LTE-Advanced: The Roadmap To 4G Mobile Wireless Networks

Amit Kumar[1] Dr. Yunfei Liu[2]

Amit Wason[3]

GJCST Classification C.1.3, C.2.1

***Abstract*- This paper addresses the performance targets and the technology components being studied by 3GPP for LTE-Advanced. The high level targets of LTE-Advanced are to meet or exceed the IMT-Advanced requirements set by ITU-R. 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, and the use of advanced relaying.**

Keywords-LTE, 3GPP, 4G, IMT-Advanced, LTE-Advanced

I. INTRODUCTION

Wireless data usage is increasing at a phenomenal rate and driving the need for continued innovations in wireless data technologies to provide more capacity and higher quality of service. The wireless ecosystem – infrastructure suppliers, service providers, device manufacturers, operating system providers and applications developers – are simultaneously working together and competing against one another to generate valuable and unparalleled products and services for consumers [8].In October 2009, 3rd Generation Partnership Project (3GPP) submitted LTE-Advanced to the ITU as a proposed candidate IMT-Advanced technology for which specifications could become available in 2011 through Release-10 [8]. The aim of "LTE-Advanced" is to further enhance LTE radio access in terms of system performance and capabilities compared to current cellular systems, including the first release of LTE, with a specific goal to ensure that LTE fulfills and even surpass the requirements of "IMT-Advanced" as defined by the International Telecommunication Union (ITU-R) [2, 5].

The IMT-Advanced system will provide access to wide range of telecommunication services, including advanced mobile services, supported by mobile and fixed networks, which are increasingly packet based. 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. 100 Mbps for high and 1 Gbps for low mobility conditions are establishes as the research objectives [3]. Majority of the world's operators and vendors are already committed to LTE deployments and developments, making LTE the market leader in the upcoming evolution to 4G wireless communication systems (see Fig. 1) [1].

II. LTE–ADVANCED REQUIREMENTS

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 in March, 2008.

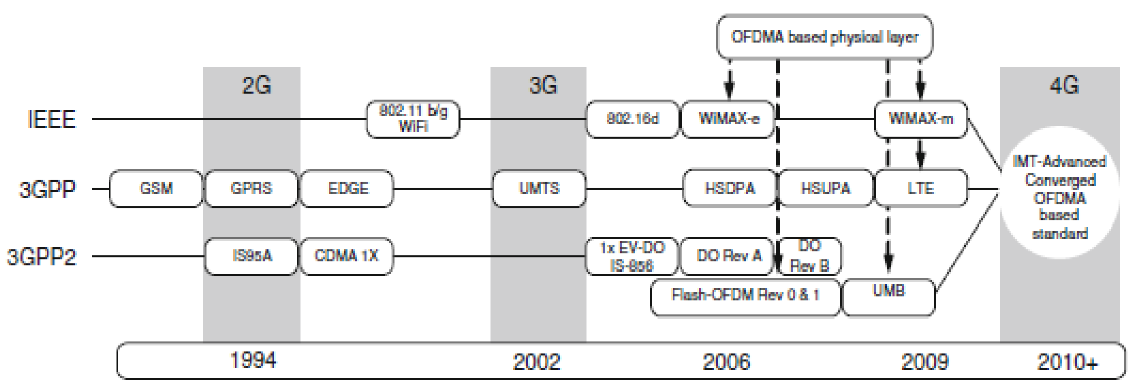

Fig. 1: Evolutionary path of cellular technology [9].

Simultaneously, 3GPP initiated a study item called LTE–Advanced, with the task of defining requirements and investigating the technology components of the evolution of LTE, to meet all the requirements of IMT-Advanced as defined by ITU. Being an evolution of LTE, LTE-Advanced should be backwards compatible in the sense that it should

About [1]-College Of Information Science And Technology, Nanjing Forestry University, Nanjing, 210037 – China
About -[2]Ganpati Institute Of Technology And Management, Jagadhari, Yamunanagar – India
(E-Mail: Amitmehta66@Gmail.Com)

be possible to deploy LTE-Advanced in spectrum already existing LTE terminals. 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 [2].

Table 1 summarizes the list of requirements established by ITU-R and 3GPP allowing a direct comparison among occupied by the first release of LTE with no impact on 4G and LTE-Advanced. According to this table, it can be concluded that 3GPP LTE-Advanced requirements are a superset of the IMT-Advanced requirements i.e. LTE-Advanced is being designed to be a strong candidate for next 4G, since it fulfils or even exceeds all IMT-Advanced requirements [2, 6].

Item	IMT-Advanced	LTE-Advanced
Peak Data Rate (DL)		1 Gbps
Peak Data Rate (UL)		500 Mbps
Spectrum Allocation	>40 MHz	Up to 100 MHz
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 (8 X 8)
Peak Spectral Efficiency (UL)	6.75 bps/Hz (2 X 4)	15 bps/Hz (4 X 4)
Average Spectral Efficiency (DL)	2.2 bps/Hz (4 X 2)	2.6 bps/Hz (4 X 2)
Average Spectral Efficiency (UL)	1.4 bps/Hz (2 X 4)	2.0 bps/Hz (2 X 4)
Cell-Edge Spectral Efficiency (DL)	0.06 bps/Hz (4 X 2)	0.09 bps/Hz (4 X 2)
Cell-Edge Spectral Efficiency (UL)	0.03 bps/Hz (2 X 4)	0.07 bps/Hz (2 X 4)
Mobility	Up to 350 km/h	Up to 350 km/h

TABLE 1: IMT-ADVANCED REQUIREMENTS RELATED TO LTE-ADVANCED REQUIREMENTS [6, 7].

III. LTE – ADVANCED TECHNOLOGY

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, and the use of advanced relaying [2].

A. *Carrier Aggregation (CA)*

In LTE-Advanced, Carrier Aggregation (CA) has been identified as a key technology to meet IMT-Advanced requirements. The need for CA in LTE-Advanced arises from the requirement to support bandwidths larger than those currently supported in LTE while at the same time ensuring backward compatibility with LTE. LTE-Advanced can exploit spectrum allocations up to 100 MHz by aggregating multiple component carriers to provide the necessary bandwidth. To an LTE Release-8 terminal, each component carrier will appear as an LTE carrier, while an LTE-Advanced terminal can exploit the total aggregated bandwidth (see Fig. 2) [8]. 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 non-contiguous spectrum fragments by allocating different fragments to different component carriers. For an LTE-Advanced 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. 2. 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 [2].

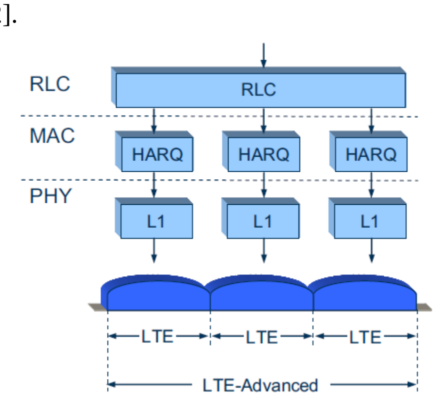

Fig. 2: Example of Carrier Aggregation in LTE protocol stack [2]

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 [4]. 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 [2].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 [2].

C. Coordinated Multiple Point Transmission and Reception (Comp)

Coordinated Multi-Point transmission/reception (Comp) is considered by 3GPP as a tool to improve coverage, cell-edge throughput, and/or system efficiency. Comp implies that when a UE is in the cell-edge region, it may be able to receive signals from multiple cell sites and the UE's transmission may be received at multiple cell sites regardless of the system load. Given that, if the signalling transmitted from the multiple cell sites is coordinated, the DL performance can be increased significantly.

This coordination can be simple as in the techniques that focus on interference avoidance or more complex as in the case where the same data is transmitted from multiple cell sites. For the UL, since the signal can be received by multiple cell sites, if the scheduling is coordinated from the different cell sites, the system can take advantage of this multiple reception to significantly improve the link performance (see Fig. 3) [4].

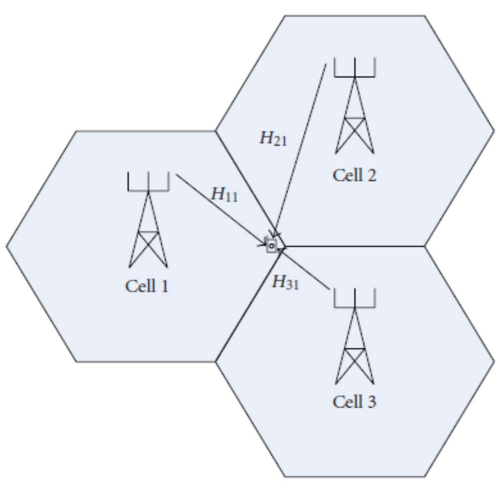

Fig. 3: Coordinated multipoint transmission in the downlink.

D. Relaying

To reduce the transmitter-to-receiver distance for achieving higher data rates, a denser infrastructure is required. The concept of Relay Node (RN) has been introduced to enable traffic/signalling forwarding between eNB and UE to improve the coverage, group mobility, cell edge coverage, and to extend coverage to heavily shadowed areas in the cell or areas beyond the cell range. It provides throughput enhancement especially for the cell edge users and offers the potential to lower the CAPEX and OPEX by keeping the cell sizes relatively large (see Fig. 4) [2, 8].

The simplest relaying is the "Layer 1" relaying, that is, the usage of repeaters. Repeaters receive the signal, amplify it and retransmit the information thus covering black holes inside cells. Terminals can make use of the repeated and direct signals. However, in order to combine constructively both signals there should be a small delay, less than the cyclic prefix, in their reception [6].

The "Layer 2" Relay performs the decode-and-forward operation and has more freedom to achieve performance optimization. Data packets are extracted from RF signals, processed and regenerated and then delivered to the next hop. This kind of relay can eliminate propagating the interference and noise to the next hop, so it can reinforce signal quality and achieve much better link performance [8].

Finally, "Layer 3" relaying is conceived to use the LTE radio access in the backhaul wireless connecting one eNB with another eNB that behaves as a central hub. This anchor eNB routes the packets between the wired and wireless backhaul, acting like an IP router [6]. "Layer 3" relaying solution let the relay perform the same functions as normally handled by the base station, e.g. hybrid-ARQ retransmissions, scheduling, and mobility functions. In essence, the relay is, from a functional perspective, a base station and therefore there is no need to define new functions for mobility [2].

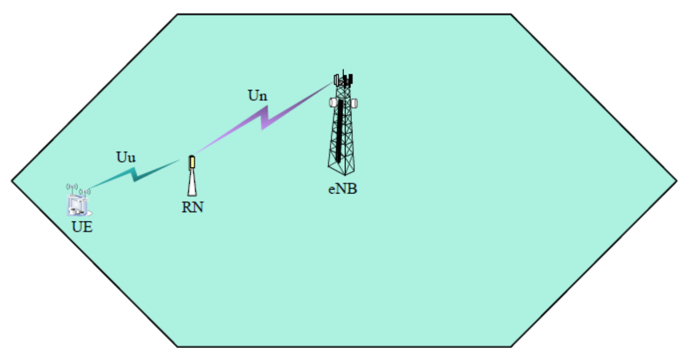

Fig. 4: Relay Node Deployment [8]

IV. Conclusion

This paper has provided a comprehensive overview of some technology components currently considered for LTE-Advanced, to further enhance the performance beyond the IMT-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 100MHz as well as enhanced multiple antenna transmission with up to eight layers in the downlink and up to four layers in the uplink. In addition to relaying and repeater solutions to enhance coverage and cell edge data rates, an evolution of the inter-cell interference coordination in the form of coordinated multipoint transmission/reception is yet another technology to enhance performance.

V. References

1) Lee, J.; Han, J.; Zhang, J. , “MIMO Technologies in 3GPP LTE and LTE-Advanced”. EURASIP Journal on Wireless Communications and Networking, Hindawi Publishing Corporation Vol. 2009.
2) Parkvall, S.; Astely, D., “The Evolution of LTE towards IMT-Advanced”. Journal of communications, Vol. 4, No. 3, APRIL 2009.
3) Kumar, S.; Marchetti, N., “IMT-Advanced: Technological Requirements and Solution Components”. In the Proceedings of IEEE CogART’09, 2009.
4) Parkvall, S.; Dahlman, E.; Furuskär, A.; Ylva Jading, Olsson, M.; Wänstedt, S.; Zangi, K., LTE-Advanced – Evolving LTE towards IMT-Advanced. [Online]. Available: www.ericsson.com/technology/research.../VTC08F_jading.pdf
5) Astély, D.; Dahlman, E.; Furuskär, A.; Jading, Y.; Lindström, M.; Parkvall, S., “LTE: The Evolution of Mobile Broadband”, Ericsson Research, IEEE Communications Magazine, 2009.
6) Mart´ın-Sacrist ´an, D.; Monserrat, J. F.; Cabrejas-Pe˜nuelas, J.; Calabuig, D.; Garrigas, S.; Cardona, N., “On the Way towards Fourth-Generation Mobile: 3GPP LTE and LTE-Advanced”. EURASIP Journal on Wireless Communications and Networking. Hindawi Publishing Corporation Vol. 2009.
7) 3gamericas (2009). HSPA to LTE-Advanced. [Online]. Available: www.3gamericas.org/.../3G_Americas_RysavyResearch_HSPA-LTE_Advanced_Sept2009.pdf
8) [3gamericas (2010). 3GPP Mobile innovation path to 4G: Release-9, Release-10 and Beyond: HSPA+, SAE/LTE and LTE-Advanced. [Online]. Available: http://www.3gamericas.org/index.cfm?fuseaction=page&sectionid=334
9) Ergen, M. ,“Mobile Broadband: Including WiMAX and LTE”. Springer, USA, 2009.