Analysis of Enabling Techniques for LTE- Advanced and Beyond

Manish Sharma and Prakhar Mishra

***Abstract*—To meet the rapidly growing IP data traffic cost-effectively and to improve cell-edge performance, 3GPP is working on the evolution of Release 8 LTE called LTE-Advanced. LTEAdvanced is introduced in Release 10 of 3GPP, and details of some of its features would be specified in Release 11 and beyond. LTE-Advanced is designed to meet or exceed the requirements of IMT-Advanced such as the support for the data rate of 1 Gbps and bandwidths up to 100 MHz. LTE-Advanced system is backward compatible with LTE [1] This paper provides a technical overview of LTE-Advanced, describing the features such as carrier aggregation, enhanced advanced antenna techniques for the DL and the UL, relays, and coordinated multipoint (CoMP) transmission and reception. Release 9 (R9) features such as location services (LCS) and eMBMS are also discussed. In summary, this paper provides a technical overview of R10 and beyond. Some of the key features of LTEAdvanced will be Worldwide functionality & roaming, Compatibility of services, Interworking with other radio access systems and Enhanced peak data rates to support advanced services and applications (100 Mbit/s for high and 1 Gbit/s for low mobility). The IMT-Advanced systems will support low to high mobility applications and wide range of data rates, in accordance with service demands in multiuser environment. This paper provides a brief insight in to the LTE-Advanced standards and its key requirements which will be a pathway to next generation of wireless communication or 4G [2].**

***Index Terms*—LTE, IMT-advanced, LTE-advanced, 4G, 3GPP**

I. INTRODUCTION

In order to fulfill the rather challenging targets for LTE Advanced, several key technology components are being investigated currently in 3GPP. The technology components considered for LTE-Advanced include extended spectrum flexibility to support up to 100MHz bandwidth, enhanced multi-antenna solutions with up to eight layer transmission in the downlink and up to four layer transmission in the uplink, coordinated multi-point transmission/reception, andthe use of advanced relaying [1].

II. LTE-ADVANCED - REQUIREMENT

With the first release of LTE, release-8, as background, the evolution of LTE towards IMT-Advanced can be discussed. IMT-Advanced is the term used by ITU for radio-access technologies beyond IMT-2000 and an invitation to submit candidate technologies for IMT- Advanced has been issued by ITU. Along with the invitation, ITU has also defined a set of requirements to be fulfilled by any IMT-Advanced candidate technology. Some of the key requirements are summarized in Table III with the full set of requirements and associated assumptions listed in. Anticipating the invitation from ITU, 3GPP already in March 2008 initiated a study item on LTE-Advanced, with the task of defining requirements and investigating the technology components for the evolution of LTE to fulfil all the requirements of IMT-Advanced as defined by ITU. Although the term LTE-Advanced is used frequently, it is important to stress that this is not a new radio access Scheme but rather the evolution of LTE to further improve the performance. LTE-Advanced is thus a name for a future release of the LTE standard, currently predicted to release-10. Being an evolution of LTE, LTE- Advanced should be backwards compatible in the sense that it should be possible to deploy LTE-Advanced in spectrum already occupied by the first release of LTE with no impact on existing LTE terminals. A direct consequence of this requirement is that, for an LTE terminal, an LTE-Advanced-capable network should appear as an LTE network. Such spectrum compatibility is of critical importance for a smooth, low-cost transition to LTE Advanced capabilities within the network and is similar to the evolution of WCDMA to HSPA.

In addition to the fundamental requirement of being an Evolution of LTE and thus backwards compatible, the 3GPP has defined a set of targets to be fulfilled by LTE Advanced. These requirements are a superset of the IMT Advanced requirements, i.e., LTE-Advanced will fulfil, and sometimes even surpass, the IMT-Advanced requirements. For example, the spectrum efficiency requirements are significantly higher for LTE-Advanced than for IMT Advanced as illustrated in Table III. In fact, many of the IMT-Advanced requirements are close to be fulfilled already with the first release of LTE. As can be seen in Table I, requirements are set not only on the peak spectral efficiency, but also on the average and celledge spectral efficiency. The latter are, in most practical deployments, more important than the peak rates and [6] therefore explicitly states that ―special focus should be put on improving the cell edge performance to provide a reasonably homogenous user experience across the cell. LTE-Advanced will also provide further enhanced spectrum flexibility beyond the capabilities of LTE Rel-8 and be capable of exploiting spectrum allocations up to 100 MHz.To fulfill these requirements, 3GPP is currently studying several key components, the main one which are described in more

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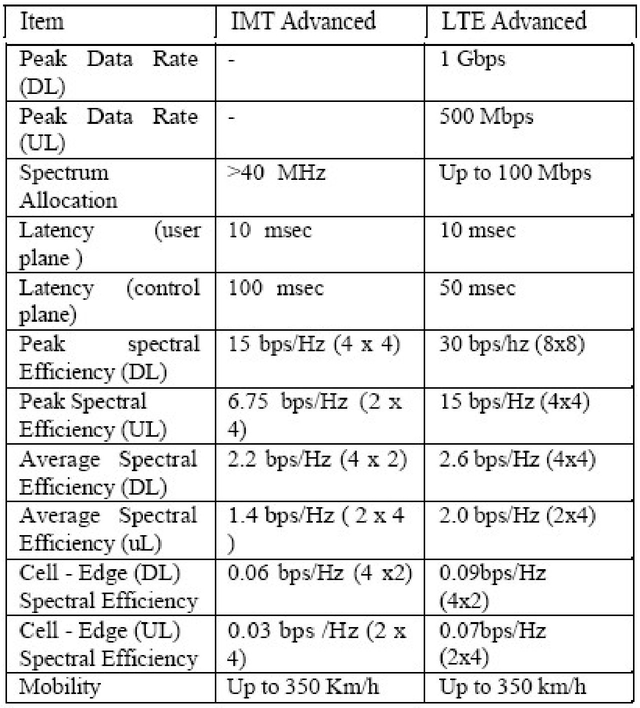
detail in the given Table I



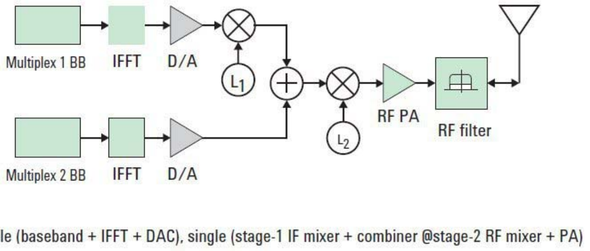
Item	IMT Advanced	LTE Advanced
Peak Data Rate (DL)	-	1 Gbps
Peak Data Rate (UL)	-	500 Mbps
Spectrum Allocation	>40 MHz	Up to 100 Mbps
Latency (user plane)	10 msec	10 msec
Latency (control plane)	100 msec	50 msec
Peak spectral Efficiency (DL)	15 bps/Hz (4 x 4)	30 bps/hz (8x8)
Peak Spectral Efficiency (UL)	6.75 bps/Hz (2 x 4)	15 bps/Hz (4x4)
Average Spectral Efficiency (DL)	2.2 bps/Hz (4 x 2)	2.6 bps/Hz (4x4)
Average Spectral Efficiency (uL)	1.4 bps/Hz (2 x 4)	2.0 bps/Hz (2x4)
Cell - Edge (DL) Spectral Efficiency	0.06 bps/Hz (4 x2)	0.09bps/Hz (4x2)
Cell - Edge (UL) Spectral Efficiency	0.03 bps /Hz (2 x 4)	0.07bps/Hz (2x4)
Mobility	Up to 350 Km/h	Up to 350 km/h

A. *Carrier Aggregation (CA)*

LTE-Advanced offers considerably high data rate than even the initial releases of LTE while the spectrum usage efficiency has been improved this alone cannot provide the required data rates that are being headlined for 4G LTE Advanced. To achieve this very high data rate it is necessary to increase the transmission bandwidth over that used by the first release of LTE. The method being proposed is termed carrier aggregation or sometimes channels aggregation. Using LTE advanced carrier aggregation it is possible to utilize several carriers and in this way increase the overall transmission bandwidth. LTEAdvanced can exploit spectrum allocations up to 100 MHz by aggregating multiple component carriers to provide the\ necessary bandwidth. To an LTE each component carrier will appear as an LTE carrier, while an LTE-Advanced terminal can exploit the total aggregated bandwidth (see Fig. 2) [4]. But access to large amounts of contiguous spectrum, in the order of 100 MHz, may not always be possible. From a baseband perspective, there is no difference if the component carriers are contiguous in frequency or not. This could allow for aggregating noncontiguous spectrum fragments by allocating different fragments to different component carriers. For an LTEAdvanced terminal capable of receiving multiple component carriers, it can be sufficient if the synchronization signals are available on one of the component carriers only. Hence, an operator can, by enabling/disabling these signals, control which part of the spectrum that should be accessible to LTE terminals.

Aggregation of the component carriers can be done at different layers in the protocol stack, In LTE Advanced, the data streams from the different component carriers are aggregated above the MAC layer as shown in Fig. 3. This implies that hybrid-ARQ retransmissions are performed independently per component carrier. In principle, transmission parameters such as modulation scheme and code rate could also be selected per component carrier. Such independent operations per component carrier are especially useful in case of aggregating component carriers from different frequency bands with different radio-channel quality [3].Various options exist for implementing carrier aggregation in the transmitter architecture depending primarily upon the frequency separation, which heavily influences where the component carriers are combined:

- at digital baseband
- in analog waveforms before the RF mixer
- after the RF mixer but before the power amplifier (PA)
- after the PA[4]



Multiple (baseband + IFFT + DAC), single (stage-1 IF mixer + combiner @stage-2 RF mixer + PA)

Fig. 1. Transmitter architecture for carrier aggregation scenarios[4]

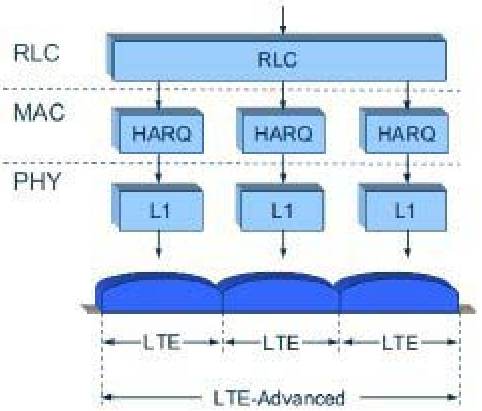


Fig. 2. Example of carrier aggregation in LTE protocol stack [3]

B. *Enhanced Multi-Antenna Transmission*

Multi-antenna technologies, including beam-forming and spatial multiplexing, are key technology components already of LTE and can safely be expected to continue to play an even more important role as part of LTE-Advanced [5]. For the downlink, up to eight layers can be transmitted using an 8 x 8 antenna configuration, allowing for a peak spectral efficiency exceeding the requirement of 30 bps/Hz and implying a possibility for data rates beyond 1 Gbps in a 40 MHz bandwidth and even higher data rates with wider bandwidth [3].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 bps/Hz can be achieved [3].

C. *Coordinated Multiple Point Transmission and Reception (CoMP)*

LTE CoMP or co- ordinate multi point is a technology that is being developed for LTE advanced. LTE co-ordinate multi point is method of transmitting to or receiving from a user, equipment using several base stations this has number of advantages in term of data throughput essentially an LTE CoMP turns the inter cell interferences in to use full signal especially at the cell borders where performance may be degraded. One of the key parameter for LTE as a whole and in particular 4G LTE- Advanced is high data rates that are achievable these data rates are relatively easy to maintain closed to the base station but as distance increase they become more difficult to maintain, Obviously the cell edge are most challenging not only is the signal power in strength because of the distance from the base station (eNB)but also interference levels from neighboring eNBs are likely to be higher or the UE will be closer to them. 4G LTE CoMP, coordinated Multipoint require also coordination between a number of geographically separated eNBs. They dynamically coordinate to provide joint scheduling and transmission as well as providing joint processing of the received signals. In this way UE at the egde of a cell is able to be served by two or more eNBs to improve signal reception/transmission and increase throughput particular under cell edge condition.

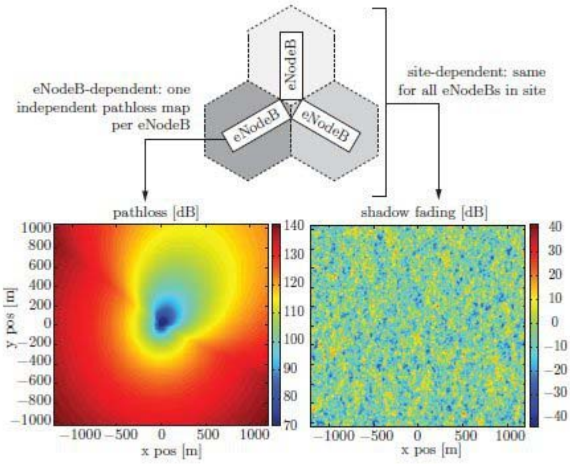


Fig. 3. eNodeB- and site-dependence of the large-scale path loss and shadow fading. Left: Large-scale pathloss and antenna gain map [dB] corresponding to the lower-leftmost eNodeB. Right: space-correlated shadow fading corresponding to the site [dB]. [14]

In essence 4G LTE CoMP, coordinated multipoint allows two nodes of operation:

Joint Simultaneous transmission of user data from multiple eNBs to a single UE

Dynamic cell selection with data transmission from one eNB

To achieve either of these modes highly detailed feedback is required on the channel properties in the fast manner so that the charges can be made. The other requirement is for very close coordination between eNBs to facilitate the combination of data or fast switching of the cell.[3]

Pathloss and fading maps

The large-scale pathloss and the shadow fading are modeled as position-dependent maps. The large-scale pathloss is calculated according to well-known models [20] and combined with the antenna gain pattern of the corresponding eNodeB.

D. *Relaying*

Relaying is one of the features being proposed for the 4G LTE- Advanced system. The aim of LTE relaying is to enhance both coverage and capacity. The idea of relays is not new, but LTE relays and LTE relaying is being considered to ensure that the optimum performance is achieved to enable the expectation of the user to be met while still keeping OPEX within budgeted bounds. One of the main drivers for the uses of LTE is the high data rate that can be achieved. however all technologies suffers from reduced data rates at the cell edge where signal level are lower and interference level are typical higher. The use of technologies such as MIMO, OFDM and advanced error correction techniques improve throughput under many condition, but do not fully mitigate the problem experienced at the cell edge. A cell edge performance is becoming more critical, with some of the technologies being pushed towards there limit. It is necessary to look at solutions that will enhance the performance at the cell edge for the comparatively low cost. One solution that is being investigated and proposed is that of use of LTE relays. LTE relaying is different to the use of repeaters which rebroadcast the signal. A relay will actually receive, demodulates and decode the data, apply any error correction etc to it and then retransmitting a new signal. In this way the signal quality is enhanced with an LTE relay, rather than suffering degradation from a reduced signal to noise ratio when using a repeaters. Relay transmission can be seen as kind of collaborator communication, in which a relays stations(RS) helps to forward user information from neighbouring user equipment (UE)/mobile station to a local eNode-B(eNB)/base station(BS). In doing this RS can be effectively extend the signal and service coverage of an eNB and enhance the throughput performance of a wireless communication system. The performance of the relay transmission is greatly affected by the collaborative strategy, which includes the selection of relay types and relay partners (i.e., to decide when, how, and with whom to collaborate).

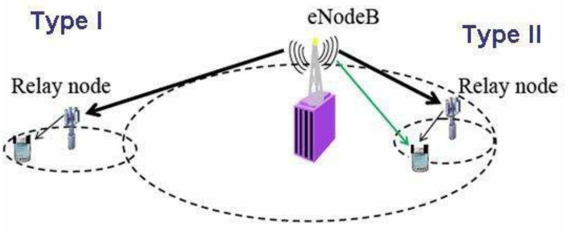


Fig. 5. Relay node deployment[16]

There are two different terminology used for relay‘s first is type - I and type- II and other is non transparency and transparency. Specifically a type -I (or non transparency) RS can help a remote UE unit which is located far away from an eNB(or BS)to access the eNB. So a type I RS needs to transmit the common references signal and control information for eNB and its main objective is to extend signal and service coverage. Type -I RSs mainly perform IP packet forwarding in the network layer (layer 3) and can make some contribution to the overall system capacity by enabling communication services and data transmission for remote UE units. On the other hand type -II (or transparency) RS can help a local UE units which is located within the coverage of an eNB (or BS) has a direct communication link with the eNB to improve its service quality and link capacity. So a type -II RS does not transmit the common reference signal or the control information and its main objective is to increase the overall system capacity by achieving multipath diversity and transmission gains for the local UE unit. Relay start becoming interesting because according to the the 3gpp LTE advanced and IEEE 802.16J an RS can act as BS for legacy UE units and should have its own physical cell identifier. It should be able to transmit its own synchronization Channels, reference symbols and downlink control information so an RS shall have full function of and eNB/BS (except for traffic back hauling) including the capabilities to knowing the radio bearer of received data packets and performing traffic aggregation to reduce signalling overhead. There should be no difference between the cell controlled by an RS and that control by a normal eNB.

III. OTHER APPEALING TOPICS

The use of contiguous spectrum reduces the waste of resources that occurs due to guard bands. On the contrary, noncontiguous carrier components will exhibit additional frequency diversity. Therefore, a deep study must be performed to assess which is the preferred option. However, the usage of non-contiguous carrier aggregation poses additional difficulties in the frequency planning. Indeed, in this case the coverage of CC will not coincide due to the large path loss differences. One solution could be to increase the power allocated of higher bands or to manage diverse coverage areas using CC HO procedures that should be further investigated. This power control is also needed when the used bandwidth is very wide, although in this last case the power difference is expected to be lower.

Another topic is related to the CC activation. Although LTEAdvanced UEs will support 100 MHz bandwidth BW however UE at any given time may not transmit/receive in the whole spectrum. Indeed, the component carrier activation/deactivation is needed to enable the UE to save battery power. could be to adjust the number of component carrier when the UE is moving in an area, most of all, in case of inter-band carrier aggregation with different coverage areas for each CC.

On the other hand, due to hardware limitations in the point of terminal complexity, no more than 8192 FFT (213) will be implemented by vendors [IEEE16mCA]. Considering LTE sub-carrier spacing this results in more than 120MHz whereas for IEEE 802.16m with component carriers of 10MHz this maximum bandwidth is reduced down to 80MHz. All other bands can be received by removing the additional band after receiving the signal of full bandwidth, although this method has problems of loss of SINR for large bandwidth. Another approach is to use multiple RF transceivers. In this case, though the guard bands of each component carrier cannot be utilized, the above-mentioned loss is minimized. Moreover, it requires additional complexity but the combination of oversampling for FFT and rate-conversion filter can be also considered.

Another issue is the existence of such a large continuous bandwidth. The result of WRC 2007 may not allow such wide carrier bandwidth for new radio systems. Given the current spectrum distribution, the only valid alternative to process the entire frequency band from about 400 MHz to about 6 GHz seems to be the use of parallel receivers for each different band.

This may lead to another hardware limitation, due to antennas, at least on the mobile side. Indeed, the antenna should cover the whole set of bands decided by WRC07, especially the lower band (698-960 MHz) (not to mention 400 MHz). If we assume its size should remain compatible with that of a smartphone, then its electrical dimension (dimension over wavelength) in the 698-960 MHz band will be about 0.25, and its relative bandwidth (bandwidth over central frequency) should be about 0.3. For these values, electromagnetic theory predicts a maximum possible radiation efficiency (ratio of power actually radiated to the power put into the antenna terminals) of about 0.25, which is quite poor. Indeed, radiation efficiency decreases as the antenna length decreases and for larger relative bandwidths. Therefore, alternative solutions should be found, such as frequency reconfigurable antennas.

Still, it may remain difficult to guarantee a large enough bandwidth at the lowest part of the band (698 MHz). Moreover, LTE standard imposes two antennas at the mobile side. These two antennas should not be coupled, in order to avoid power loss. In addition, for MIMO algorithms to be efficient, these antennas should be decor related.

IV. CONCLUSION

This paper has provided a comprehensive overview of some technology components currently considered for LTE Advanced requirements while maintaining backwards compatibility with earlier releases of LTE (3GPP release 8). The technology components being considered for LTE - Advanced include carrier aggregation, both for contiguous and non contiguous spectrum to support bandwidths up to 100 MHz as well as enhanced multiple antenna transmission with up to eight layers in the downlink and up to four layers in uplink. In addition to relaying and repeater solution to enhance coverage and cell edge data rates, an evolution of the intercell interference coordination in the form of coordinated multipoint transmission/reception is yet another technology to enhance performance.

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