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Performance Analysis of 4G LTE-Advanced Carrier Aggregation

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Abstract-This paper presents the analysis of carrier aggregation (CA) technique in 4G LTE-Advanced. LTE-Advanced has brought revolution in the field of wireless communication. With the emerging technology of carrier aggregation (CA) supported by LTE-Advanced, it becomes possible to achieve high data rates by aggregating the bandwidth. A brief introduction of carrier aggregation (CA) is discussed and also the performance analysis of contiguous carrier aggregation is done. The component carrier parameters and sampling rate are found, and power spectrum is plotted. High throughput is achieved by increasing the number of component carriers aggregated.

Keywords: LTE-Advanced, Carrier Aggregation, Component Carrier, Contiguous

1. INTRODUCTION

The mobile communication industry has witness-ed a successful revolution in packet data application services (Zhang *et. al.* 2015). The need of high quality of service is increasing at the consumer end (Lee *et. al. 2016*). Due to the demand of high quality of service for mobile applications, there is a need of high data rate and throughput. LTE-Advanced has brought revolution the field of wireless communication by providing high data rate of up to 1Gbps (Parkvall *et. al. 2011*). The key enhancement feature of the LTE-Advanced is the extension of bandwidth by combining different component carriers to support deployment bandwidth of up to 100 MHz (Xu and Darwazeh. 2015). This aggregation of bandwidth is possible due to the carrier aggregation (CA) feature of LTE-Advanced that bonds together bands of spectrum to form wider channels and provide high speeds at consumer end (Yuan *et. al. 2010*). The main principle of the carrier aggregation technique is to aggregate the component carriers. The carriers aggregated are basically the LTE Release 8 carriers, which facilitate backward compatibility. In LTE Release 10 a user equipment (UE) which is CA-capable can access the multiple component carriers to achieve higher data rate (Ratasuk *et. al. 2010*).

The component carriers (CCs) used can take any of the transmission bandwidth i.e. 1.4,3,5,10,15 or 20 MHz respectively. The resource blocks corresponding to the channel bandwidth supported by LTE-Advanced are 6,15,25,50,75 or 100 resource blocks (RBs) respectively. LTE-Advanced uses single carrier frequency division multiple access (SC-FDMA) to transmit data from user equipment (UE) to the base station (eNB) and orthogonal frequency division multiple access (OFDMA) in the downlink to transmit data from base station (eNB) to user equipment (UE) (Pedersen *et. al. 2011*).

The remaining paper is structured as follows: The overview of carrier aggregation (CA) technique is discussed in Section 2. The different scenarios of carrier aggregation are discussed in Section 3. Section 4 represents the methodology and algorithm used. The simulations results are discussed in the Section 5 and Section 6 concludes the paper.

2. CARRIER AGGREGATION

Carrier aggregation (CA) is a technique that com-bines multiple component carriers of same or different channel bandwidth to increase the transmission bandwidth and overall data rate. Carrier aggregation (CA) for LTE-Advanced was introduced in the Release 10, due to its support of high data rate and utilization of segmented spectrum (Shayea *et. al. 2012*). [8]. In the beginning, the carrier aggregation (CA) supported aggregation of five component carriers but deployment was limited to two component carrier-s to achieve aggregated bandwidth of 40 MHz. In Release 11 and 12, the number of component carriers aggregated was increased from two to three. In Release 13, aggregation of five component carriers is successfully achieved for accounts of 100 MHz bandwidth per subscriber (Park *et. al. 2013*).

Carrier Aggregation (CA) Modes

Carrier Aggregation (CA) implemented in both Time Division Duplexing (TDD) and Frequency Division Duplexing mode, by which demanding frequency resources and time slots are shared am- ong mobile users. LTE-Advanced utilizes both of these

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carrier aggregation (CA) modes to facilitate the mobile users to utilize the limited spectrum efficiently. Both carrier aggregation (CA) modes ca- n deliver a strong mixture of low-band FDD for justified coverage and high-band TDD with additional spectrum to achieve higher data rates (Wang *et. al.* 2011).

In Time Division Duplexing (TDD) mode, the number of component carriers is equal in uplink a-nd downlink direction. The frequency is same in both directions but uses different time slots to map data. In Frequency Division Duplexing (FDD) m-ode, different frequency slots are used in uplink and downlink direction. This mode enhances coverage and data rates (Abdullah *et. al.* 2013).

3. CARRIER AGGREGATION SCENORIOS

There are three different carrier aggregation (CA) scenarios based on different component carriers assigned from available frequency spectrum. These scenarios are intra-band contiguous carrier aggregation, intra-band non-contiguous aggregation and inter-band non-contiguous carrier aggregation.

a) *Intra-band Contiguous Carrier Aggregation*

Intra-band contiguous carrier aggregation is a common deployment scheme. It combines multiple component carriers in the same frequency band. It is used to enhance the capacity of the network, but the limitation is that it is not always possible because of present operator's frequency assignment service (Ntouni *et. al.* 2014).

b) *Intra-band Non-Contiguous Carrier Aggregation*

This type of carrier aggregation (CA) combines multiple component carriers in the same frequency band but they are not adjacent to each other. For this scenario the user equipment (UE) must uses separate transceiver for each component carrier (Ntouni *et. al.* 2014).

c) *Inter-band Non-Contiguous Carrier Aggregation*

In this type of deployment scenario, carrier aggregation aggregates different component carriers in different frequency bands e.g. 900MHz and 1800 Mhz. This is a complicated scenario as compared to the intra-band contiguous case because multiple carrier signals are considered as single signal. Therefore, the user equipment (UE) demand more complex and advance transmitters and receivers (Ntouni *et. al.* 2014). There are two types of component carriers used in the carrier aggregation (CA), the primary component carrier (PCC) which is the fundament-al carrier in any group and the secondary component carriers (SCC) which are added and detached as per user requirement (Ntouni *et. al.* 2014).

The three carrier aggregation (CA) scenarios are shown in the **(Fig. 1).**

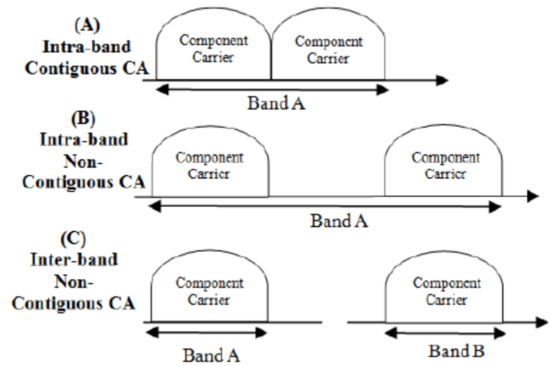

Fig 1. Carrier Aggregation (CA) Scenarios

4. ALGORITHM

The flowchart of the algorithm used is given below in Fig. 2.

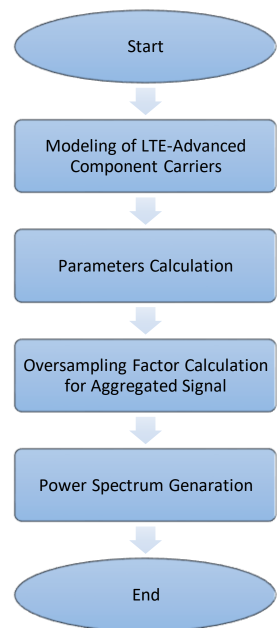

Fig. 2.Flow chart diagram proposed algorithm

The first step is the modeling of LTE-Advanced component carriers i.e. two, three, four and five component carriers. After that, the parameters are calculated for each component carrier. The third step is the oversampling factor calculation for a common sampling rate for aggregated signal.

Finally, the power spectrum is generated for aggregated LTE-Advanced.

5. RESULTS AND DISCUSSION

Modeling and simulation of LTE-Advanced carrier aggregation is done in MATLAB by combining LTE component carriers (CCs) of 20MHz to achieve bandwidth of 40,60,80 and 100 MHz.

a) *Aggregation of contiguous CCs to achieve bandwidth of 40MHz*

By aggregating the two component carriers (CCs) of 20 MHz, channel bandwidth of 40 MHz is achieved. The two component carriers are centered at -9.9 MHz and 9.9 MHz respectively. The output sample rate is 61.44 Ms/s. The power spectrum of the carrier aggregation is shown in the **(Fig.3).**

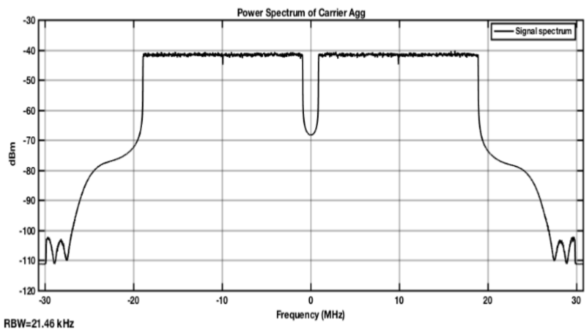

Fig.3. Power spectrum showing aggregated bandwidth of 40 MHz

b) *Aggregation of contiguous CCs to achieve bandwidth of 60MHz*

By aggregating the three component carriers (CCs) of 20 MHz, channel bandwidth of 60 MHz is achieved. The three component carriers are centered at -19.8 MHz, 0 MHz and 19.8 MHz respectively. The output sample rate is 122.88 Ms/s. The power spectrum of the carrier aggregation is shown in the Fig. 4.

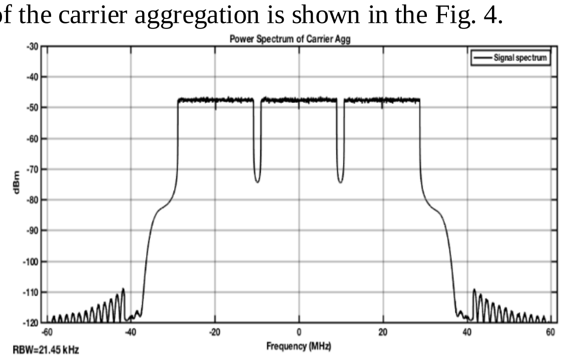

Fig.4. Power spectrum showing aggregated bandwidth of 60 MHz

c) *C. Aggregation of contiguous CCs to achieve bandwidth of 80MHz*

By aggregating the four component carriers (CCs) of 20 MHz, channel bandwidth of 80 MHz is achieved. The four component carriers are centered at -29.7 MHz, -9.9 MHz, 9.9 MHz and 29.7MHz respectively. The output sample rate is 122.88 Ms/s. The power spectrum of the carrier aggregation is shown in the **(Fig.5).**

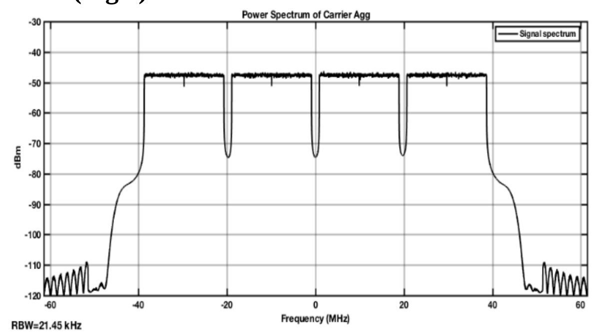

Fig.5. Power spectrum showing aggregated bandwidth of 80 MHz

d) *D. Aggregation of contiguous CCs to achieve bandwidth of 100MHz*

By aggregating the five component carriers (CCs) of 20 MHz, channel bandwidth of 100 MHz is achieved. The five component carriers are centered at-39.6 MHz, -19.8 MHz, 0 MHz, 19.8MHz and 39.6 MHz respectively. The output sample rate is 122.88 Ms/s. The power spectrum of the carrier aggregation is shown in the **(Fig.6).**

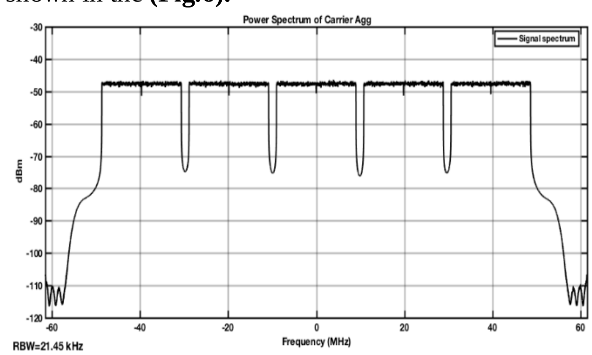

Fig.6. Power spectrum showing aggregated bandwidth of 100 MHz

e) *E. Throughput Analysis*

Throughput is the amount of data passed through a channel in a given period of time. The unit of throughput is bits per second. Throughput can be calculated by the following formula:

$$Throughput = \frac{No\ of\ frames}{Time}$$

As it is mentioned before LTE-Advanced can support high data rate of up to 1Gbps, we will find the throughput for channel bandwidth of 100 MHz which is achieved as a result of carrier aggregation.

The simulation and modeling are done in MAT-LAB, the throughput for channel bandwidth of 100 MHz is calculated using the 64 QAM modulation scheme and results are shown in the **(Fig. 7).**

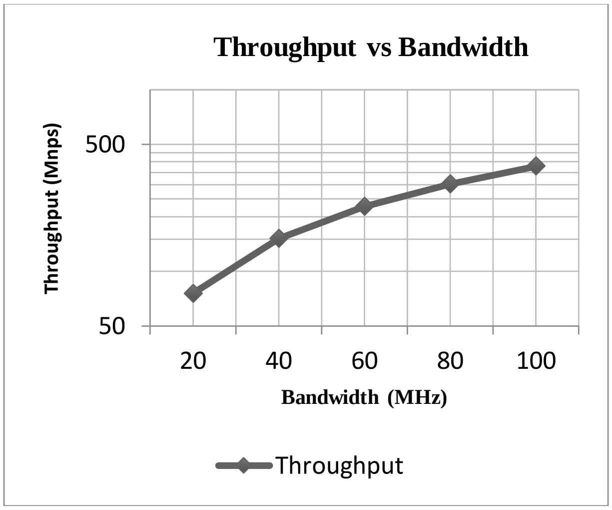

Fig. 7. Throughput Analysis using 64 QAM

As the bandwidth increases, the throughput sup- ported by LTE-Advanced increases. By increasing bandwidth from 40 MHz to 100 MHz, the throughput increases from 151.2 Mbps to 378 Mbps. The modulation scheme used is 64 QAM (6 bits per symbol) as supported by LTE-Advanced in the downlink.

6. CONCLUSION

From the work done, it is clearly concluded that carrier aggregation (CA) introduced in Release 10 of LTE-Advanced supports high data rates and efficiently utilize the fragmented spectrum. Now in Release 13 the carrier aggregation (CA) is capable of deploying five component carriers which increases the throughput of user equipment (UE). Bandwidth aggregation using different LTE component carriers (CCs) can lead to increase in user throughput. The maximum throughput achieved through aggregation of channel bandwidth of 100 MHz is 378 Mbps by using the modulation scheme 64 QAM that carry 6 bits per symbol. The two other modulation schemes supported by LTE-Advanced in the downlink are 16 QAM and QPSK that carry 4 bits and 2 bits per symbol respectively.

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