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LTE Advanced: Carrier Aggregation Deployments

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Abstract

LTE-Advanced is the evolution of LTE to 4G. Standardization work was done as part of Release 10 of the 3GPP specification, with further enhancements in Release 11 and beyond. LTE-Advanced introduces a number of enhancements and new technologies to enable peak data rates of up to 1 Gbps in the downlink and 500 Mbps in the uplink. Carrier aggregation (CA) is one of the key features for LTE-Advanced. By means of CA, users gain access to a total bandwidth of up to 100 MHz in order to meet the IMT-Advanced requirements. Carrier aggregation is used in LTE-Advanced in order to increase the bandwidth, and thereby increase the bitrates. This paper presents a review on the features and current advancements in Carrier Aggregation. It also includes the overview of deployments and future scope of Carrier Aggregation in various parts of world.

Keywords: Carrier Aggregation (CA), Inter-band aggregation, Intra-band aggregation, LTE-Advanced, 4G.

Introduction

LTE Advanced is a mobile communication standard, formally submitted as a candidate 4G system to ITU-T in late 2009, was approved into ITU, International Telecommunications Union, IMT-Advanced and was finalized by 3GPP in March 2011[1]. It is standardized by the 3rd Generation Partnership Project (3GPP) as a major enhancement of the Long Term Evolution (LTE) standard. The work by 3GPP to define a 4G candidate radio interface technology started in Release 9 with the study phase for LTE-Advanced. Being described as a 3.9G (beyond 3G but pre-4G), the first release of LTE does not meet the requirements for 4G (also called IMT Advanced as defined by the International Telecommunication Union) such as peak data rates up to 1 Gb/s.

The driving force to further develop LTE towards LTE–Advanced - LTE Release10 is set to provide higher bitrates in a cost efficient way and, at the same time, completely fulfill the requirements set by ITU for IMT Advanced, also referred to as 4G [2]. In LTE-Advanced focus is on higher capacity:

Increased peak data rate, DL 3 Gbps, UL 1.5 Gbps, Higher spectral efficiency, from a maximum of 16bps/Hz in R8 to 30 bps/Hz in R10, Increased number of simultaneously active subscribers, Improved performance at cell edges, e.g. for DL 2x2 MIMO at least 2.40 bps/Hz/cell[3] .

The key features introduced in LTE-Advanced are Carrier Aggregation (CA), enhanced use of multi-antenna techniques and support for Relay Nodes (RN).

Carrier Aggregation is one of the most important feature of LTE-Advanced as it deals with the fulfillment of the required data rates that are being headlined for 4G LTE Advanced. It is necessary to increase the transmission bandwidths in order to achieve the higher bitrates. Using LTE Advanced CA, it is possible to utilize more than one carrier and in this way increase the overall transmission bandwidth.

Carrier Aggregation

Carrier aggregation is one key enabler of LTE-Advanced to meet the IMT-Advanced requirements in terms of peak data rates . It is desirable to improve the spectral efficiency of the initial releases of LTE. In many areas, only small bands are available, often as small as 10 Mhz. With CA, such small bands can be aggregated to utilize the fragmented spectrum more efficiently, thereby, increasing the data rates. In the case of carrier aggregation, multiple LTE carriers, each with a bandwidth up to 20 MHz, can be transmitted in parallel to/from the same terminal, thereby allowing for an overall wider bandwidth and correspondingly higher per-link data rates[4]. In release-10, up to five carriers can be aggregated , each known as a component carrier (CC). Each CC is fully backward compatible to Release-8/9 due to which it is possible to use the technologies developed for LTE Release-8/9 to be fully reused in Release-10.

Carrier Aggregation is supported by both formats of LTE, namely the FDD and TDD variants.

LTE carriers can be aggregated in many ways :

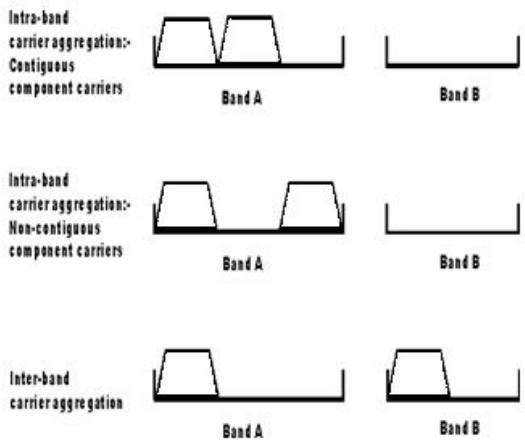


Figure I. Ways of Carrier Aggregation

A. Intra-band: This type of carrier aggregation uses a single band. There are two main formats for this type of carrier aggregation:

Contiguous: The Intra-band contiguous carrier aggregation is the easiest form of LTE carrier aggregation to implement. Here the carriers are adjacent to each other. The aggregated channel can be considered by the terminal as a single enlarged channel from the RF viewpoint. In this instance, only one transceiver is required within the terminal or User Equipment (UE), whereas more are required where the channels are not adjacent. However as the RF bandwidth increases it is necessary to ensure that the UE in particular is able to operate over such a wide bandwidth without a reduction in performance. Although the performance requirements are the same for the base station, the space, power consumption, and cost requirements are considerably less stringent, allowing greater flexibility in the design.

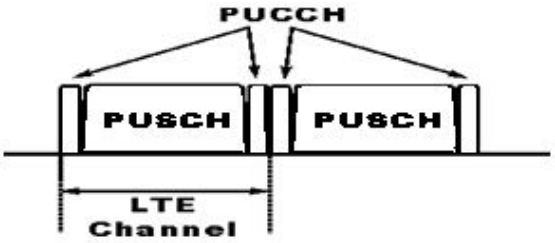


Figure II. Contiguous aggregation of two uplink component carriers

Non-contiguous: Non-contiguous intra-band carrier aggregation is somewhat more complicated than the instance where adjacent carriers are used. No longer can the multi-carrier signal be treated as a single signal and therefore two transceivers are required. This adds significant complexity, particularly to the UE where space, power and cost are prime considerations.

B. Inter-band non-contiguous: This form of carrier aggregation uses different bands. It will be of particular use because of the fragmentation of bands - some of which are only 10 MHz wide. For the UE it requires the use of multiple transceivers within the single item, with the usual impact on cost, performance and power. In addition to this there are also additional complexities resulting from the requirements to reduce inter-modulation and cross modulation from the two transceivers.

The current standards allow for up to five 20 MHz carriers to be aggregated, although in practice two or three is likely to be the practical limit. These aggregated carriers can be transmitted in parallel to or from the same terminal, thereby enabling a much higher throughput to be obtained.

Carrier Aggregation Bandwidth: There are several definitions required for the bandwidth of the combined channels during the aggregation of carriers for an LTE signal. It is necessary to define these several bandwidths in order to reduce the confusion.

There are total of six different carrier aggregation, CA bandwidth classes which are being defined.

CARRIER AGGREGATION BANDWIDTH CLASS	AGGREGATED TRANSMISSION BW CONFIGURATION	NUMBER OF COMPONENT CARRIERS
A	≤100	1
B	≤ 100	2
C	100-200	2

TABLE I. **BANDWIDTH CLASSES**

Note: Classes D, E, & F are in the study phase.

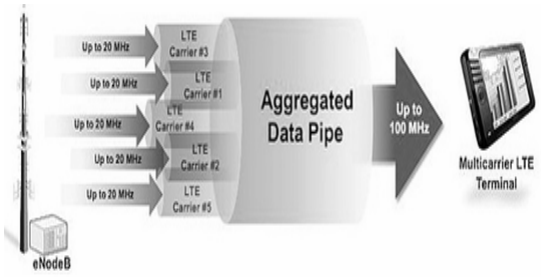
Deployments

There are three main motivations in introducing carrier aggregation for LTE-Advanced in Release 10, due to its support of high data rates, efficient utilization of fragmented spectrum, and support of heterogeneous network deployments by means of cross-carrier scheduling. A combination with other features defined in LTE Release 10, such as higher order MIMO, CA provides a powerful means to boost the peak user throughput in LTE Release 10 and to meet the IMT-Advanced requirements set by the ITU-R. CA allows aggregation of CCs dispersed across different bands as well as CCs having different bandwidths. CA also allows aggregation of cells having different coverage, thereby enabling flexible network deployments according to traffic demands. In exploiting cross-

carrier scheduling, efficient interference management is possible in heterogeneous network deployments, thereby improving system capacity. Moreover, each CC is backwards compatible with LTE Release 8/9, allowing smooth upgrade and migration of LTE networks towards LTE-Advanced.

Further evolution of CA is expected in future releases of LTE to include more advanced features such as inter-band CA for the UL and separate timing control for different UL CCs, to support additional deployment scenarios.

One of the important aspects to consider is that carrier aggregation should allow aggregation of not only the existing bands, but also bands that are introduced in future, e.g., 3.5 GHz band, etc. While existing bands already have certain deployments, new deployments can be considered for new bands that are introduced. Since introduction of new bands is done in a release independent fashion, considerations for such future bands are essential already in Rel-10. When higher frequencies such as 3.5 GHz are considered, path loss can be significant (e.g., 4-10 dB difference in link budget) when compared to 2 GHz. Hence, the most efficient deployment may not be to stick with the traditional macro-overlaying approach. Carrier aggregation should allow more flexible use of such new bands, since coverage and mobility can be ascertained by the existing band deployments, e.g., 2 GHz.



Ultra Wide Deployments with Multicarrier

A brief summary of status of mobile carriers' LTE-A (Carrier Aggregation) penetration and deployment is provided below:

SK Telecom: SK Telecom has successfully tested their core LTE-Advanced technologies as of July 5th, 2012[5]. CoMP (Coordinated Multi-Point) technology has been commercialized in January 2012[6]. eICIC (Enhanced Inter-Cell Interference Coordination) technology has been successfully tested in collaboration with Qualcomm and Nokia Siemens Network. They are planning to commercialize Carrier Aggregation towards the end of 2013. SK Telecom already has 100 mbps wireless service using a heterogeneous network of LTE and Wifi.

Russian Yota: Yota has launched the first commercial network using LTE Advanced, though its vendor. Huawei, also describes it as a test LTE-A network. LTE Advanced technology has been installed on 11 base stations in the city, and initial transmissions have achieved the target 300 megabits speed[7]. No user terminals are yet available. Yota expects delivery of the first devices in the first half of 2013.

Sprint: Sprint plans to deploy its LTE-Advanced network
800 MHz spectrum by first half of 2013

AT&T: AT&T confirms LTE-Advanced deployment in 2013

T-Mobile: T-Mobile has signed multi-year agreements with Ericsson and Nokia Siemens Networks. 3GPP Release 10 equipment will be provided by the two companies. LTE-Advanced trials set to begin this summer..

Clearwire: Clearwire plans to deploy an LTE Advanced-ready network by June 2013. It will allow for peak rates of 168Mbps through carrier aggregation. It will not be in commercial products until 2014.

Telstra: Telstra could possibly operate advanced LTE services on the 900 MHz and 1800 MHz bands[8].

It plans to upgrade approximately 7,500 cell sites and base stations over the next 12 months.

NTT DoCoMo: NTT DoCoMo has begun building test network near Tokyo. They have achieved downlink speeds of around 1Gbps and uplinks of around 200Mbps in LTE Advanced lab tests.

Future Scope

In 2014 there will be cases where a device will be required to support 5 to 6 bands just for a single operator and globally it is foreseen that there will be around 18 bands in use for LTE. This means that efficient multi band support will become an important matter to get devices that can be used globally.

Even before the initial roll-out of LTE has been completed, many operators are gearing up to take the next step by deploying LTE Advanced. LTE Advanced will bring increased network efficiency, higher throughput to end users in more locations, as well as, support for various advanced deployment scenarios.

More than 90% of all contiguous spectrum allocations today are 15MHz or lower. A significant part is even below 10MHz. This limitation makes it difficult for many operators to support 100Mbps data rate, or more, without using Carrier Aggregation.

The LTE Carrier Aggregation roll out will start during 2013 and we expect significant growth 2014. U.S., Korean and Japanese operators already have firm deployment plans for Carrier Aggregation. In

the first phase, up to 20MHz of spectrum will be aggregated enabling subscribers to enjoy up to 150Mbps downlink data throughput, or even higher in the future.

There are also interest in Carrier Aggregation on the European market but not as crucial for a quick roll-out since operators already have up to 20 MHz allocations either in the 1.8 GHz and 2.6 GHz bands.

One of the big challenges for Carrier Aggregation is to develop a RF front-end flexible enough to support a majority of domestic, and international, bands together with possible future Carrier Aggregation combinations. Besides that, device manufacturers expect excellent device performance with respect to data throughput, and still maintain a small size and decent battery life time.

Conclusion

Carrier Aggregation is a key feature of LTE-Advanced that is enabling the various operators to create larger "virtual" carrier bandwidths by combining separate spectrum allocations. The benefits of this aggregation include higher peak data rates, increased average data rates for users and improved spectral efficiency. LTE-Advanced technology is getting deployed at a very fast pace. It can be foreseen from the current deployments that LTE-Advanced has a long run in the field of wireless communication providing higher bit rates and increased bandwidth which is an important requirement of today's technology inspired world.

Acknowledgment

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