CARRIER AGGREGATION IN LTE

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ABSTRACT: Much advancement in Long Term Evolution (LTE) has been made as per 3GPP release papers. Release 8/9 terminals were not capable of providing greater data speed and hence did not meet the International Mobile Telecommunications – Advanced (IMT A) requirements. Therefore, there was need to increase the downlink and uplink data speed. Release 10 introduced a new feature in LTE called carrier aggregation in which different component carriers are aggregated in order to increase the overall bandwidth. In LTE-Advance, upto five component carriers can be aggregated but commercial solutions use up to three component carriers thus providing a maximum downlink speed of upto 450Mbps. This paper provides an overview of carrier aggregation and its needs. For cell edge users, carrier aggregation can be supported by enabling cross carrier scheduling which solves the problem of Inter Cell Interference. Carrier scheduling is enabled by eNodeb (eNB). In the later part of this paper, a simulation is discussed which provides understanding of calculation of various frequency parameters which are specified by 3GPP and also shows the plot of intra-band contiguous carrier aggregation which is commonly used.

KEYWORDS: aggregation, downlink, uplink, duplexing, contiguous.

INTRODUCTION

The Advanced E-Utra Aims To Support Downlink Data Speed Of 1gbps And An Uplink Data Speed Of 0.5mbps [3]. Release 8 Supports Only One Component Carrier (Cc) Which Provides A Maximum Bandwidth Of 20mhz. In Order To Improve The Spectral Efficiency And Increase The Data Rate, Two Ways Are Proposed. Firstly, By Increasing The Capabilities Of Antenna Supporting 8x8 Single User Mimo In The Downlink And 4x4 Single User Mimo In The Uplink. Secondly, Release 10 Allows Five Ccs Which Can Be Aggregated At The Terminal Allowing A Maximum Bandwidth Of 100mhz [5]. This Concept Of Aggregating Ccs Is Called Carrier Aggregation (Ca). Only Release 10 Users Can Experience The Benefits Of Carrier Aggregation And It Is Also Backward Compatible But Release 8/9 Users Do Not Support Ca So They Can Only Use One Cc.

There are 44 frequency bands available for LTE network providers starting from 700MHz to 2.7 GHz and theoretically maximum aggregated bandwidth that can be achieved is 100MHz. Commercially only three CCs can be aggregated while aggregating two CCs is commonly preferred. For further details regarding CA bands, [4] can be referred. There are two duplexing schemes available namely Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD). In FDD, there are two different sets of uplink and downlink frequencies available whereas in TDD, both uplink and downlink share the same frequencies. In FDD, the number of CCs used for uplink is always less than that of downlink whereas in TDD, it is normally same for both uplink and downlink [4]. Each CC which has fixed bandwidth is assigned number of downlink resource blocks (NDLRB) as shown in Table 1 [1].

Table. 1. Transmission Bandwidth Configuration And Ndlrb

Bandwidth (MHz)	1.4	3	5	10	15	20
NDLRB	6	15	25	50	75	100

As discussed earlier that there are many frequency bands available, so in order to utilize the bandwidth of the respective frequency band, CCs can be placed in the frequency band in three possible ways namely: Intra-band contiguous CA, Intra-band non-contiguous CA and Inter-band contiguous CA. In Intra-band contiguous CA, the CCs are placed contiguous to each other in the same frequency band allowing the elimination of undesirable bandwidth segmentation whereas in inter-band non-contiguous CA, the CCs are also placed in the same frequency band but separated by a gap which creates segmentation in the bandwidth as shown in Figure 1. In the latter case the multicarrier signal cannot be treated as a single signal so two transceivers are required at the User Equipment (UE) terminal that adds to complexity design in the UE terminal [6].

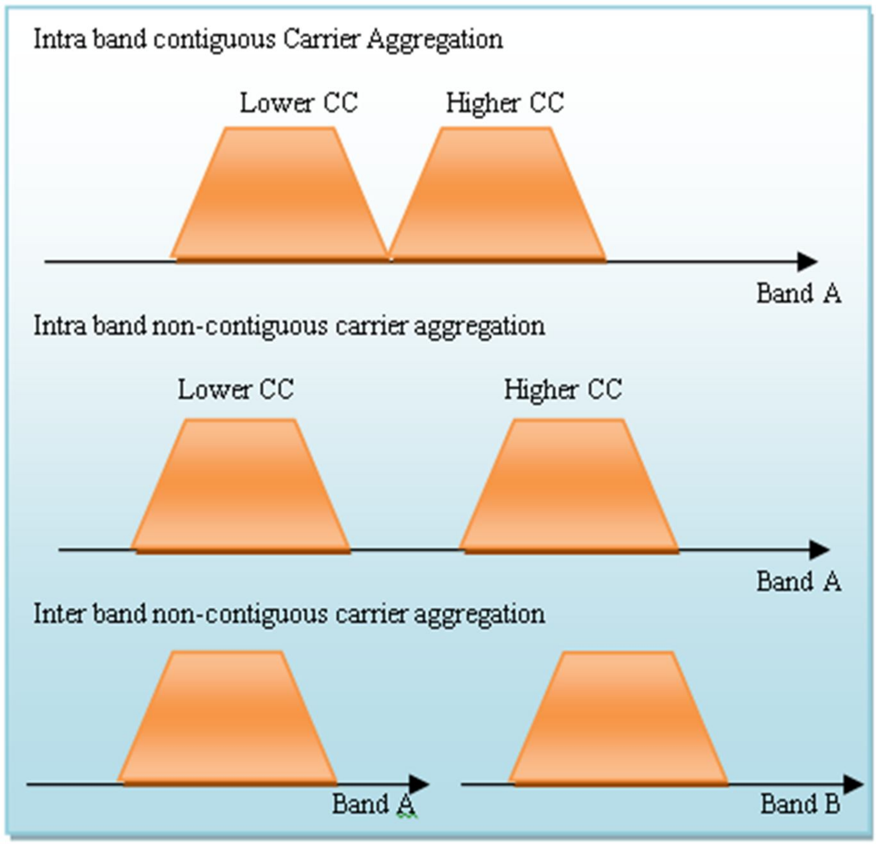

Figure. 1. Classification of Carrier aggregation

Inter-band non-contiguous CA is supported with CCs placed in different frequency bands. However, this case of CA consumes more power at the UE terminal since multiple transmitters and receivers are used due to which UE design complexity and cost is increased, since aggregating CC from different operating bands requires simultaneous operation of parallel receiver /transmitter. In practice, this situation demands the base station to operate in two different frequency bands [2]. For the simulation purpose which is discussed in later section only intra band contiguous carrier aggregation is discussed.

As discussed earlier that only LTE-Advanced terminals are capable of CA, now the question arises how CA is activated in the network? For every LTE-Advanced terminal, there is a primary component carrier (PCC) associated in both uplink and downlink directions. Similarly, there are secondary component carriers (SCC) but the association between PCC and SCC is cell specific. The configuration of PCC is device/terminal specific as different terminals have different carriers as their PCC. As for release8 users, initially to get connected to the network, the device has to perform cell search and selection, system information acquisition and initial random access. These same idle mode procedures are also performed by CA compatible terminal which is taken care by the PCC [5]. Once these generic access procedures are performed, the terminal gets connected to the network and the terminal enter into the connected mode. In the connected mode, the SCCs can be configured that can be used to transmit the additional information and CA can be used provided if the terminal supports CA. Therefore, CA is terminal specific [2].

There many ways in which resources can be scheduled, either using same CC on which uplink grant is received or using cross carrier scheduling. Cross carrier scheduling is discussed in detail in the next section.

CROSS CARRIER SCHEDULING

Cross carrier scheduling is enabled in UEs if they are compatible with release10 specifications. Cross carrier scheduling solves the problem of cell edge users which undergo inter cell interference. In order to avoid the effects caused by inter cell interference, cross carrier scheduling is used. PDCCH which is a control channel is transmitted with more power than the traffic channel since the UE cannot afford to lose it. When cross carrier scheduling is enabled by eNodeb (eNB), the CC are divided into two types of carriers namely, primary component carrier (PCC) and secondary component carrier (SCC). The primary cell (PCell) is being served by PCC and the secondary cell (SCell) is being served by SCC as shown in fig.2.

The PCC carries the PDCCH (Physical Downlink Control Channel) of both PCC and SCC. The PDCCH carries the downlink control information (DCI) that carries the detailed information about the resource blocks. The DCI helps in scheduling decisions which is required for the reception of PDSCH (Physical Downlink Shared Channel).. Therefore, the PDSCH is received on a different CC other than the one on which PDCCH was received. Cross carrier scheduling is enabled by UE to support cell edge users to avoid inter cell interference [7].

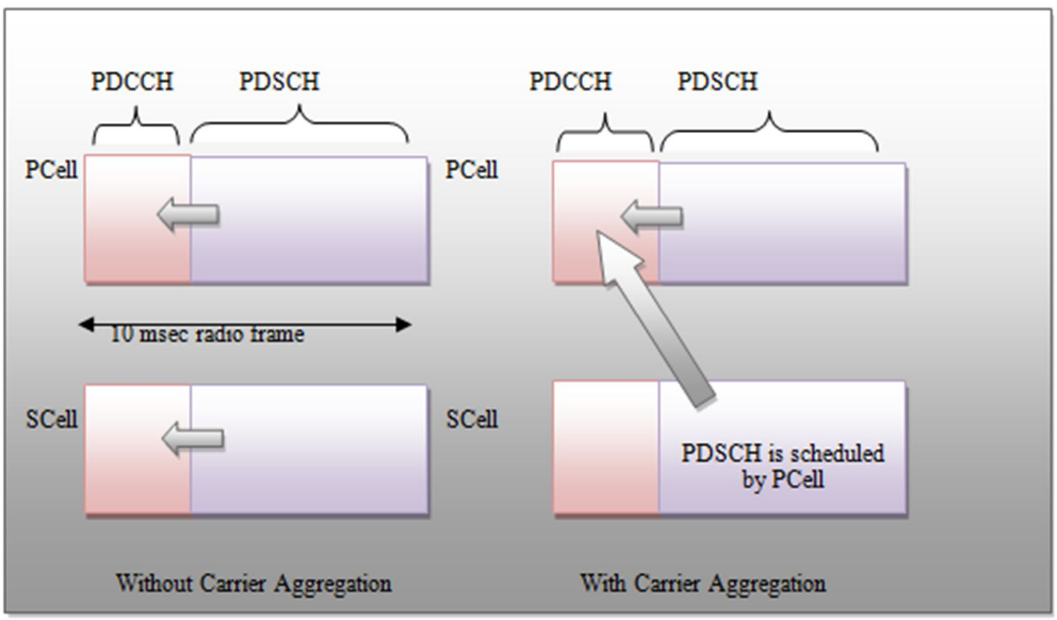

Figure. 2. Diagrammatic explanation of carrier aggregation

SPECIFICATIONS

According to release 10, some specifications were set by 3GPP in context to the CA. These specifications are only followed for intra-band contiguous CA. There are some frequency parameters whose definitions are explained in fig.3. The CC which is placed on the lower frequency of the respective band is called lower CC and the CC which is placed on the higher frequency of the same band is called higher CC. The frequency band in which the component carriers are placed have two edge frequencies namely lower and higher edge frequencies placed on the either side of the component carrier. On the either side of each of the edge frequency, a guard band is inserted which is function of the bandwidth and number of the CC used which is shown in table II. The calculation of the guard band depends on the band class. The aggregated channel bandwidth is the difference between the two edge frequencies as shown in (1).

$$\boldsymbol{BW_{Channel\_CA}} = \boldsymbol{f_{edge,low}} - \boldsymbol{f_{edge,high}} \quad [MHz] \qquad (1)$$

Each component carrier has a center frequency, $F_{c,low}$ and $F_{c,high}$ respectively, which are separated by a multiple of 300 KHz. The center spacing between the CC is given by (2),

$$Nominal\ Channel\ Spacing = \left[\frac{BW_{Channel(1)}+BW_{Channel(2)}-0.1\left|BW_{Channel(1)}-BW_{Channel(2)}\right|}{0.6}\right]0.3 \quad [MHz] \qquad (2)$$

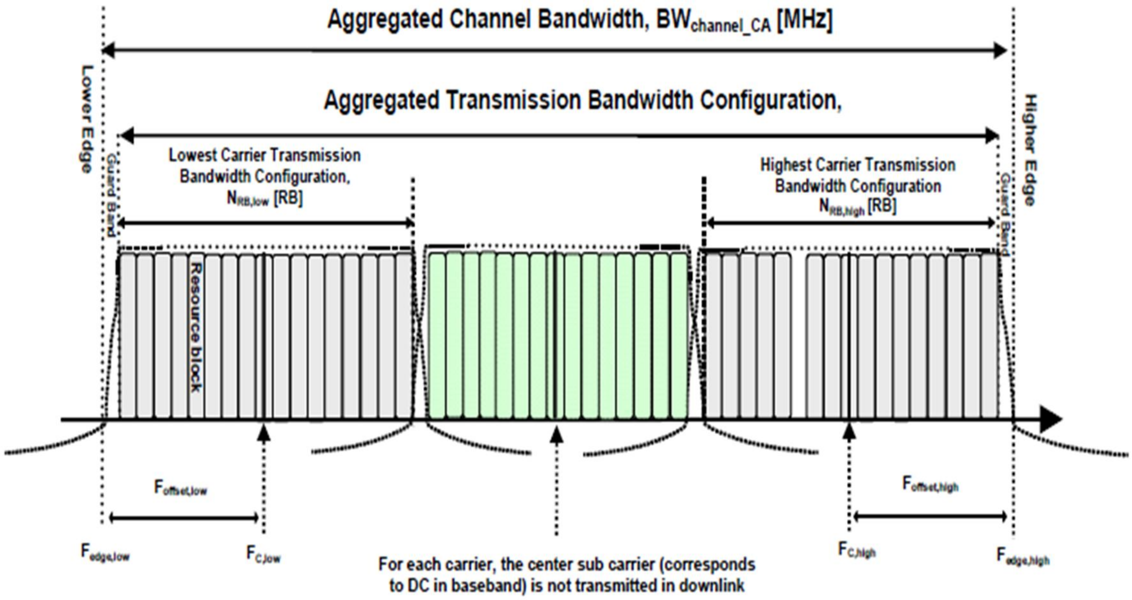

Figure. 3. Definition of various frequency parameters used for contiguous carrier aggregation [1]

Table. 2. Carrier Aggregation Bandwidth Classes

Band-width Class	Aggregated Transmission Resource blocks (NDLRB)	Number of Component Carriers	Guard band
A	NDLRB ≤ 100	1	$0.05\ BW_{Channel(1)}$
B	NDLRB ≤ 100	2	Under study
C	101 < NDLRB ≤ 200	2	$0.05\ \max\ (BW_{Channel(1)}, BW_{Channel(2)})$
D, E, F	Under study	Future use	Under study

The center spacing is also called as nominal channel spacing and depends on the bandwidth of the adjacent channels. As long as the component carriers do not overlap, for compact spacing between the CCs, any center spacing lesser than the nominal channel spacing can be used provided only if it is a multiple of 300 KHz. The edge frequencies which are defined relative to each of the carriers can be calculated by (3), (4) which is function of frequency offset $F_{offset,high}$.

$$F_{edge,low} = F_{c,low} - F_{offset,low} \tag{3}$$

$$F_{edge,high} = F_{c,high} + F_{offset,high} \tag{4}$$

The factor 0.18 corresponds to the physical resource bandwidth (PRB) which is obtained by multiplying 15 KHz subcarrier spacing with 12 (number of subcarriers in one resource block). *NDLRB* depends on the CC used while transmitted by eNB according to Table 1.

$$F_{offset,low} = 0.18\ NDLRB_{low} + BW_{GB} \tag{5}$$

$$F_{offset,high} = 0.18\ NDLRB_{high} + BW_{GB} \tag{6}$$

The offset frequencies of both CCs depends on both the configuration of the transmitted resource blocks and the bandwidth of the guard band as shown in (5), (6) [1], [2].

SIMULATION

This section discusses about the simulation of intra-band contiguous CA. Based on the frequency parameters explained in the previous section, a simulation is performed which plots individual CC and aggregated CC against the frequency as shown in fig.4, fig.5 and fig.6.

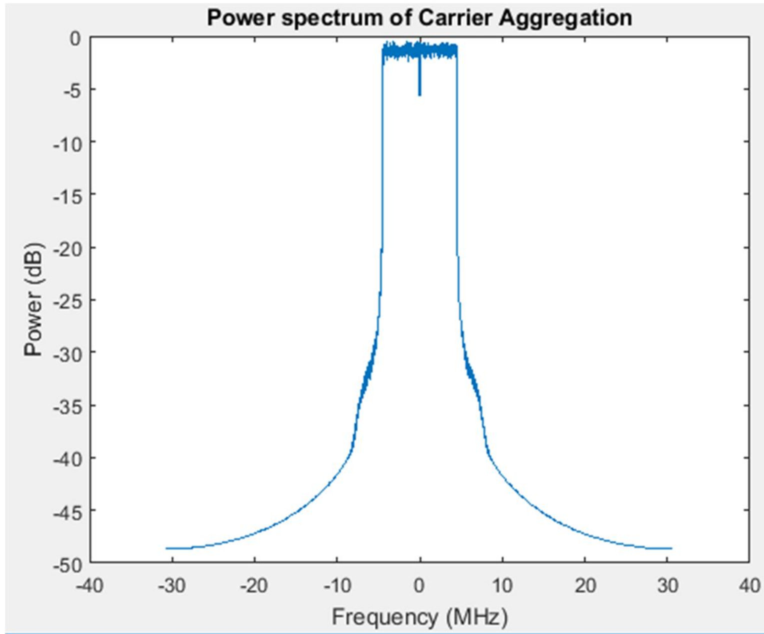

Figure. 4. Lower component carrier with 10 MHz bandwidth

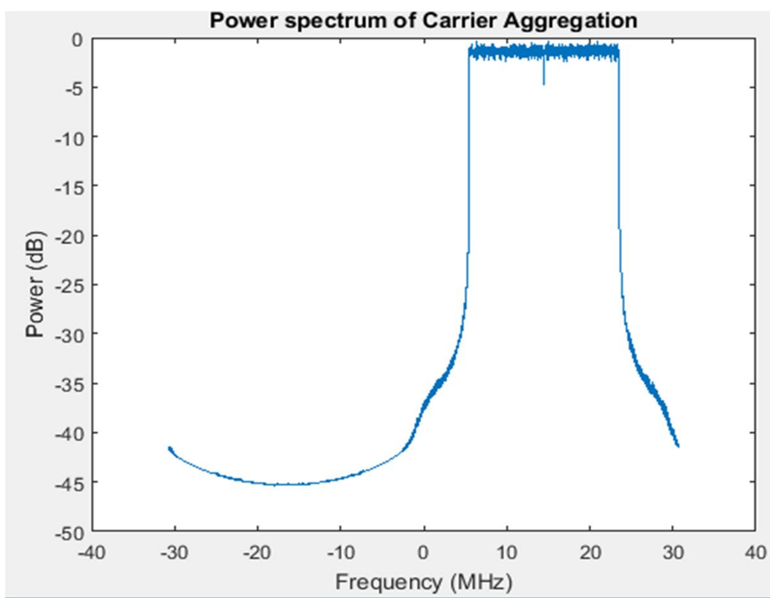

Figure. 5. Component carrier with 20 MHz bandwidth

The plot in fig.4 is plot of the power spectrum of lower CC and on the left side of it, a guard band is inserted which is required for emissions to reach a level, where out of band emissions limits in terms of an emission mask that are applied [2]. Similarly fig.5 is plot of higher CC and a same guard band is inserted on the right side of the higher CC. As the simulation gives a plot of two aggregated CC, the guard band is calculated by choosing bandwidth class C from table II. The center frequency of the lower CC is assumed to be kept at 0 Hz. According to (3), (4), the lower and higher edge frequencies are obtained as -5.5 MHz and 24.5 MHz respectively as shown in fig.4 and fig.5. The frequency spacing according to (2) is calculated to be 14.5MHz which implies that the center frequency of higher CC is also 14.5MHz obtained by adding center frequency of lower CC with nominal channel spacing (multiple of 300 KHz) as shown in fig.5. The lower and higher offset frequencies are obtained from (5) and (6) and calculated as 5.5MHz and 10MHz respectively.

The plots of fig.4 and fig.5 are aggregated appropriately in order to obtain a net aggregated bandwidth of 30 MHz according to (1). Similarly, aggregated bandwidth can be further increased or decreased by making an appropriate adjustment to the bandwidth of each of the CC and a similar analysis can be made.

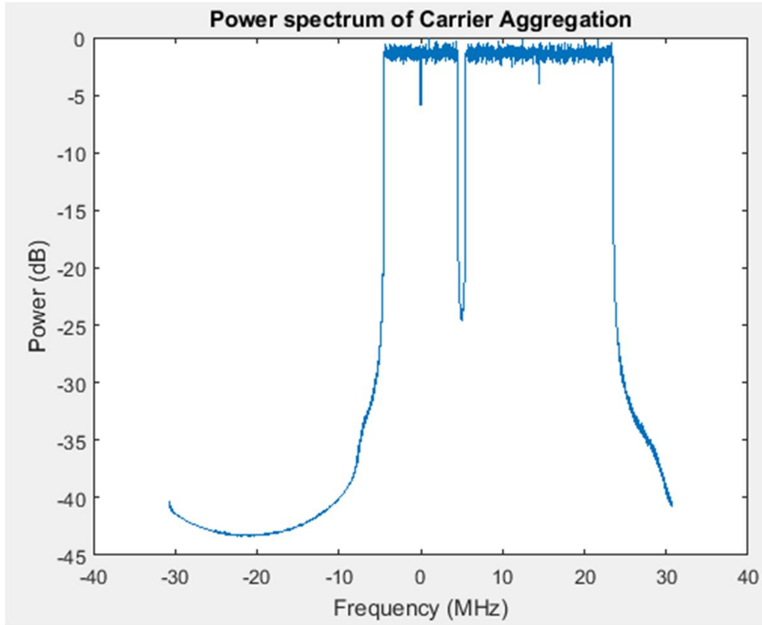

Figure. 6. Aggregated component carriers

CONCLUSION

The concept of carrier aggregation is used to efficiently utilize the spectrum and increase the data rates. Further advancements can be made for 5G which is next generation of mobile broadband technology. In current technology, only five CCs can be aggregated which allows a net aggregated bandwidth of 100 MHz but in 5G the number of CC can be extended upto 32 as per release 13 paper released by 3GPP giving a net aggregated bandwidth of 640 MHz allowing an average downlink speed of more than 2Gbps. Carrier aggregation also provides opportunities for commencement of Internet of Things (IoT) as several devices communicate together simultaneously, therefore bandwidth requirements will be large. Carrier aggregation is one solution through which limitations caused by the shortage of bandwidth can be reduced up to some extent.

REFERENCES

[1] 3GPP TS36.101, LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception, v10.1.1, January 2011.

[2] A.Z Yonis, M.F.L. Abdullah, M.F. Ghanim,“Effective Carrier Aggregation on the LTE-Advanced Systems”,*International Journal of Advanced Science and Technology*, University of Mosul, Mosul, Iraq, April 2012, vol. 41.

[3] 3GPP TR36..913, LTE; Requirements for further advancements for Evolved Universal Terrestrial Radiop Access (E-UTRA) (LTE-Advanced), v9.0.0, Februaury 2012.

[4] Jeantter Wannstrom (2013, June), *Carrier Aggregation explained* [Online]. Availble: http://www.3gpp.org/technologies/keywords-acronyms/101-carrier-aggregation-explained.

[5] Andreas Roessler, Meik Kottkamp, Sandra Merkel, “Carrier aggregation- (one) key enabler for LTE-Advanced”, *Rohde & Schwarz*, Germany, PD 3606.7630.62, Oct. 2012, v01.01.

[6] Mohammed Abduljawad M. Al-Shibly, Mohamed Hadi Habaebi, Jalel Chebil, “Carrier Aggregation in Long Term Evolution- Advanced”, *IEEE Control and system Graduate Research Colloq.*, July 2012.

[7] Liang Zeng, Qimei Cui, ”A Novel Cross-Carrier Scheduling Method”, *IEEE 2013*, published.