Future of mobile broadband…. *LTE Advanced*

LTE standardization has come to a mature state by now where changes on the specification are limited to corrections and bug fixes. With the matured standards for LTE, the Long Term Evolution of the 3G services, eyes are now turning towards the next development, that of the truly 4G technology named IMT Advanced. The new technology being developed under the auspices of 3GPP to meet these requirements is often termed LTE-Advanced.

In order that the correct solution is adopted for the 4G system, the ITU-R (International Telecommunications Union – Radio communications sector) has started its evaluation process to develop the recommendations for the terrestrial components of the IMT Advanced radio interface. One of the main competitors for this is the LTE Advanced solution.

One of the key milestones is October 2010 when the ITU-R decides the framework and key characteristics for the IMT Advanced standard. Before this, the ITU-R undertook the evaluation of the various proposed radio interface technologies of which LTE Advanced is a major contender.

The idea behind the introduction of LTE-Advanced is to support the requirements of IMT-Advanced and shall have better performance than LTE. LTE-Advanced should be real broadband wireless network that provides peak data rates equal to or greater than those for wired networks, i.e., FTTH (Fiber to the Home), while providing better QoS. The major high-level requirements of LTE-Advanced are reduced network cost (cost per bit), better service provisioning and compatibility with 3GPP systems. LTE-Advanced being an evolution from LTE is backward compatible.

Operators are increasingly facing the need to deliver higher data rates. In this regard, LTE-A (Release 10) facilitates carrier aggregation, allowing for the parallel transmission of multiple LTE carriers to and from a single terminal. This enables an increased overall bandwidth and corresponding data rates. Up to five 20 MHz carriers can be aggregated, resulting in an overall bandwidth of up to 100 MHz for both downlink and uplink.
In addition to the aggregation of contiguous carriers within a single frequency band, LTE also supports aggregation of carriers in different frequency bands. Such out-of-band carrier aggregation or spectrum aggregation allows operators with fragmented spectra to provide wider bandwidths, enabling higher data rates and more efficient utilisation of available spectrum.

Key milestones for ITU-R IMT Advanced evaluation

The ITU-R has set a number of milestones to ensure that the evaluation of IMT Advanced technologies occurs in a timely fashion. A summary of the main milestones is given below and this defines many of the overall timescales for the development of IMT Advanced and in this case LTE Advanced as one of the main technologies to be evaluated.

Milestone	Date
Issue invitation to propose Radio Interface Technologies.	March 2008
ITU date for cut-off for submission of proposed Radio Interface Technologies.	October 2009
Cutoff date for evaluation report to ITU.	June 2010
Decision on framework of key characteristics of IMT Advanced Radio Interface Technologies.	October 2010
Completion of development of radio interface specification recommendations.	February 2011

LTE Advanced key features

With work starting on LTE Advanced, a number of key requirements and key features are coming to light. Although not fixed yet in the specifications, there are many high level aims for the new LTE Advanced specification. These will need to be verified and much work remains to be undertaken in the specifications before these are all fixed. Currently some of the main headline aims for LTE Advanced can be seen below:

1. Peak data rates: downlink - 1 Gbps; uplink - 500 Mbps.
2. Spectrum efficiency: 3 times greater than LTE.
3. Peak spectrum efficiency: downlink - 30 bps/Hz; uplink - 15 bps/Hz.
4. Spectrum use: the ability to support scalable bandwidth use and spectrum aggregation where non-contiguous spectrum needs to be used.
5. Latency: from Idle to Connected in less than 50 ms and then shorter than 5 ms one way for individual packet transmission.
6. Cell edge user throughput to be twice that of LTE.
7. Average user throughput to be 3 times that of LTE.
8. Mobility: Same as that in LTE
9. Compatibility: LTE Advanced shall be capable of interworking with LTE and 3GPP legacy systems.

LTE-Advanced Spectrum

One key issue for LTE-Advanced is the availability of radio spectrum. Increased data bandwidth comes at the cost of requiring wider transmission bandwidths. Even though the spectrum can be used more efficiently using techniques such as MIMO and beam forming, it is still necessary to have greater levels of available spectrum. As a result some new bands were identified for use by IMT/IMT Advanced technologies at the World Radio Conference in 2007. Possible bands included:

- 450-470 MHz
- 698-862 MHz
- 790-862 MHz
- 2.3-2.4 GHz
- 3.4-3.6 GHz

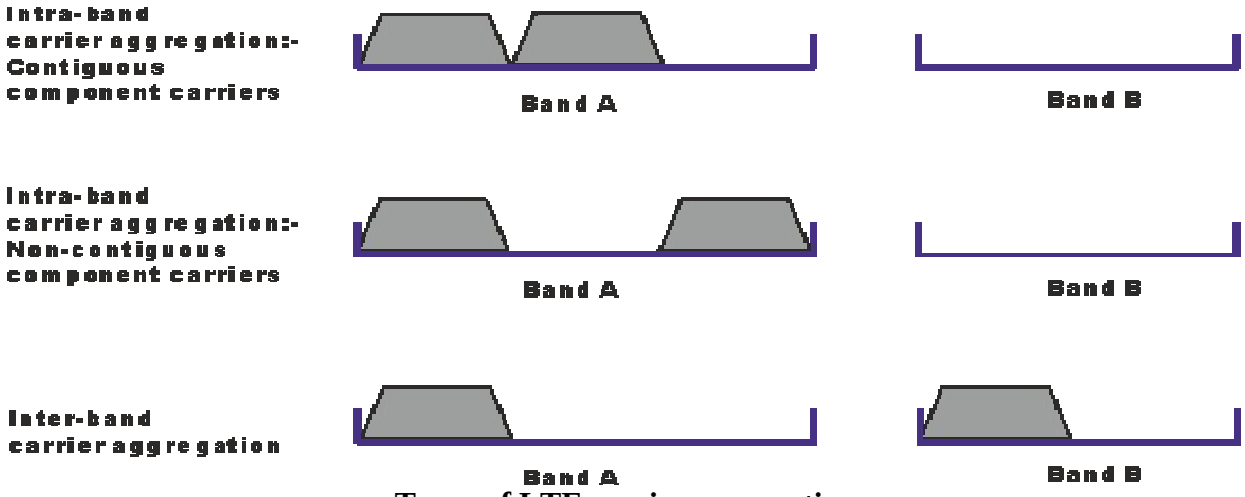
Note that frequency bands are considered release- independent features, which means that it is acceptable to deploy an earlier release product in a band not defined until a later release.

SUPPORT OF WIDER BANDWIDTH- Carrier Aggregation

A significant underlying feature of LTE-Advanced will be the flexible spectrum usage. The framework for the LTE-Advanced air-interface technology is mostly determined by the use of wider bandwidths, potentially even up to 100 MHz, noncontiguous spectrum deployments, also referred to as spectrum or carrier aggregation, and a need for flexible spectrum usage. The concept is two or more component careers are aggregated in order to support wider transmission bandwidths upto 100 MHz. It shall be possible to configure all component carriers which are LTE Rel-8 compatible, at least when the aggregated numbers of component carriers in the UL and the DL are the same. Not all component carriers may necessarily be LTE Rel-8 compatible. An LTE-Advanced terminal with reception and/or transmission capabilities for carrier aggregation can simultaneously receive and/or transmit on multiple component carriers.

RF aspects of carrier aggregation

There are a number of ways in which LTE carriers can be aggregated:



Types of LTE carrier aggregation

Concerning the resource allocation in the eNB and the backward compatibility, minimum changes in the specifications will be required if scheduling, MIMO, Link Adaptation and HARQ are performed over groups of carriers of 20MHz.For instance, a user receiving information in 100MHz bandwidth will need 5 receiver chains, one per each 20MHz block. Carrier aggregation is supported for both contiguous and non-contiguous component carriers with each component carrier limited to a maximum of 110 Resource Blocks in the frequency domain using the LTE Rel-8 numerology. It is possible to configure a UE to aggregate a different number of component carriers originating from the same eNB and of possibly different bandwidths in the UL and the DL and ofcourse in typical TDD deployments, the number of component carriers and the bandwidth of each component carrier in UL and DL will be the same.

CO-ORDINATED MULTIPOINT TRANSMISSION AND RECEPTION (COMP)

Coordinated Multi-Point transmission and reception (CoMP) is another technique being extensively discussed within the context of LTE-Advanced. The basic idea behind CoMP is to apply tight coordination between the transmissions at different cell sites, thereby achieving higher system capacity and, especially important, improved cell-edge data rates.

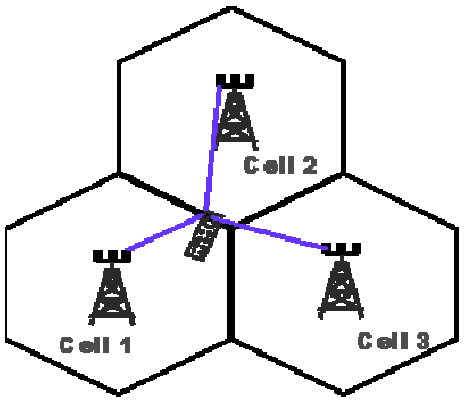
CoMP Advantages

Although LTE Advanced CoMP, Coordinated Multipoint is a complex set of techniques, it brings many advantages to the user as well as the network operator.

- ***Makes better utilisation of network:*** By providing connections to several base stations at once, using CoMP, data can be passed through least loaded base stations for better resource utilisation.
- ***Provides enhanced reception performance:*** Using several cell sites for each connection means that overall reception will be improved and the number of dropped calls should be reduced.
- ***Multiple site reception increases received power:*** The joint reception from multiple base stations or sites using LTE Coordinated Multipoint techniques enables the overall received power at the handset to be increased.
- ***Interference reduction:*** By using specialised combining techniques it is possible to utilise the interference constructively rather than destructively, thereby reducing interference levels.

Coordination schemes can be divided into two categories, used either alone or in combination:

- Dynamic scheduling coordination between multiple cells.
- Joint transmission/reception from multiple cells.



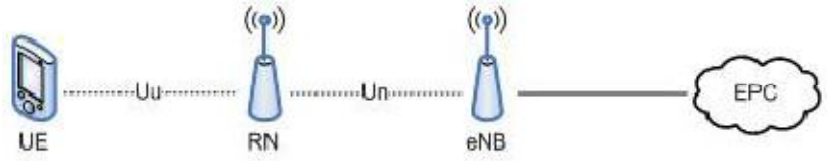
Concept of LTE Advanced CoMP - Coordinated Multipoint

In the former case, CoMP can to some extent be seen as an extension of the inter-cell interference coordination part present already in LTE Rel-8. In LTE-Advanced, the coordination can be in terms of the scheduling at the different cell sites, thereby achieving an even more dynamic and adaptive inter-cell interference coordination. Alternatively, or as a complement, transmissions can be carried out to a mobile terminal jointly from several cell sites, thereby not only reducing the interference but also increasing the received power. The transmission from the cell sites can also take the instantaneous channel conditions into account, thereby achieving multi-cell beam-forming or precoding gains. The channel-estimate required for demodulation of the downlink transmission at the terminal can basically be obtained using either cell-specific or UE-specific reference signals. To determine the CoMP processing to apply on the transmitter side, channel knowledge is needed by the network. This can be accomplished by generalizing the single-cell channel-status reports in LTE to multi-cell reports, i.e., the terminal need to report the perceived channel-quality from multiple cells. Estimating the channel quality can be done by exploiting the cell specific reference signals already transmitted. In the uplink, the receiver processing is implementation specific and no major specification impact is foreseen. Consequently, it can be applied also to Rel-8 terminals. In principle, uplink CoMP is similar to softer handover applied already in WCDMA networks. Maximum-ratio combining and interference-rejection combining are examples of schemes that can be used to combine the uplink transmission received at multiple points.

RELAYING

The very high data rates targeted by LTE-Advanced requires, as already mentioned, a tighter infrastructure. Coordinated multipoint transmission, described above, is one possibility for deploying a denser infrastructure. Another possibility for providing a denser infrastructure from a link-budget perspective is to deploy different types of relaying solutions. In essence, the intention is to reduce the transmitter-to-receiver distance, thereby allowing for higher data rates. Depending on the scheme applied, different types of relaying solutions can be envisioned, although they all share the basic property of relaying the communication between the donor cell and the terminal. The donor cell may, in addition to serving one or several relays, also communicate directly with other terminals. The relay node (RN) is wirelessly connected to a

donor cell of a donor eNB via the Un interface, and UEs connect to the RN via the Uu interface as shown in the below figure

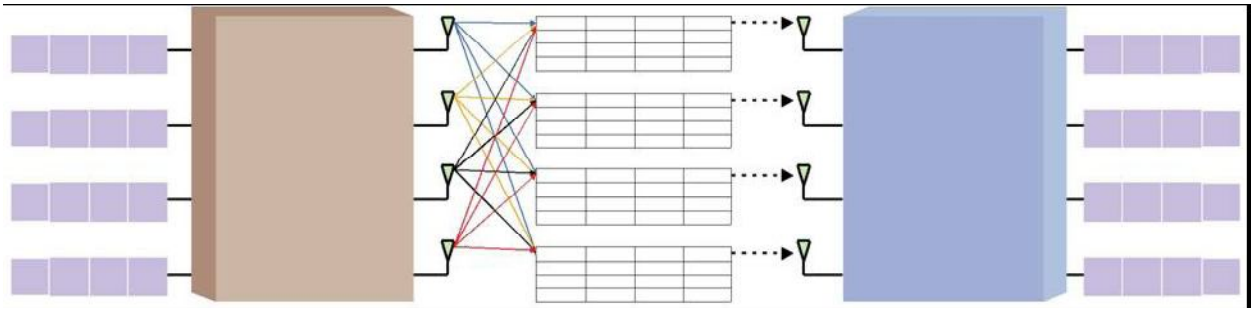


With respect to the relay node's usage of spectrum, its operation can be classified into:

- Inband, in which case the eNB-RN link shares the same carrier frequency with RN-UE links. Rel-8 UEs should be able to connect to the donor cell in this case.
- Outband, in which case the eNB-RN link does not operate in the same carrier frequency as RN-UE links. Rel-8 UEs should be able to connect to the donor cell in this case.

ENHANCED MULTIPLE INPUT MULTIPLE OUTPUT TRANSMISSION (MIMO)

In addition to wider bandwidth, LTE-Advanced is also expected to provide higher data rates and improved system performance by further extending the support for multi-antenna transmission compared to the first release of LTE. For the downlink, up to eight layers can be transmitted using an 8x8 antenna configuration, allowing for a peak spectral efficiency exceeding the requirement of 30 bit/s/Hz and implying a possibility for data rates beyond 1 Gbit/s in a 40 MHz bandwidth and even higher data rates with wider bandwidth. This calls for the introduction of additional reference signals not only for channel estimation but also for measurements such as channel quality to enable adaptive multi-antenna transmission. Backwards compatibility needs to be considered and both additional cell-specific as well as additional UE-specific reference signals are possible candidates.



Furthermore, LTE-Advanced will include spatial multiplexing of up to four layers also for the uplink. With four-layer transmission in the uplink, a peak uplink spectral efficiency exceeding 15 bit/s/Hz can be achieved. Many of the techniques employed for downlink spatial multiplexing already in LTE Rel-8 such as codebook based and non-codebook-based channel-dependent precoding can be considered in order to not only enhance peak rates but also cell-edge data rates.

Enhanced support for heterogeneous network deployments

Densification of radio access networks can help in meeting future traffic and data rate demand. This includes complementing a macro-cell layer with additional low-power pico-cells that can extend traffic and data rate capabilities as per requirement.

Such heterogeneous network (HetNet) deployments are possible in current mobile communication networks, including the first release of LTE. However, LTE Release 10 has features that can further mitigate interference among the cell layers, thereby increasing the scope for HetNet deployments.

Spectrum convergence

A key benefit of all LTE releases is that they provide convergence in terms of radio access for paired and unpaired spectrum, allowing for more efficient spectrum utilisation.There are two duplex alternatives for mobile communication – FDD for paired spectrum and TDD for unpaired spectrum. These duplex schemes have been supported by different 3GPP radio access technologies so far – GSM and WCDMA/HSPA for FDD and TD-SCDMA for TDD. Although FDD has historically been the dominant duplex scheme for mobile communication, interest in TDD is growing. One of the reasons for this is the availability of unpaired spectrum, the efficient use of which requires a highly capable and globally accepted TDD technology.

By supporting both FDD and TDD through the same radio access technology, LTE provides convergence of radio access for paired and unpaired spectrum into a single globally accepted technology. This is especially beneficial for TDD and utilisation of unpaired spectrum, which have so far suffered from limited terminal availability and market momentum.

Conclusion

LTE networks are now in commercial operation alongside HSPA networks. The evolution of LTE provides bandwidth extension and spectrum aggregation, extended multi-antenna transmission, relaying capability and enhanced support for HetNet deployments.

Therefore, LTE-A is a 4G technology that is positioned to meet the ever-growing requirements of not only today’s mobile broadband networks, but also those of the future.