
	CA_1A_21A	35	1 + 1
	CA_2A_17A	20	1 + 1
	CA_2A_29A	20	1 + 1
	CA_3A_5A	30	1 + 1
	CA_3A_7A	40	1 + 1
	CA_3A_8A	30	1 + 1
	CA_3A_20A	30	1 + 1
Inter-band FDD	CA_4A_5A	20	1 + 1
	CA_4A_7A	30	1 + 1
	CA_4A_12A	20	1 + 1
	CA_4A_13A	30	1 + 1
	CA_4A_17A	20	1 + 1
	CA_4A_29A	20	1 + 1
	CA_5A_12A	20	1 + 1
	CA_5A_17A	20	1 + 1
	CA_7A_20A	30	1 + 1
	CA_8A_20A	20	1 + 1
	CA_11A_18A	25	1 + 1

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Intra-band non-contiguous FDD	CA_25A_25A 20	1 + 1
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Table 2. CA configurations defined in R11

In later releases more configurations will be added. For example, in R12 configurations for UL inter-band CA configuration will be introduced.

When carrier aggregation is used there are a number of serving cells, one for each component carrier. The coverage of the serving cells may differ, for example due to that CCs on different frequency bands will experience different pathloss, see figure 3. The RRC connection is only handled by one cell, the Primary serving cell, served by the Primary component carrier (DL and UL PCC). It is also on the DL PCC that the UE receives NAS information, such as security parameters. In idle mode the UE listens to system information on the DL PCC. On the UL PCC PUCCH is sent. The other component carriers are all referred to as Secondary component carriers (DL and UL SCC), serving the Secondary serving cells, see figure 3. The SCCs are added and removed as required, while the PCC is only changed at handover.

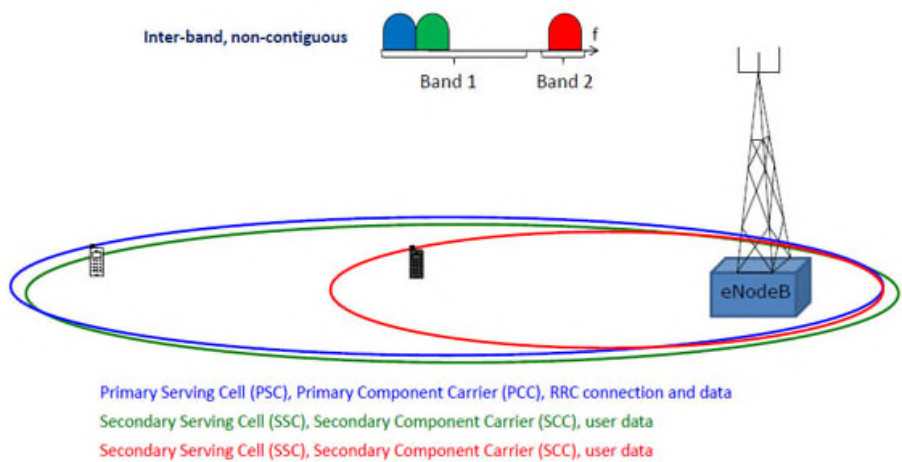


Figure 3. Carrier Aggregation; Primary and Secondary serving cells. Each component carrier corresponds to a serving cell. The different serving cells may have different coverage.

Different component carriers can be planned to provide different coverage, i.e. different cell size. In the case of inter-band carrier aggregation the component carriers will experience different pathloss, which increases with increasing frequency. In the example shown in figure 3 carrier

aggregation on all three component carriers can only be used for the black UE, the white UE is not within the coverage area of the red component carrier. Note that for UEs using the same set of CCs, can have different PCC.

Introduction of carrier aggregation influences mainly MAC and the physical layer protocol, but also some new RRC messages are introduced. In order to keep R8/R9 compatibility the protocol changes will be kept to a minimum. Basically each component carrier is treated as an R8 carrier. However some changes are required, such as new RRC messages in order to handle SCC, and MAC must be able to handle scheduling on a number of CCs. Major changes on the physical layer are for example that signaling information about scheduling on CCs must be provided DL as well as HARQ ACK/NACK per CC must be delivered UL and DL, see figure 4.

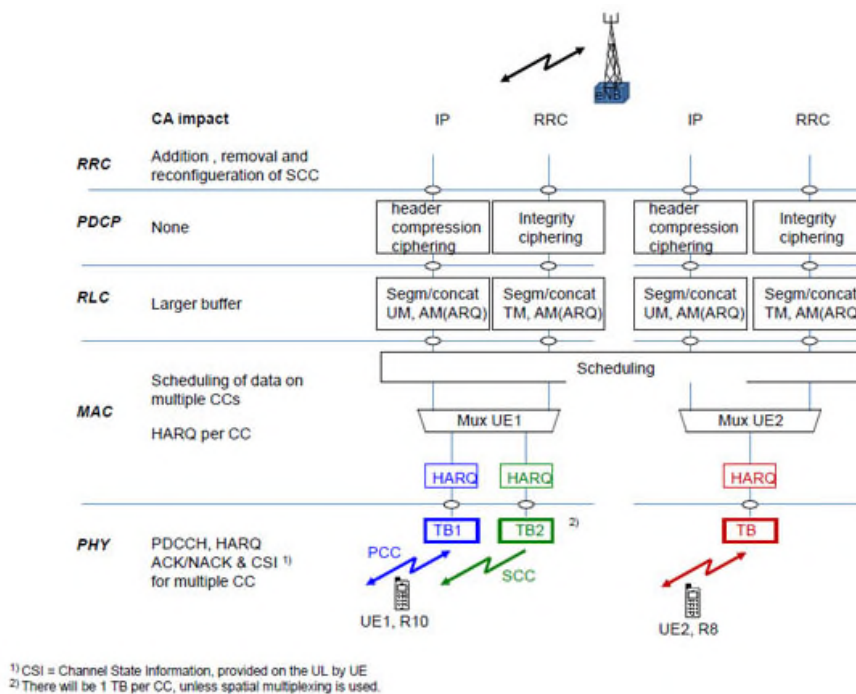


Figure 4. LTE protocols for the radio interface, with main changes due to introduction of CA

Regarding scheduling there are two main alternatives for CA, either resources are scheduled on the same carrier as the grant is received, or so called cross-carrier scheduling may be used, see figure 5.

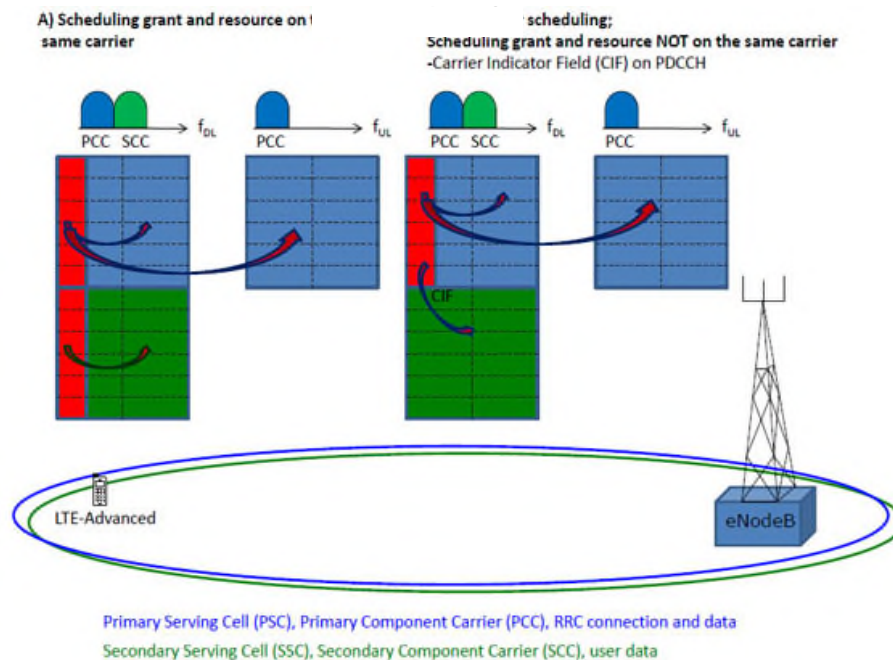


Figure 5. CA scheduling (FDD); Cross- carrier scheduling is only used to schedule resources on SCC without PDCCH. The CIF (Carrier Indicator Field) on PDCCH (represented by the red area) indicates on which carrier the scheduled resource is located.

For heterogeneous network planning the use of for example remote radio heads (RRH) is of importance. From R11 it will be possible to handle CA with CCs requiring different timing advance (TA), for example combining CC from eNB with CC from RRH, see figure 6.

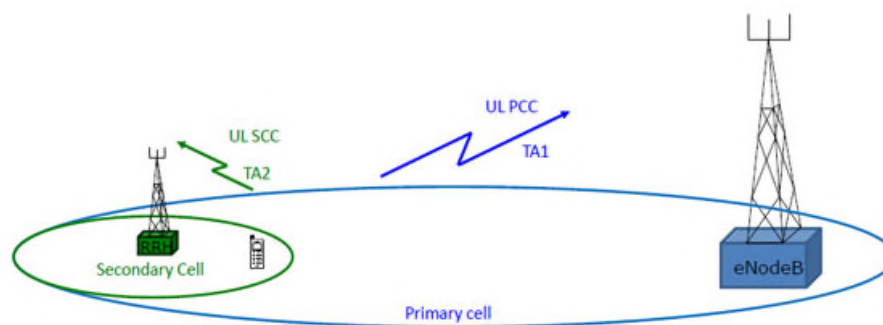


Figure 6. In R11 it will be possible to support serving cells with different Timing Advance (TA). Serving cells with the same TA belongs to the same TA Group (TAG).

Further reading

See a new article on the website: [Carrier Aggregation on Mobile Networks](#) (August 2022)

TR 36.808 Evolved Universal Terrestrial Radio Access (E-UTRA);
Carrier Aggregation; Base Station (BS) radio transmission and reception

TR 36.814 Evolved Universal Terrestrial Radio Access (E-UTRA);
Further advancements for E-UTRA physical layer aspects

TR 36.815 Further Advancements for E-UTRA; LTE-Advanced feasibility
studies in RAN WG4

TR 36.823 Evolved Universal Terrestrial Radio Access (E-UTRA);
Carrier Aggregation Enhancements; UE and BS radio transmission and
reception

TR 36.912 Feasibility study for Further Advancements for E-UTRA (LTE-
Advanced)

TR 36.913 Requirements for further advancements for Evolved Universal
Terrestrial Radio Access (E-UTRA) (LTE-Advanced)

TS 36.101 Evolved Universal Terrestrial Radio Access (E-UTRA); User
Equipment (UE) radio transmission and reception

TS 36.211 Evolved Universal Terrestrial Radio Access (E-UTRA);
Physical channels and modulation

TS 36.212 Evolved Universal Terrestrial Radio Access (E-UTRA);
Multiplexing and channel coding

TS 36.213 Evolved Universal Terrestrial Radio Access (E-UTRA);
Physical layer procedures

TS 36.300 Evolved Universal Terrestrial Radio Access (E-UTRA) and
Evolved Universal Terrestrial Radio Access Network (E-UTRAN);
Overall description; Stage 2

Go to 36 Series specs. here... <https://www.3gpp.org/specifications-technologies/specifications-by-series>

Corrections and comments

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kevin.flynn@3gpp.org, Kevin is responsible for marketing and
communications for 3GPP.