TM500 Family

White Paper

The most important thing we build is trust

December 2015

Testing Carrier Aggregation in LTE-Advanced Network Infrastructure

Contents

For LTE-Advanced, 3GPP Release 10 introduced several new features to augment the existing LTE standard, and these are aimed at raising the peak downlink data rate to 1 Gbps and beyond, as well as reducing latency and improving spectrum efficiency. Targets have also been set enabling the highest possible cell edge user throughput to be achieved.

If the high data rate targets are to be met, LTE-Advanced will require a channel bandwidth that is much wider than the 20 MHz currently specified for LTE. This will not be possible with just a single carrier in the limited spectrum bands available to most operators. Consequently, carrier aggregation—the ability to combine multiple carriers scattered around the spectrum—will be a key measure to achieve the wider effective bandwidth that will be required, typically up to 100 MHz. This means that multiple carriers comprised of either contiguous or non-contiguous spectrum need to be added together to allow these wider channel bandwidths—and thus faster data rates—to be achieved.

Implementing carrier aggregation in a network will mean that operators and infrastructure vendors will require a test mobile equipped with carrier aggregation, ahead of real mobile terminals becoming available.

Evolution to LTE-Advanced

The aim of the 3GPP program for LTE-Advanced is to meet or exceed the requirements of IMT-Advanced within the time frame laid down by the International Telecommunications Union Radio Communication Sector (ITU-R).

The key targets of IMT-Advanced are: 100 MHz bandwidth, a data rate of 1 Gbps in the downlink and 500 Mbps in the uplink, with 8x8 MIMO and 4x4 MIMO, respectively, in the downlink and uplink. C-plane latency will be a maximum of 50 ms, while U-plane latency will be less than or equal to 5 ms. Table 1 compares these targets with the specification for LTE Release 8 and for LTE-Advanced.

The evolved standard will offer a higher average spectrum efficiency and cell edge user throughput than Release 8 LTE, with greater spectrum flexibility due to newly allocated bands. Self-organising networking and deployment will be an integral part of LTE-A, because the network complexity will make manual optimisation unfeasible. It is envisaged that there will be a smooth and low cost transition from LTE (Release 8) to LTE-A over the intervening period.

Furthermore, LTE-A will need to coexist with LTE, with a progressive development in infrastructure and gradual upgrades to terminals. Functionality will also need to be scalable.

Bandwidths

As the spectrum is already crowded it is difficult for the regulatory bodies to allocate a non-fragmented part of the spectrum with 100 MHz bandwidth. Likewise the majority of the bands already assigned for LTE (see Tables 2(a) and (b)) are not broad enough on their own to provide the 100 MHz bandwidth specified for LTE-A. There is also an issue with legacy systems, where bandwidth is occupied by standards that pre-date LTE Release 8. Hence there is a need to combine the available spectrum bands in one of a number of prescribed ways, a technique collectively known as carrier aggregation.

Carrier aggregation is a means of flexible spectrum allocation in order to achieve wider bandwidth transmission. A complete system bandwidth of up to 100 MHz may consist of between two and five basic frequency blocks called component carriers (CC). At least some of the CCs are backward compatible with Release 8 LTE, and the aggregated bandwidth may be made up from either CCs from the same band (intra-band CA) or CCs from different bands (inter-band CA). LTE-A supports both contiguous and non-contiguous spectra for intra-band CA. Some examples are given in Figure 1.

The first diagram in Figure 1 shows the case of contiguous intra-band carrier aggregation, where 100 MHz bandwidth is obtained by aggregating five component carriers from adjacent bands. The second diagram shows the non-contiguous intra-band carrier aggregation case. It can be seen that there is fragmented bandwidth in between the CCs. The final diagram shows inter-band carrier aggregation: the inter-band carrier aggregation is clearly non-contiguous as there is a fragmented bandwidth between the component carriers.

For Frequency Division Duplexing (FDD), asymmetric bandwidth may be supported for uplink and downlink. Symmetric operation is defined as the case where there are equal numbers of CCs f/or the downlink and uplink, while asymmetric operation uses a larger number of CCs for the downlink than for the uplink. In Time Division Duplexing (TDD), the uplink and downlink are always symmetric because they share the same carrier. A further consideration is intra-band symmetry, as shown in Figure 2, which relates to whether or not the aggregated carriers form a mirror image across the aggregate bandwidth.

For LTE-A (3GPP Release 10), carrier aggregation is assumed to be symmetrical within the band, unless an exception is stated. The advantage of symmetry is that for a zero-IF receiver it avoids the data resource element (RE) overlapping at the DC point.

3GPP has specified a range of carrier aggregation scenarios for initial investigation for LTE-A, with architecture using up to three transceiver chains, which can operate anywhere in the range 300 MHz – 6 GHz. This poses some huge design problems for both eNodeBs and user equipment (UE). In the future all five of the CCs will be allowed to be non-contiguous, as shown in Figure 3, which further increases the number of transceiver chains.

Applications

A pair of component carriers is called a serving cell. One of the serving cells are designated the primary cell, while the rest are known as secondary cells. The primary cell is the most important, and manages the CA configuration. RACH procedure is not allowed in a secondary cell. When a cell is configured, it is given a 'serving cell index', which denotes its relative importance – the smaller the serving cell index, the more important the serving cell will be. The serving cell index for the primary cell is always equal to zero.

The versatility of carrier aggregation makes for much easier network deployment, because the second component carrier can be used either to boost the data rates close to the eNodeB, to eliminate weak coverage at the cell edge, or to serve hot spots where peak rates are very important. Figure 4 shows examples of each of these applications, which were identified by 3GPP during its feasibility study. Two further applications scenarios (not shown) use remote radio heads (RRH) for non co-located cells, which will be supported in Release 11.

Demonstration

The TM500 Test Mobile was a key component in an early demonstration of LTE carrier aggregation at the 2011 Mobile World Congress, successfully combining 800 MHz and 2.6 GHz spectrum. This enabled a leading network infrastructure vendor to deliver a huge LTE data “pipe” that combined the capacity of both frequency bands while maximizing the benefits of the superior propagation capability in the lower frequency band.

A type of carrier aggregation had already been provided on the TM500 for 3G, making use of the availability of dual-carrier HSDPA (DC-HSDPA). This feature is now available on the production model of the TM500 LTE Test Mobile, the de facto industry standard for testing LTE base stations or eNodeBs.

Conclusion

Carrier aggregation of contiguous and non-contiguous spectrum bands has been identified as one of the most crucial aspects in the evolution towards LTE-Advanced, and has also been recognized as presenting a major challenge to the design of user equipment and eNodeBs. Cellular infrastructure vendors need a reliable test mobile to test their networks ahead of the availability of real terminals and handsets, and providing them with carrier aggregation capability at this early stage is proving essential to the development of the eNodeBs that will be used to roll out LTE-Advanced.

Tables and Figures

		Release 8 LTE	LTE-Advanced	IMT-Advanced target
Peak data rate	Downlink	300 Mbps	1 Gbps	1 Gbps*
	Uplink	75 Mbps	500 Mbps	
Peak spectrum efficien-cy [bps/Hz]	Downlink	15 (4x4 MIMO)	30 (up to 8x8 MIMO)	15 (4x4 MIMO)
	Uplink	3.75 (64QAM SISO)	15 (up to 4x4 MIMO)	6.75 (2x4 MIMO)

*100 Mbps for high mobility and 1 Gbps for low mobility

Table 1. 3GPP LTE-Advanced specification compared with LTE Release 8 and IMT-Advanced targets

LTE BAND NUMBER	UPLINK (MHZ)	DOWNLINK (MHZ)	MAIN REGIONS OF USE
1	1920 - 1980	2110 - 2170	Asia, Europe
2	1850 - 1910	1930 - 1990	Americas, Asia
3	1710 - 1785	1805 -1880	Americas, Asia, Europe
4	1710 - 1755	2110 - 2155	Americas
5	824 - 849	869 - 894	Americas
6	830 - 840	875 - 885	Japan
7	2500 - 2570	2620 - 2690	Asia, Europe
8	880 - 915	925 - 960	Asia, Europe
9	1749.9 - 1784.9	1844.9 - 1879.9	Japan
10	1710 - 1770	2110 - 2170	Americas
11	1427.9 - 1452.9	1475.9 - 1500.9	Japan
12	698 - 716	728 - 746	USA
13	777 - 787	746 - 756	USA
14	788 - 798	758 - 768	USA
17	704 - 716	734 - 746	USA
18	815 - 830	860 - 875	Japan
19	830 - 845	875 - 890	Japan
20	832 - 862	791 - 821	Europe
21	1447.9 - 1462.9	1495.5 - 1510.9	Japan
22	3410 - 3500	3510 - 3600	

Table 2(a). Band designations for LTE FDD

LTE BAND NUMBER	ALLOCATION (MHZ)	MAIN REGIONS OF USE
33	1900 - 1920	Asia (not Japan), Europe
34	2010 - 2025	Asia, Europe
35	1850 - 1910	Americas
36	1930 - 1990	Americas
37	1910 - 1930	
38	2570 - 2620	Europe
39	1880 - 1920	China
40	2300 - 2400	Asia, Europe
41	2496 - 2690	USA

Table 2(b). Band designations for LTE TDD

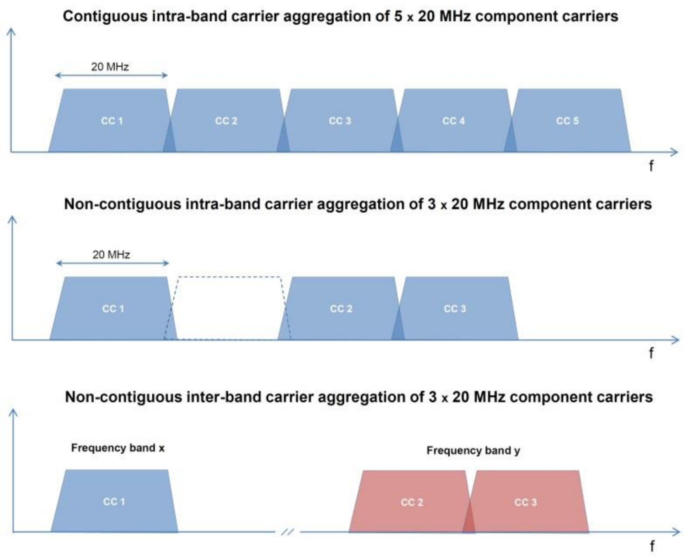


Figure 1. Examples of carrier aggregation

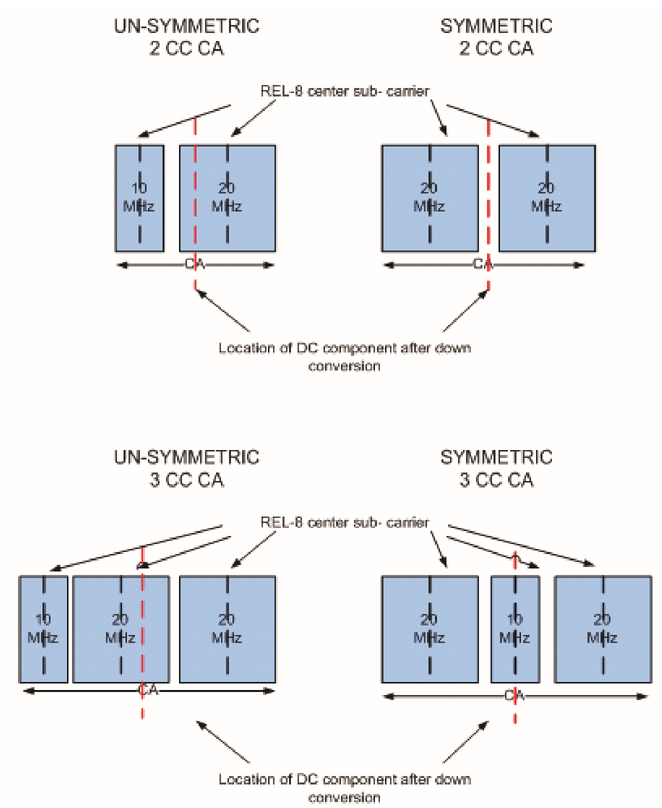


Figure 2. Intra-band symmetry

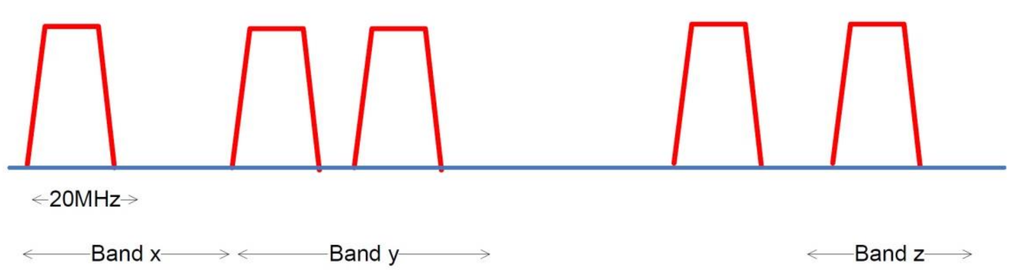
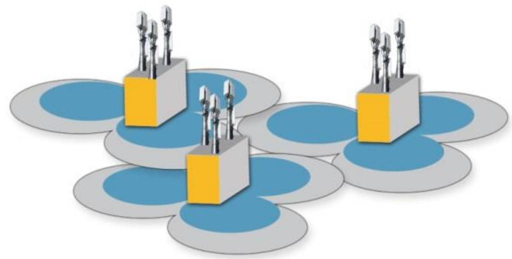
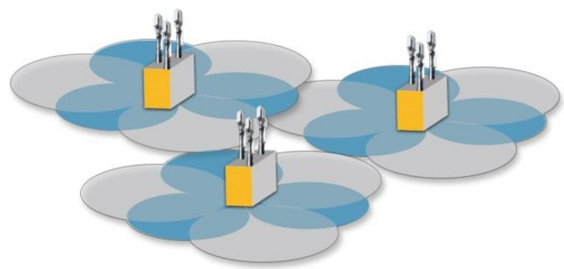


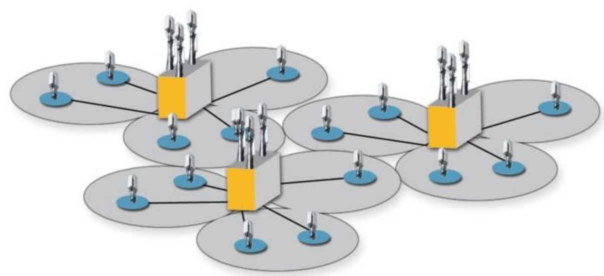
Figure 3. Five non-contiguous component carriers



(a)



(b)



(c)

Figure 4 shows three of the many possible LTE-Advanced carrier aggregation application scenarios, where in each case frequency f_1 is shown in grey and f_2 is shown in blue: (a) f_1 is used to increase coverage and f_2 is used to boost the data rate ($f_2 > f_1$); (b) both frequencies are used to increase cell throughput; and (c) f_1 provides macro coverage and f_2 is used to boost throughput in hotspots.

For further information please contact:

Cobham Wireless

UK: +44 (0) 1438 742200

info@aeroflex.com

www.cobham.com/wireless