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Performance evaluation of Downlink Non Contiguous Carrier Aggregation in LTE-A

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Abstract

Long Term Evolution-Advanced (LTE-A) has brought revolution in the field of wireless communication technology by providing high data rates of up to 1Gbps. One key enhancement feature of LTE-A is bandwidth extension by the use of multi-carrier technology to support deployment bandwidth of up to 100MHz. To achieve such high data rate in IMT-Advanced mobile systems, carrier aggregation technology by 3GPP has been introduced to support very-high-data rate transmissions over wide frequency bandwidth in the new LTE-Advanced standards. This work includes the details of Downlink LTE Advanced System Model and thereby all the performance analysis of Non Contiguous Carrier Aggregation are done and an overview of LTE-Advanced CA scenarios is discussed. Also component carrier parameters and oversampling factor are found and using these parameters power spectrum is plotted. The main outcome from this work is increase in the throughput of the system by increasing the number of carrier components or by increasing bandwidth. Many proposals on carrier aggregation in LTE-A have been published but still there is a need of research to be carried out in this field as this technology has not fully matured.

Keywords: *Carrier Aggregation, LTE Advance, Non Contiguous*

1. Introduction

In recent years the communication industry has witnessed a successful revolution in packet data application services [1]. Providing high quality of service for mobile applications in a cost-effective manner becomes increasingly important for operators to meet consumer needs [2]. LTE Advanced has brought revolution in the field of wireless communication technology by providing high data rates of up to 1Gbps. To achieve peak data rates required by IMT-Advanced, carrier aggregation (CA) evolved as one of the main features of LTE-Advanced to scale the system bandwidth beyond 20MHz up to 100MHz. However, in practice such a large portion of continuous spectrum is rarely available. Therefore, LTE-Advanced uses CA that may be supported by simultaneously aggregating up to five CCs of 20MHz, subject to spectrum availability and the UE's capability. Also, CA enables efficient use of fragmented spectrum, irrespective of the peak data rate. The CA technology allows scalable expansion of effective bandwidth provided to a user terminal through simultaneous utilization of radio resources across multiple carriers [5]. Each CC may take any of the transmission bandwidths supported by LTE i.e. 6, 15, 25, 50, 75 or 100 Resource Blocks (RBs), corresponding to channel bandwidths of 1.4, 3, 5, 10, 15 and 20 MHz respectively.

There are two main parts in LTE-Advanced the first is uplink that is present in Single Carrier Frequency Division Multiple Access (SC-FDMA) that is mean transmit the data of mobile from user equipment (UE) to base station (eNB), while the second is downlink that is present in Orthogonal Frequency- Division Multiple Access (OFDMA) that is mean transmit the data of mobile from base station (eNB) to user equipment (UE). In this

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work the downlink is used and all the required analysis and performance are done. Increasing the number of component carriers leads to reach bandwidth equal to 100MHz.

The rest of the paper is organized as technical background in section (2), Methodology of algorithm used in section (3), Simulation Results and Discussion in section (4) and finally section (5) concludes the paper.

2. Background

Carrier Aggregation is a technique of aggregating multiple carriers of same or varying bandwidths to increase the overall transmission bandwidth and thereby increasing the bit rate of transmission. Downlink LTE system is based on OFDMA air interface transmission scheme. OFDMA is a combination of Time division multiple access (TDMA). The basic idea of OFDMA systems is the division of the frequency spectrum into several orthogonal sub-carriers using the OFDM multiplexing technique [2]. Those frequency sub-carriers are shared between users using access technique.
Various types of component carriers are:

- Backward-compatible carrier: All LTE UE may access this type of carrier regardless of the supported release. In this case all current LTE features must be supported.
- Non-backward-compatible carrier: Only LTE-A UE's may access this type of carrier. Advanced features such as control-less operations or the anchor-carrier concept are supported by non-backward-compatible carrier.
- Extension carrier: This type of carrier operates as an extension of another carrier. The extension carrier is addressed by using a separate PDCCH and also uses a separate HARQ process [13].

Carrier aggregation is supported by both the formats of LTE i.e. frequency Division Duplex (FDD) and Time Division Duplex (TDD) variants. In TDD carrier aggregation, the number of component carriers and bandwidth of each component carriers are same for both uplink and downlink assignments to UE [6].Whereas the number of CC's will be different in both uplink and downlink in FDD carrier aggregation. They will also be having different bandwidths in uplink and downlink. Both FDD LTE and TDD LTE are able to meet the high data throughput requirements placed upon them [9].

Scenarios of Carrier Aggregation

CA systems improve the data rates for users within overlapped areas of cells by allowing the operators to deploy a system with extended bandwidth. Increased transmission data rates may be achieved by aggregating several smaller CCs, while providing backward compatibility to legacy users [6]. To provide wider transmission bandwidths of up to 100MHz two or more component carriers may be aggregated. Spectrum deployments may be either contiguous or noncontiguous. Generally, there are three different spectrum scenarios as follows-

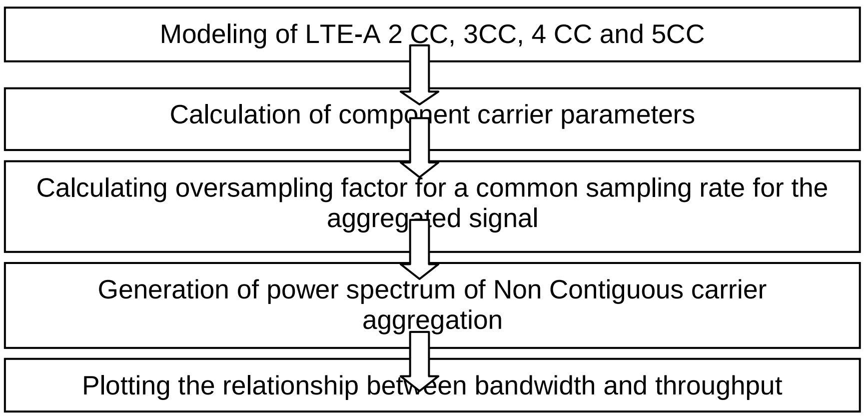
a) **Intra-band contiguous carrier aggregation**: Here a single frequency band is used and all CCs used are adjacent to each other. The spacing between the center frequencies of the contiguously aggregated CCs is a multiple of 300 KHz to be compatible with the 100 KHz frequency of Release 8/9 and preserving orthogonality of the sub-carriers with 15 KHz spacing. Although this can be a less likely scenario today, but it may be common when new spectrum bands like 3.5 GHz will be allocated in the future in various parts of the world[4]. It is the simplest form of LTE carrier aggregation to implement [10].

b) **Intra-band Non-contiguous carrier aggregation:** A single frequency band is used but the CCs used are not adjacent to each other, i.e., the CCs are separated from each other. This adds complexity, especially to the User Equipment (UE), where space, power and cost are major considerations. This form is more complicated than the first case where adjacent carriers are used. The multi-carrier signal cannot be treated as a single signal and therefore two transceivers are required [3].

c) **Inter-band non-contiguous carrier aggregation:** The CCs used belong to different frequency bands, and they are separated from each other. This scenario is very promising for future high data-rate mobile communications due to the inevitable fragmentation of bands, some of that are only 10MHz wide. Concerning the UE, it requires the use of multiple transceivers within the single item, thus introducing new challenges related to cost, performance and power consumption [4]. With this type of aggregation, mobility robustness may potentially be improved by exploiting radio propagation characteristics of different bands [11].

In all cases, multiple CCs are aggregated to serve a single LTE-Advanced UE unit. Regarding the UE cost, complexity and power consumption, it is easier to implement continuous CA without making many changes to the physical structure of existing LTE systems. It is possible to use a single Fast Fourier Transform (FFT) module and a single radio frequency component to achieve continuous CA for the LTE-Advanced UE unit, while providing backward compatibility to LTE systems. As compared to non-continuous CA, it is easier to implement resource allocation and management algorithms for continuous CA [12]. However, due to the fact that the spectrum currently allocated is scattered and a continuous 100MHz bandwidth is unlikely to be available for LTE-Advanced system, the non-contiguous CA approach seems to be more practical [4].

3. Methodology of Algorithm Used



4. Simulation Results and Discussion

Modeling of LTE Advance Carrier Aggregation with a 10MHz (NDLRB=50) carrier as the first component carrier and 20MHz (NDLRB=100) carrier as second component carrier is done. Corresponding Component carrier parameters calculated are as follows-

Component Carrier 1: Lower band edge: -13.952 MHz; Upper band edge: -4.952 MHz

Component Carrier 2: Lower band edge: -4.052 MHz; Upper band edge: 13.952 MHz

For a common sampling rate for the aggregated signal the required oversampling factor for each component carrier OSRs are calculated and it comes out to be-

Output sample rate: 61.450 Ms/s

The power spectrum of the carrier aggregated signal is displayed using hCarrierAggregationPlotFFT.m. Two individual carrier bandwidths are visible in the spectrum, centered at -9.5MHz and 5.0MHz.

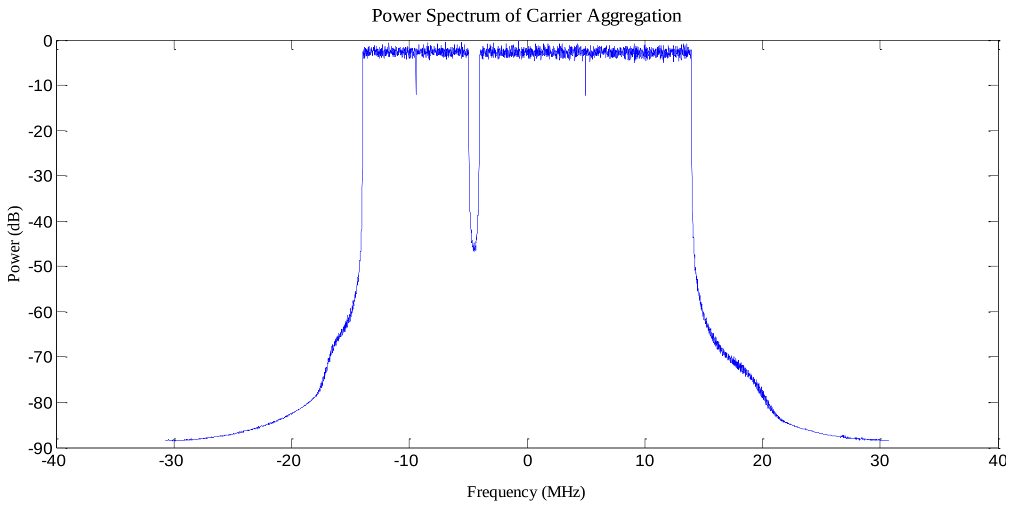


Figure 1

From the different cases of the scenario of LTE-Advanced, the following cases are chosen to show the main improvement in the performance of LTE Advanced after increasing the bandwidth. The following results are obtained for non- contiguous carrier aggregation with different bandwidth (60MHz, 80MHz and 100MHz).

CASE 1:

Firstly, Downlink LTE-Advanced is designed to support 60MHz carrier aggregation with maximum 2 component carriers. Figure 5 shows that each CC has maximum of 20MHz.

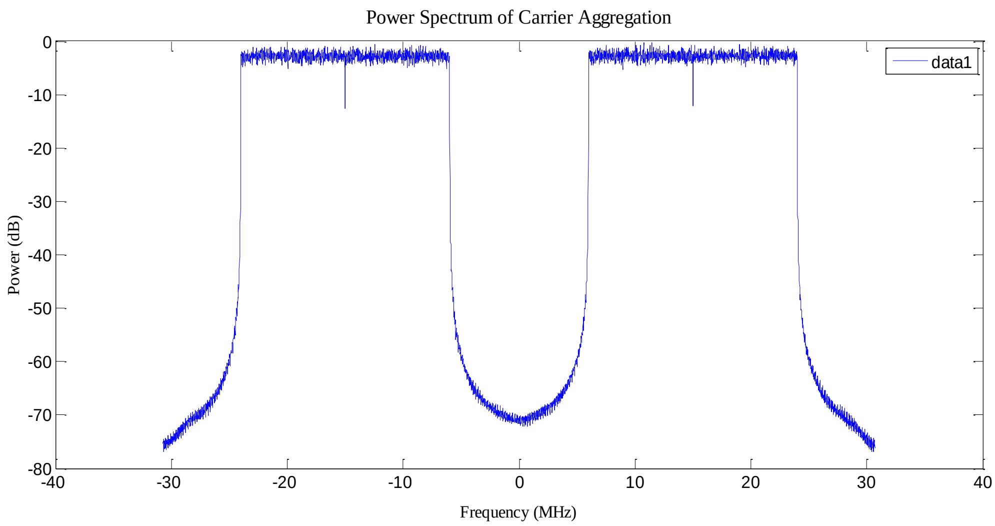


Figure 2

Component Carrier 1: Lower band edge: -24.00MHz; Upper band edge: -6.00 MHz
Component Carrier 2: Lower band edge: -6.00MHz; Upper band edge: 24.00 MHz

CASE 2:

Secondly, to increase the throughput of the system, 3CCs are used in this step.

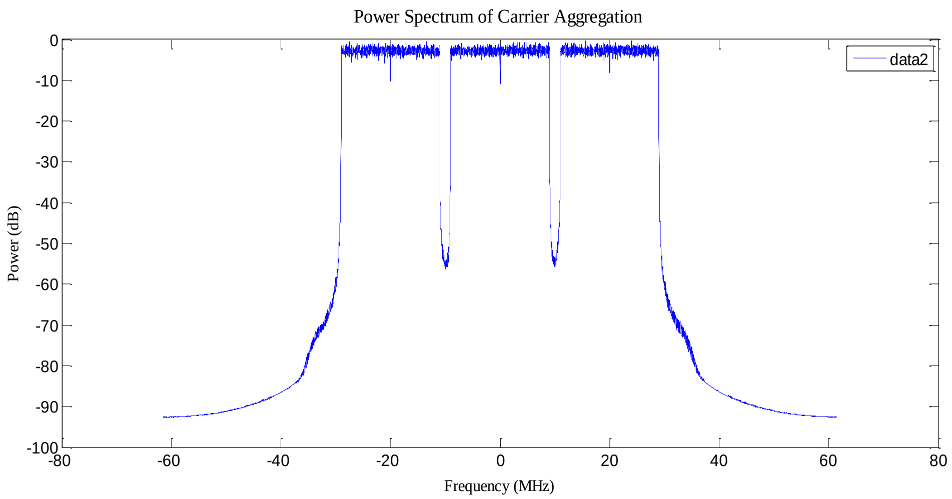


Figure 3

Component Carrier 1: Lower band edge: -39.00MHz; Upper band edge: -21.00 MHz
Component Carrier 2: Lower band edge: -9.00MHz; Upper band edge: 9.00 MHz
Component Carrier 3: Lower band edge: 21.00MHz; Upper band edge: 39.00 MHz

CASE 3:

The next step when the system has bandwidth carrier aggregation equal to 100 MHz with four CCs. This shows the maximum bandwidth of LTE-Advanced.

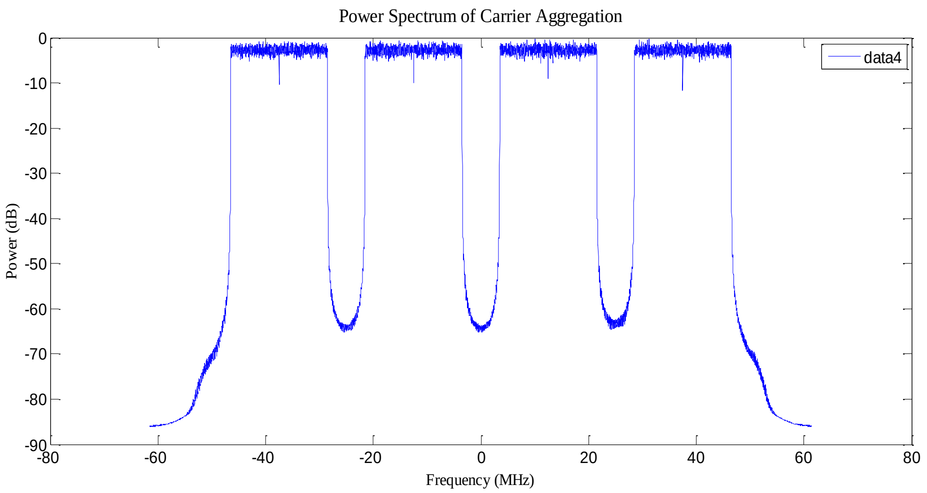


Figure 4

Component Carrier 1: Lower band edge: -46.50MHz; Upper band edge: -28.50 MHz
Component Carrier 2: Lower band edge: -21.50MHz; Upper band edge: 3.50 MHz
Component Carrier 3: Lower band edge: 3.50MHz; Upper band edge: 21.50 MHz
Component Carrier 4: Lower band edge: 28.50MHz; Upper band edge: 46.50 MHz

From the above main cases of the system, it is noticeable that increasing the bandwidth from 60MHz to 100MHz leads to the advantage of increasing the throughput from 330Mbps to 1682Mbps as shown in the following figure.

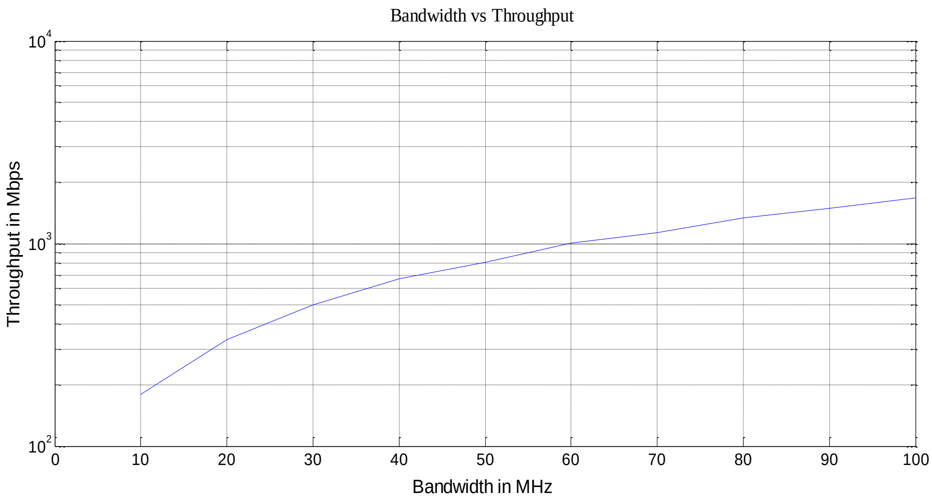


Figure 5

Table 1. Throughput and Bandwidth

Channel Bandwidth(MHz)	20	40	60	80	100
Peak date rate (Mbps)	330	670	1007	1342	1682

5. Conclusion

The main technology components for LTE Advanced have been listed in this work. The theoretical peak data rate of LTE Advanced may be even up to 1 gigabit per sec. CA helps to achieve higher peak data rates and also helps to achieve better coverage for medium data rates. For medium data rates, it allows the use of lower code rates, which would reduce the transmission power, required link budget, and interference. The design and implementation of LTE-A that supports wider bandwidth up to 100 MHz is done using MATLAB program in this work to improve the throughput and peak data rate of the system. LTE-Advanced offers higher data rates than even the initial release-8; while the spectrum purpose efficiency has been amended. As a result in this work, designing of the noncontiguous component carrier to increase the bandwidth to support 80 MHz with frequency 100 MHz and get higher throughput up to 1.682Gbps are contained within the specifications. The main outcome from this work is increasing the throughput of the system by increasing the number of carrier components.

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