LTE-Advanced

by Jeanette Wannstrom, for 3GPP

(Submission, May 2012)

The driving force to further develop LTE towards LTE–Advanced, LTE R-10 is to provide higher bitrates in a cost efficient way, and at the same time completely fulfil the requirements set by ITU for IMT Advanced, also referred to as 4G.

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.

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

Carrier Aggregation

The most straightforward way to increase capacity is to add more bandwidth. Since it is important to keep backward compatibility with R8 and R9 mobiles the increase in bandwidth in LTE-Advanced is provided through aggregation of R8/R9 carriers. Carrier aggregation can be used for both FDD and TDD.

Each aggregated carrier is referred to as a component carrier. The component carrier can have a bandwidth of 1.4, 3, 5, 10, 15 or 20 MHz and a maximum of five component carriers can be aggregated. Hence the maximum bandwidth is 100 MHz. The number of aggregated carriers can be different in DL and UL, however the number of UL component carriers is never larger than the number of DL component carriers. The individual component carriers can also be of different bandwidths, see figure 1.

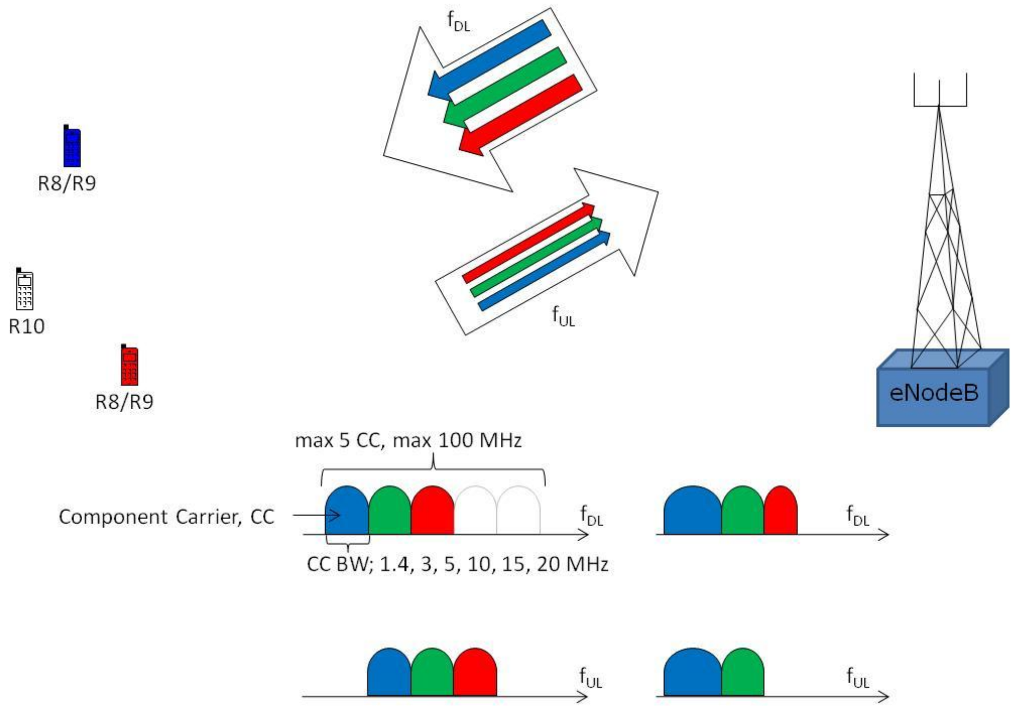

Figure 1. Carrier Aggregation – FDD
The R10 UE can be allocated resources DL and UL on up to five Component Carriers (CC). The R8/R9 UEs can be allocated resources on any ONE of the CCs. The CCs can be of different bandwidths.

The easiest way to arrange aggregation is to use contiguous component carriers within the same operating frequency band (as defined for LTE), so called intra-band contiguous. This might not always be possible, due to frequency allocation scenarios. For non-contiguous allocation it could either be intra-band, i.e. the component carriers belong to the same operating frequency band, but are separated by a frequency gap, or it could be inter-band, in which case the component carriers belong to different operating frequency bands, see figure 2.

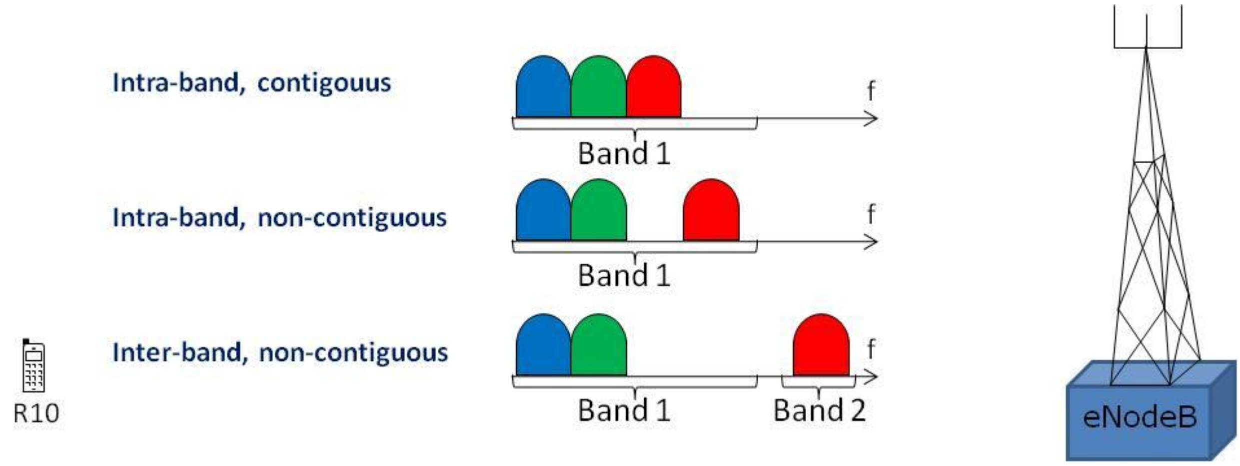

Figure 2 Carrier Aggregation – Intra- and inter-band alternatives.

When carrier aggregation is used there is a number of serving cells, one for each component carrier. The coverage of the serving cells may differ – both due to component carrier frequencies but also from power planning – useful for heterogeneous network planning. The RRC connection is handled by one cell, the Primary serving cell, served by the Primary component carrier (DL and UL PCC). The other component carriers are all referred to as Secondary component carrier (DL and UL SCC), serving the Secondary serving cells.

Different component carriers can be planned to provide different coverage, i.e. different cell size. In the case of inter-band carrier aggregation the component carriers will experience different pathloss, which increases with increasing frequency. In the example shown in figure 3 the carrier aggregation on all three component carriers can only be used for the black UE, the white UE is not within the coverage area of the red component carrier.

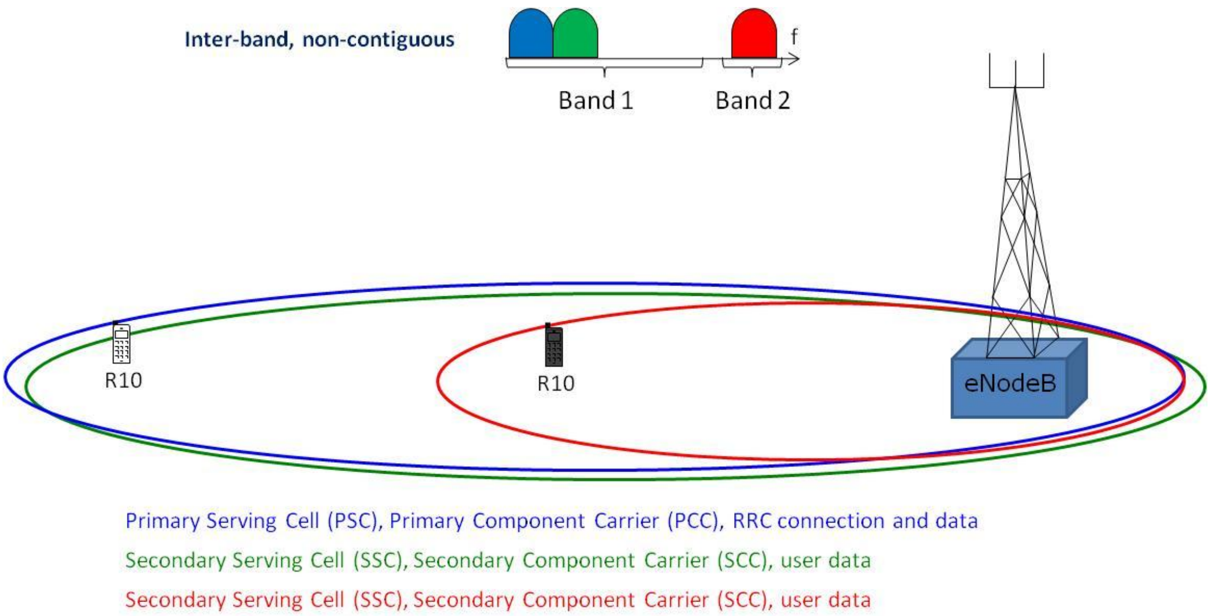

Figure 3. Carrier Aggregation; Serving Cells
Each Component Carrier corresponds to a serving cell. The different serving cella may have different coverage.

Introduction of carrier aggregation influences mainly MAC and the physical layer protocol, but also some new RRC messages are introduced.

MIMO, Multiple Input Multiple Output – or spatial multiplexing

MIMO is used to increase the overall bitrate through transmission of two (or more) different data streams on two (or more) different antennas - using the same resources in both frequency and time, separated only through use of different reference signals - to be received by two or more antennas, see figure 4.

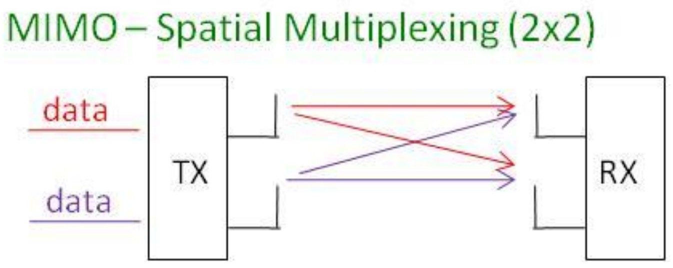

Figure 4. Simplified illustration of 2x2 MIMO (Spatial Multiplexing). Two different data streams are transmitted on two TX antennas and received by two RX antennas, using the same frequency and time, separated only by the use of different reference signals.

One or two transport blocks are transmitted per TTI. A major change in LTE-Advanced is the introduction of higher order MIMO; 8x8 in the DL and 4x4 in the UL.

MIMO shall be used when S/N (Signal to Noise ratio) is high, i.e. high quality radio channel. For situations with low S/N it is better to use other types of multi-antenna techniques to improve S/N, e.g. TX-diversity, see figure 5.

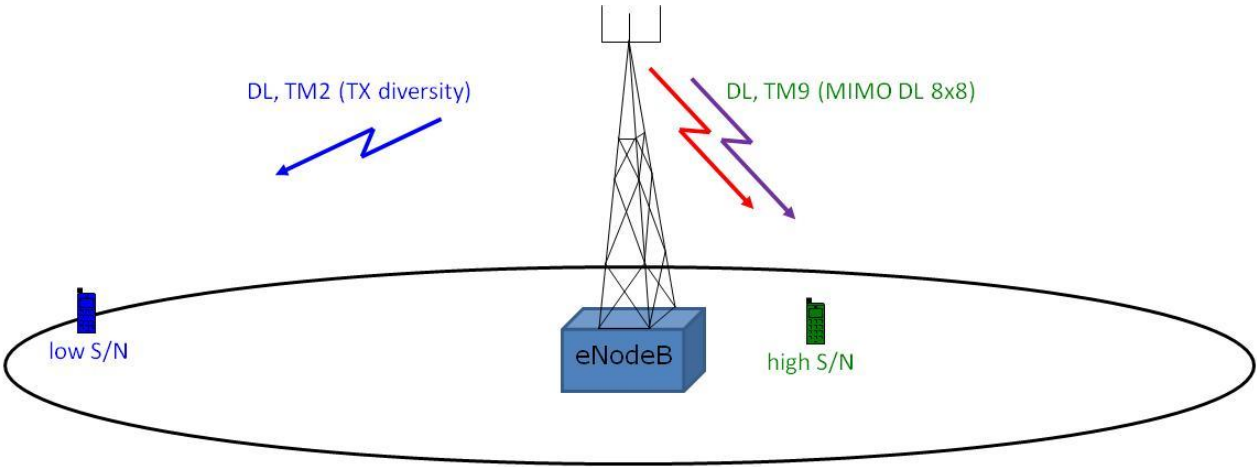

Figure 5. MIMO is recommended for high S/N and TX diversity is preferably used for low S/N scenarios.

To be able to adjust the type of multi-antenna technique to use according to e.g. radio environment a number of different Transmission Modes (TM) has been defined. The UE will through RRC signalling be informed about the TM to use. In the DL there are nine different TMs, where TM1-7 were introduced in Release 8, TM8 was introduced in Release 9 and TM9 was introduced in Release 10. In the UL there are TM1 and TM2, where TM1 is the default, and it was introduced in Release 8 and TM2 is introduced in Release 10. The different TMs differ in

- Number of layers (streams, or rank)
- Antenna ports used

- Type of reference signal, Cell Specific Reference (CRS) or Demodulation Reference Signal (introduced in Release 10)
- precoding type

Through the introduction of TM9 8x8 MIMO is supported DL, and through the introduction of TM2 UL use of 4x4 MIMO UL is enabled.

In multi-antenna techniques precoding is used to map the modulation symbols onto the different antennas. The type of precoding depends on multi-antenna technique used as well as on number of layers and number of antenna ports.

The aim with the precoding is to achieve best possible data reception at the receiver. Note that the signal will be influenced by fading of various types, which can also be seen as some type of coding caused by the radio channel.

In R8 the reference signal is added to the signal after precoding, one CRS (Cell-specific Reference Signal) per antenna. From the received CRS the UE will estimate how the radio channel influenced the signal. Using this together with knowledge about the used code-book based precoding, the UE will demodulate the received signal and regenerate the information sent.

In R10 the DM-RSs (Demodulation Reference Signals) are added to the different data streams before precoding. Knowledge about the reference signal will provide information about the combined influence of radio channel and precoding, no pre-knowledge about the precoder is required by the receiver, this case is referred to as non-codebook based precoding, see figure 6.

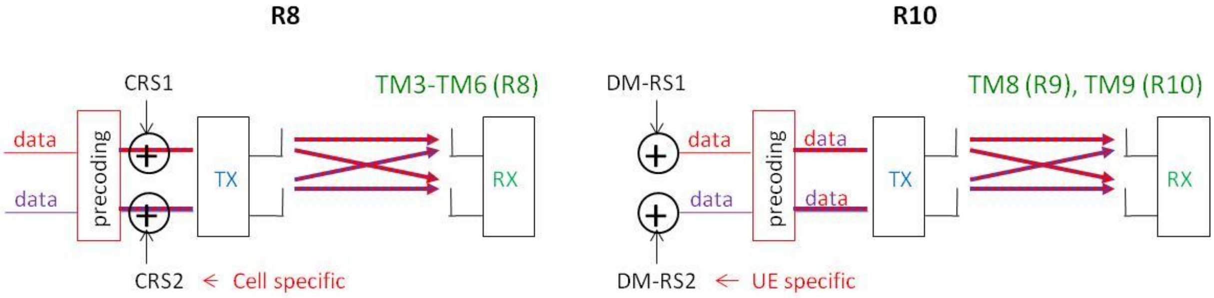

Figure 6. MIMO DL with precoding and reference signal for demodulation in R8 and R10. CRS is a cell specific reference signal, DM-RS is a UE specific reference signal, also specific per data stream.

Relay Nodes

In LTE advanced, the possibility for efficient heterogeneous network planning – i.e. a mix of large and small cells - is increased by introduction of Relay Nodes (RNs). The Relay Nodes are low power base stations that will provide enhanced coverage and capacity at cell edges and it can also be used to connect to remote areas without fibre connection. The Relay Node is connected to the Donor eNB (DeNB) via a radio interface, Un, which is a modification of the E-UTRAN air interface Uu. Hence in the Donor cell the radio resources are shared between UEs served directly by the DeNB and the Relay Nodes. When the Uu and Un use different frequencies the Relay Node is referred to as a Type 1a RN, for Type 1 RN Uu and Un utilize the same frequencies, see figure 7. In the latter case there is a high risk for self interference in the Relay Node, when receiving on Uu and transmitting on Un at the same time (or vice versa). This can be avoided through time sharing between Uu and Un, or having different locations of the transmitter and receiver. The RN will to a large extent support the same functionalities as the eNB – however the DeNB will be responsible for MME selection.

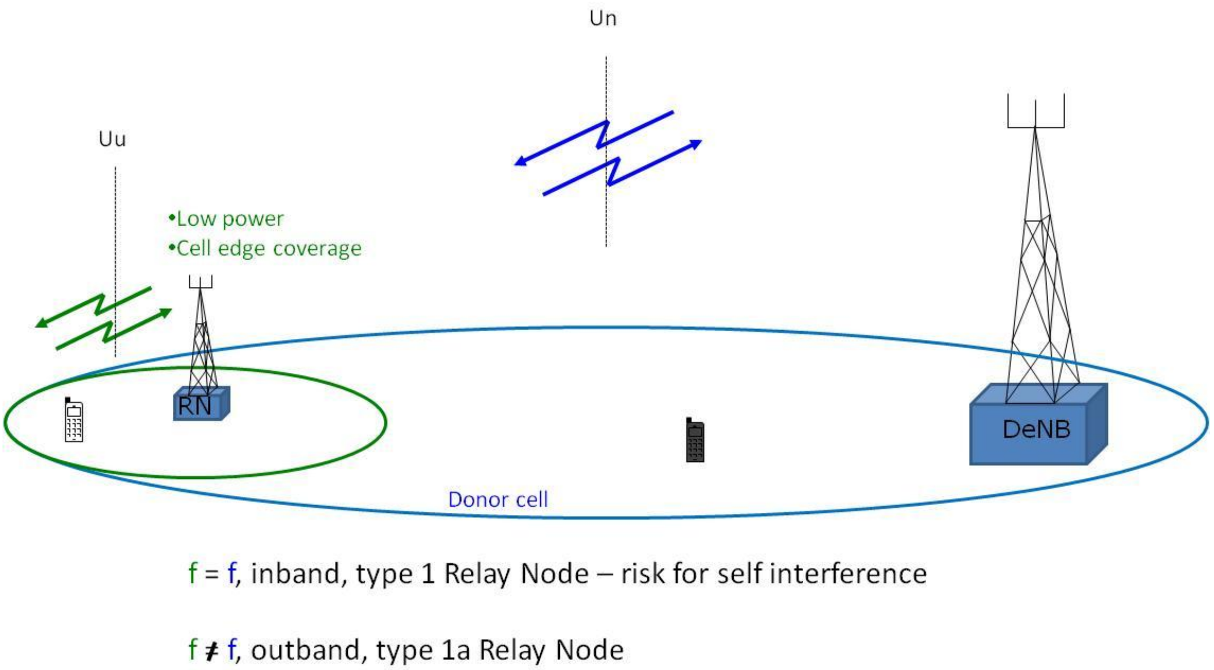

Figure 7. The Relay Node (RN) is connected to the DeNB via the radio interface Un. UEs at the edge of the donor cell are connected to the RN via Uu, while UEs closer to the DeNB are directly connected to the DeNB via the Uu interface. The frequencies used on Un and Uu can be different, outband, or the same, inband. In the inband case there is a risk for self interference in the RN.

Further reading

TR 36.806 Evolved Universal Terrestrial Radio Access (E-UTRA); Relay architectures for E-UTRA (LTE-Advanced)

(TR 36.808 Evolved Universal Terrestrial Radio Access (E-UTRA); Carrier Aggregation; Base Station (BS) radio transmission and reception)

TR 36.814 Evolved Universal Terrestrial Radio Access (E-UTRA); Further advancements for E-UTRA physical layer aspects

TR 36.815 Further Advancements for E-UTRA; LTE-Advanced feasibility studies in RAN WG4

TR 36.817 Evolved Universal Terrestrial Radio Access (E-UTRA); Uplink multiple antenna transmission; Base Station (BS) radio transmission and reception

TR 36.826 Evolved Universal Terrestrial Radio Access (E-UTRA); Relay radio transmission and reception

TR 36.871 Evolved Universal Terrestrial Radio Access (E-UTRA); Downlink Multiple Input Multiple Output (MIMO) enhancement for LTE-Advanced

TR 36.912 Feasibility study for Further Advancements for E-UTRA (LTE-Advanced)

TR 36.913 Requirements for further advancements for Evolved Universal Terrestrial Radio Access (E-UTRA) (LTE-Advanced)

TS 36.211 Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation

TS 36.212 Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding

TS 36.213 Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures

TS 36.216 Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer for relaying operation

TS 36.300 Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2