Studies on Carrier Aggregation in LTE-Advanced

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Abstract- New technologies are developing each day to satisfy the needs of the human kind. LTE-Advanced is an improved technology over the Long Term Evolution (LTE) in satisfying the requirement of data rate. Carrier Aggregation is the main mechanism adopted in LTE-Advanced. It supports higher data rate through bandwidth extension. This paper summarizes the study on carrier aggregation and the technology being deployed.
Keywords – LTE-Advanced, Carrier Aggregation, Bandwidth

I. INTRODUCTION

Urge for high data rate and speed on the mobile network has given rise to various advancements in the wireless technology. The demands for the multimedia services on wireless networks require very high bandwidth. 3GPP developed Long Term Evolution (LTE) to meet the user's requirements by using more than ten frequency bands as of December 2012 [1]. Initial Release 8 (LTE) was the basis for LTE standard. The improvements made on Release 8 have been considered in Release 10, called LTE-Advanced.
In this paper the comparison of LTE Release 8 is made with LTE-Advanced, followed by understanding the Carrier Aggregation in section II. The paper continues with the update on Carrier Aggregation being deployed in section III and some of the opportunities that can be addressed in section IV. Section V provides the concluding remarks.

1.1 LTE Release 8

Release 8 or LTE provided peak downlink data rate of 300Mbps and the uplink rate of 75Mbps. It could be implemented in 1.4, 3, 5, 10, 15 or 20 MHz bandwidth in order to support various deployment scenarios[2][3]. Its basic functionality was to provide high data rate and latency of about 10ms through an air interface with better performance. Orthogonal Frequency Division Multiple Access (OFDMA) is used for the downlink while Single Carrier Frequency Division Multiple Access (SC-FDMA) is for the uplink. Communication was improved with the use of Multiple Input Multiple Output (MIMO) antennas. Network efficiency was improved using flat radio network architecture using eNodeB as the home base station. The distribution of the functionalities among the base stations reduced the infrastructure cost. 3GPP later improved LTE system to satisfy the demands for different markets giving rise to Release 9. Release 9 saw an enhancement in the optimization [4]. Continuous increase in demands by the users caused a huge improvement in the mobile data traffic beyond Release 8. Hence Release 10 was rolled out during June 2011.

1.2 LTE Release 10

LTE release 10 or LTE-Advanced is a broadband wireless network that is capable of providing peak data rate that is greater than that of fiber to the home (FTTH). It provides better user experience because of its higher data rates, low latencies, higher throughput and good coverage. It also supports mobility across the cellular networks [4]. Other technology mechanisms in LTE-Advanced include enhanced MIMO to improve the spectrum efficiencies, heterogeneous networks that improve the spectral efficiency per unit area and relay [5].
Aspects of LTE-Advanced include [3] [6] improved peak data rate of up to 3000Mbps in the downlink and 1.5Gbps in the uplink. With Carrier Aggregation (CA), bandwidth of about 100MHz and the spectral efficiency as high as 30bps/Hz could be achieved. Better performance can be obtained at the cell edges and allows more number of active subscribers to communicate at the same time. LTE-Advanced uses higher order MIMO antenna configurations up to 8x8 for downlink and 4x4 for uplink. Heterogeneous networks are supported through relay nodes to support variety of cell sizes.

Table -1 Comparison of LTE with LTE-Advanced [4][5][7]

Parameter	LTE	LTE-Advanced
Generation	3.9G	4G
Scalable bandwidth	1.4 – 20MHz	20-100MHz
Number of carriers	Single	Maximum of five

maximum data rate (downlink) (Uplink)	300 Mbps	1 Gbps
	75 Mbps	0.5Gbps
bandwidth (downlink) (uplink)	20 MHz	100 MHz
	20 MHz	40MHz
Peak Spectrum Efficiency [bps/Hz] (downlink) (uplink)	15	30(up-to 8X8 MIMO)
	3.75	15(up-to 4X4 MIMO)
Latency From idle to connect mode	100ms	<50ms
Latency From dormant to active mode	50ms	<10ms

II. CARRIER AGGREGATION

Carrier Aggregation is the prominent techniques used in LTE-Advanced that aims at achieving high data rate, high speed, and high throughput along with good quality of service. This is achieved by increasing the bandwidth between the user equipment (UE) and the e-node B (e-NB) in the downlink or the uplink. The bandwidth can be extended up to 100 MHz by combining of about five separate carriers of about 20MHz each [8]. The operators are able to roll out the system with wider bandwidth through Carrier Aggregation by aggregating different carriers called component carriers (CC). Carrier Aggregation supports Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD) while taking care of backward compatibility with LTE.

2.1. Types of Carrier Aggregation

Carrier Aggregation may be done in three ways [8] [9]. When the component carriers of the same band of frequency and next to each other are aggregated, it is termed Intra-band contiguous Carrier Aggregation. If the component carriers are of the same frequency band but not close to the other, the aggregation is termed as Intra-band non-contiguous carrier aggregation. Component carriers of different frequency bands can also be aggregated and is called Inter-band non-contiguous aggregation. The mentioned Carrier Aggregation schemes are shown in figure 1.

Every carrier when aggregated is termed as a component carrier (CC). The component carriers can be Primary Component Carrier (PCC) or secondary component carrier (SCC). In any group, the primary carrier is the PCC. It is device specific but not cell specific. Any carrier can be used as PCC. A primary downlink carrier will have a corresponding primary component carrier in the uplink. Different devices may use different carriers, but it is cell specific. Carrier Aggregation is activated by the network when in the connected mode. Before the activation, Primary Component Carrier (PCC) is used to carry out some generic access procedures like cell search, cell selection, acquisition of system information and the initial random access, by the mobile device that supports LTE-Advanced for both downlink and uplink. There can be more than one secondary component carriers (SCC) and are activated based on the capacity requirement [11]. Carrier Aggregation can be [9] Symmetric Carrier Aggregation that has equal number of component carriers in both uplink and downlink while they are not the same in the Asymmetric Carrier Aggregation. Figure 2 shows the symmetric carrier aggregation.

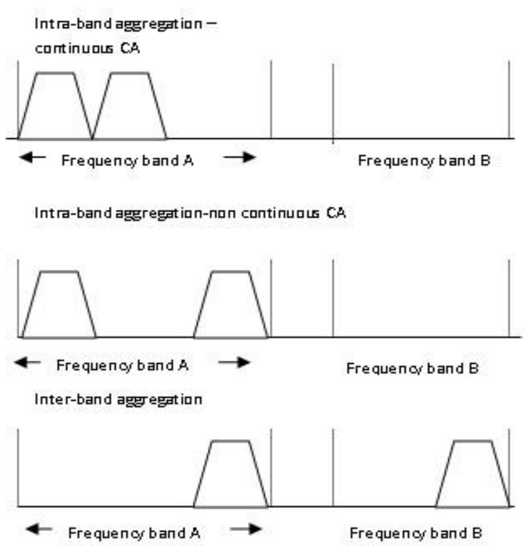

Figure1. Different schemes of carrier aggregation [10]

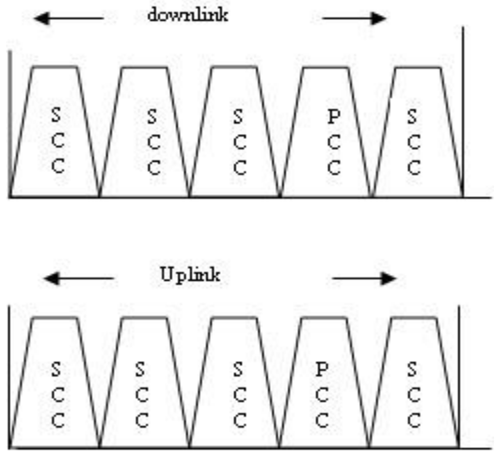

Figure2. Systematic Carrier Aggregation [9][10]

LTE release 10 makes use of Intra-band carrier aggregation for the uplink and Intra-band and Inter- band carrier aggregation for the downlink with specific RF requirements being developed[10][12]. Similar frequency range is to be maintained when inter-band aggregation is employed to satisfy the compatibility in hardware configurations [5].

2.2. Bandwidth expansion

To begin with, LTE used only single carrier technology with the bandwidth of about 1.4MHz to 20MHz. As of 3GPP Release 10 (LTE-Advanced), to achieve high data rates of about 1Gbps, Carrier Aggregation (CA) was proposed. Here a maximum of five component carriers of each 20MHz are aggregated to attain a total bandwidth of up to 100MHz. Thus the user is assigned a total bandwidth of up to 100MHz instead of 20MHz and hence high data rate.

Carrier components spread across different bands and with different bandwidths can be aggregated [12].Aggregated bandwidth has sub-bands, guard band and guard resource with center frequency at the center of aggregated bandwidth [13]. The center frequencies of the carriers should be separated by the multiples of 300 KHz [5].

Carrier aggregation combines the unused carrier of the spectrum with the primary component carriers (PCC) of the user to achieve data rates greater than LTE. It is possible in different ways based on the component carrier, response of the antennas and the coverage. Hence the cell edge users can also avail better throughput.

2.3. Backward compatibility

Attracting feature here is the backward compatibility of component carriers with LTE Release 8/9. The 5MHz, 10MHz, 15MHz and 20MHz channel bandwidth employed by Radio Access Network working group 4 (RAN4) is compliant with Release 8 of 3GPP[10]. The UE can use LTE and LTE-Advanced technology with the same carrier [12]. Also studies show that RF implementations at the eNB- UE for LTE may be used for LTE-A due to the backward compatibility [13].

2.4. Data rates and capacity:

Peak rates will scale linearly with Carrier Aggregation as shown in table 2.

Table -2 Data Rate Improvement with Carrier Aggregation [2]

		bandwidth	Peak data rate
Specifications without Carrier Aggregation	DL	20MHz	150.752Mbps
	UL		75.376Mbps
With carrier aggregation	DL	5X20MHz	1.5Gbps
	UL		376.88Mbps

2.5. Performance in UL and DL:

In [13], studies show that as the Component Carriers (CC) increases, the performance of the CA also increases depending on the average user throughput within the cell as shown in figure 3. System capacity can also improve in terms of active users in the cell through CA.

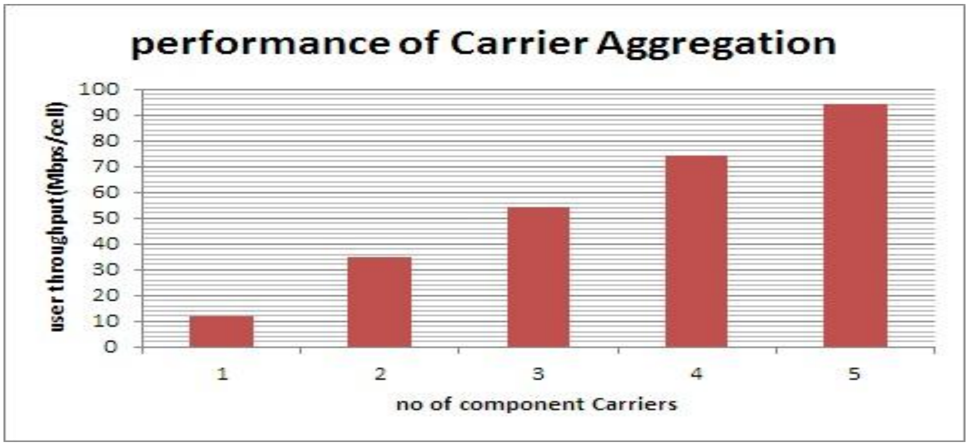

Figure3. Performance of carrier Aggregation [13]

In [14] the performance of CA is compared for 2 CC and 3CC. The maximum average cell throughput of 71.6Mbps was obtained by Aggregating 2 CCs of 20 MHz from 1800MHz band and 20MHz from 2100MHz. This inter band combination of CCs was considered as best combination. Aggregation of 3 CCs to obtain the maximum bandwidth of 50 MHz was possible by combining 10MHz from 900MHz, 20MHz from 1800MHz and 20 MHz from 2100MHz. The peak average cell throughput obtained from this combination 79.93Mbps.

A peak data rate of 500Mbps in the uplink can be achieved with enhancements like UL spatial multiplexing [2]. Higher the number of CC to a UE in downlink, the better is the throughput due to increased bandwidth and higher transmission power. In uplink, increasing the number of CC may reduce the transmission power of the UE [15]. Allocating different CC for the UE in LTE-Advanced is done based on the UE capabilities.

Single Carrier Frequency Division Multiple Access (SC-FDMA) has been selected for the uplink and OFDMA for the downlink. Due to the RF issues in the simultaneous transmission on multiple carriers, intra and inter band schemes are used for DL, while for UL, only intra band scheme is used [13].

III. DEPLOYMENT

Operators at United states, Korea and Japan had planned the deployment of Carrier Aggregation during the early 2014 with up to 20MHz of spectrum being aggregated to provide the downlink data throughput of about 150Mbps [1].

According to the sources from internet, CA is implemented in today’s mobile communication systems like LTE and Wi-Fi. Samsung had demonstrated the aggregation of 3 carriers of 20MHz to achieve peak downlink user data rate of 450Mbps during 2014.

At the national level, first carrier Aggregation was deployed by Airtel in February 2016, where bandwidth capabilities of 2300 MHz and 1800MHz spectrum band were combined for better spectrum utilization and efficiency [16]. Airtel has the carrier aggregation technology being deployed in Kerala, Mumbai and Bengaluru. The network could achieve a data speed of about 135 Mbps on mobile devices available commercially.

From the sources [17], Airtel is said to have used three carriers of 20 MHz each from unlicensed spectrum and one 5 MHz carrier for aggregation. This aggregation of 4 component carriers was possible using 4x4 MIMO antenna and 256 QAM technologies for the testing.

IV. CHALLENGES

Carrier aggregation being deployed as mentioned above still offer a number of challenges for research. Single transceiver may be required in user equipment in intra-band continuous carrier aggregation. This is because the aggregated channel is now a single channel with large bandwidth to an LTE Advanced terminal. When the carriers are not close to each other as in non-continuous carrier aggregation, more than one transceiver may be required within the single UE and hence the complexity increases.

As the User equipment (UE) may be assigned different UL and DL component carrier (CC) sets, different users within the cell can be configured differently giving rise to implementation flexibility. The challenge is to have a Carrier Aggregation solution that does not involve major changes in the design of the PCB and the cost [1]. The flexibility in the implementation requires robust control channel design to support different configurations. Devices today are limited by the size and battery capacity. Limitation on the UE transmission power is another important

issue with CA. Components and equipment that can support the large bandwidth is the requirement which needs to satisfy the design criteria like cost, speed, and size, quality of service, battery life and complexity.
In [18] work was done on mitigating the receiver desensitization in the UE that support the carrier aggregation. They developed the technique to estimate and cancel the 2nd order intermodulation signal getting leaked into the unpaired band. Further work can be done in supporting carrier aggregation in both uplink and downlink capable of transmitting and receiving in multiple bands simultaneously. Different scheduling algorithms, interference mitigation techniques, control signaling can be developed for different types of CA.

V. CONCLUSION

With the intension of satisfying the IMT-Advanced requirements of data rate set by the ITU-R, Carrier Aggregation is found to be the better solution. Multiple uplink and down links are already in use today to increase the data rate. Also lot of research opportunities is open leading to the growth of the technology to meet the demands of the society. In this paper, the attempt is made to study the Carrier aggregation used in LTE-Advanced. It is observed that LTE-Advanced offers increased data rates with improved spectrum efficiency and coverage with Carrier Aggregation. Work on LTA-Advanced is in progress to further enhance the spectrum efficiency and data rates though the researchers are preparing for 5G.

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