

Performance Analysis of HSPA and LTE Advanced With Focusing On Downlink

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Abstract: This paper describes the main activities involved in defining 4G technologies within the International Telecommunications Union (ITU) under the IMT-Advanced banner, the work of the Third-Generation Partnership Project (3GPP) towards LTE-Advanced. In Rel 7, 3GPP standardized HSPA Evolution (HSPA+) which was specified to deliver maximum user data rates up to 42 Mbps by using dual Carrier Aggregation and 64 QAM in the Downlink. However, there is no clear dividing line between the technology generations and this confusion is exacerbated by the terms 3.5G or 3.9G which are often used to describe evolutions of 3G technologies such as HSPA+, LTE (3GPP Release 8) or Wi-MAX Release 1.5. This paper focus on new technologies which have been standardized by 3GPP in Rel 8/9/10. Although Long Term Evolution (LTE) network performance was studied by other researchers, the aim of this paper is to analysis the performance of LTE advanced and HSPA in different spectrum bands to meet the International Mobile Telecommunications Advanced (IMT-Advanced) requirements.

Keywords: HSPA, LTE, IMT, ITU, 3GPP and QAM.

I. INTRODUCTION

Mobile broadband is expected to contribute substantially to a continued spreading of Internet access; either as complement to, or substitute for, wire-line broadband access. Similar to the formidable success of mobile telephony, it is envisaged that the 3rd Generation Partnership Project (3GPP) family of standards will contribute substantially to a high penetration of mobile broadband globally. While GSM/GPRS/EDGE has been the most successful system for mobile telephony and rudimentary data access, and LTE is an attractive technology in the longer term, High Speed Packet Access (HSPA) – including High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA; also known as Enhanced Uplink, or EUL) – will in many markets be the primary mobile broadband technology for the next decade. After its launch in 2005/2006, HSPA is today (2009) a global success with commercial deployments in more than 100 countries [1, 2, 3]. The number of HSPA subscriptions exceeds 80 millions and show an accelerated

growth, which will lead to greater economies of scale and thereby increased affordability of mobile broadband services for different markets, customer segments, and applications.

It is precisely that this increasing market demand and its enormous economic benefits, together with the new challenges that come with the requirements in higher spectralefficiency and services aggregation, raised the need to allocate new frequency channels to mobile communications systems. That is why the ITU-R WP 8F started in October 2005 the definition of the future Fourth Generation Mobile (4G), also known as International Mobile Telecommunications (IMT) Advanced, following the same model of global standardization used with the Third Generation, IMT-2000. The objective of this initiative is to specify a set of requirements in terms of transmission capacity and quality of service, in such a way that if a certain technology fulfills all these requirements it is included by the ITU in the IMT-Advanced set of standards. This inclusion firstly endorses technologies and motivates operators to invest in them, but furthermore it allows these standards to make use of the frequency bands.

The race towards IMT-Advanced was officially started in March 2008, when a Circular Letter was distributed asking for the submission of new technology proposals [4]. Previous to this official call, the 3rd Generation Partnership Project (3GPP) established the Long Term Evolution (LTE) standardization activity as an ongoing task to build up a framework for the evolution of the 3GPP radio technologies, concretely UMTS, towards 4G. The 3GPP divided this work into two phases: the former concerns the completion of the first LTE standard (Release 8), whereas the latter intends to adapt LTE to the requirements of 4G through the specification of a new technology called LTE-Advanced (Release 9 and 10). Following this plan, in December 2008 3GPP approved the specifications of LTE Release 8 which encompasses the Evolved UTRAN (E-UTRAN) and the Evolved Packet Core (EPC). Otherwise, the LTE Advanced Study Item was launched in May 2008, expecting its

completion in October 2009 according to the ITU-R schedule for the IMT-Advanced process. In the mean time, research community has been called for the performance assessment of the definitive LTE Release 8 standard.

Actually, several papers deal with the performance evaluation of LTE. However, up to date this assessment has been partially done because of one of these two reasons. First, some of these works only focused on the physical layer, leaving out the retransmission processes and error correction [6–10]. System level analysis needs MAC layer performance information and cannot be carried out with only a physical layer characterization. Second, other papers assessing the performance of LTE radio access network assumed ideal channel estimation, which results in an optimistic estimation of LTE capacity [11–13].

This paper describes the main characteristics of LTE Release 8 and evaluates LTE link level performance considering a transmission chain fully compliant with LTE Release 8 and including realistic HARQ and turbo-decoding. Besides the capacity of LTE systems is analyzed in terms of maximum achievable throughput and cell capacity distribution in a conventional scenario. These studies allow having a rough idea on the benefits and capabilities of the new standard. Finally, this paper offers an overview of the current research trends followed by 3GPP in the definition process of LTE Advanced thus foreseeing the main characteristics of next generation mobile.

II. SYSTEM MODEL

A. HSPA Analysis

In this section briefly describe the impact of Multi-Carrier HSPA on radio access network architecture & protocols and the user equipment. Focus is on Dual-Carrier HSDPA, standardized in 3GPP Release 8, but the concept is readily extendable to uplink and beyond two carriers in downlink. If both the network and the user equipment are capable of Dual-Carrier HSDPA operation, the network will be able to configure the user equipment not only with a (primary) serving cell but also with a secondary serving cell originating from the same base station but on an adjacent carrier frequency. From the point of view of the user equipment, only the primary serving cell has a corresponding uplink channel, and non-HSDPA-related information such as the synchronization channel (SCH) and transmit power control (TPC) commands are always mapped to the primary serving cell, never to these secondary serving cell as shown in the figure 1. However, from a network point of view, a particular cell can be the primary serving cell for some users and the secondary serving cell for others. Furthermore, legacy single carrier users can be supported in any cell. The user data processing – including channel coding, interleaving, modulation and hybrid ARQ retransmission protocol, as well as the corresponding signaling of related physical layer control information to the user equipment are performed independently for each one of

the two serving cells, meaning that the user can be scheduled independently in the two serving cells.

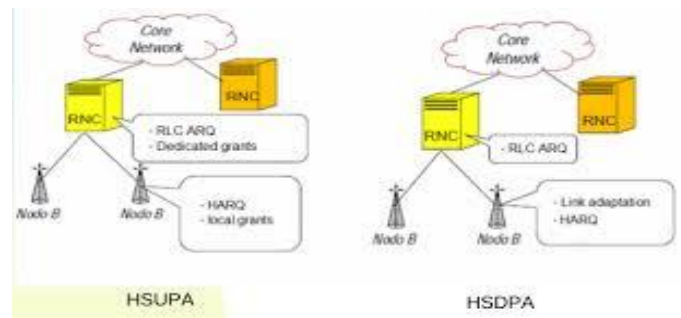


Figure1: HSPA architecture

The introduction of multi-carrier operation opens up the possibility to exploit an increased system bandwidth for individual connections, which increases system capacity and the end-user experience. In particular, assuming N carriers, the N -fold increase of system bandwidth directly translates to an N -fold improvement of the peak data rate of the system. In fact, given that the transmission power is scaled accordingly such that the power spectral density is maintained users served by the multi-carrier system will experience an N -times higher data rate on the physical layer throughout the network. In addition, channel aware scheduling can now operate also in the frequency dimension, and the opportunity to balance the load of the carriers *per sub-frame* (2 ms) is introduced.

B. LTE-Advanced and the Fourth-Generation Mobile

3GPP Long Term Evolution is the name given to the new standard developed by 3GPP to cope with the increasing throughput requirements of the market. LTE is the next step in the evolution of 2G and 3G systems and also in the provisioning of quality levels similar to those of current wired networks. 3GPP RAN working groups started LTE/EPC standardization in December 2004 with a feasibility study for an evolved UTRAN and for the all IP-based EPC. Besides, EPC functional specifications reached major milestones for interworking with 3GPP and CDMA networks. In 2008 3GPP working groups were running to finish all protocol and performance specifications, being these tasks completed in December 2008 hence ending Release 8. The process of defining the future IMT-Advanced family was started with a Circular Letter issued by ITU-R calling for submission of candidate Radio Interface Technologies (RITs) and few candidate sets of Radio Interface Technologies (SRITs) for IMT-Advanced. However, all documents available in that moment concerning IMT-Advanced did not specify any new technical details about the properties of future 4G systems. Instead, they just reference the Recommendation M.1645, in which the objectives of the future development of IMT-Advanced family was barely defined: to reach 100Mb/s for mobile access and up to 1Gb/s for nomadic wireless

access. Unfortunately, it was not until November 2008 when the requirements related to technical performance for IMT-Advanced candidate radio interfaces were described [20]. If you look at the Home eNode B (Femtocell) architecture, the HeNB is connected to its gateway which in turn is connected to MME/S-GW. There is a considerable amount of technology investment in this approach. The HeNB consists of complete protocol stack, the HeNB-GW is an expensive piece of equipment and there are lots of other things including the management software, etc.

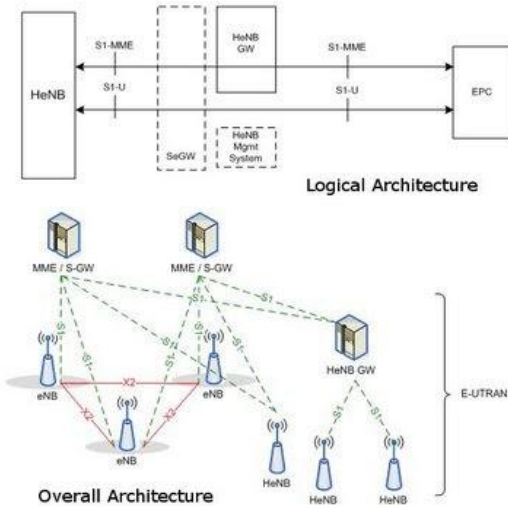


Figure2: LTE architecture

Figure 2.represents a high-level view of LTE architecture. This is a snapshot of the part that most closely interacts with the UE, or mobile device. The entire architecture is much more complex; a complete diagram would show the entire Internet and other aspects of network connectivity supporting handoffs among 3G, 2G, WiMAX, and other standards. This particular device shows the eNodeB, which is another name for the base station, and the interfaces between the eNodeB and UEs. The E-UTRAN is the entire network, which is the “official” standards name for LTE.

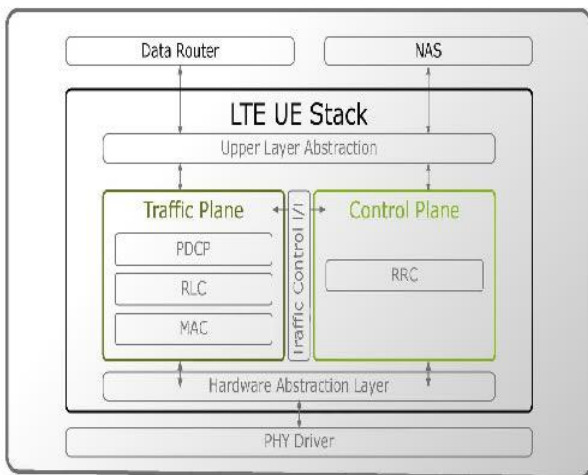


Figure3: LTE protocol stack

The figure 3 represents all the mandatory and optional features stated in the latest version of the 3GPP LTE standard. This grant UE chip manufacturers a complete interoperability with the LTE ecosystem. "With a highly skilled on-site support team, and a standardized design that exactly fits with the customer needs and "chip-friendly" protocol stack that gives them the chance to be the first into the LTE market."

III. SIMULATION RESULTS

In figure 4 the average user throughput is plotted as a function of offered load (average sector throughput). The performance is depicted for different number of carriers for single-carrier HSDPA and Multi-Carrier HSDPA systems, respectively. Up to the points where systems become severely congested (and user throughput approaches 0 Mbps), the Multi-Carrier HSDPA system configurations with N carriers bring the expected N -fold gain in average user throughput as compared to the single carrier HSDPA system with an equal number of carriers.

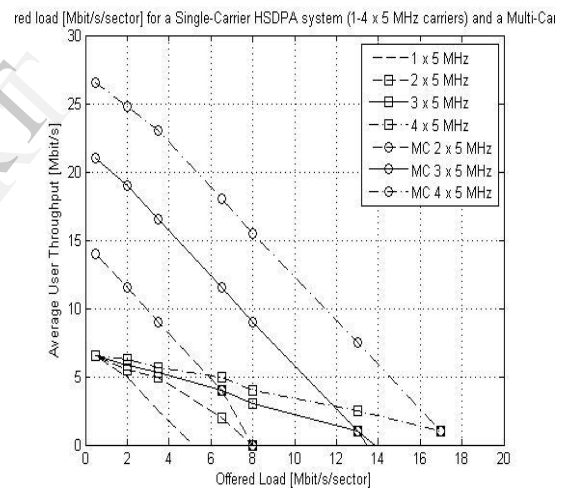


Figure 4: Average user throughput [Mbit/s] as a function of offered load[Mbit/s/sector] for a Single-Carrier HSDPA system (1-4 x 5 MHz carriers) and a Multi-Carrier HSDPA system (2-4 x 5 MHz carriers), respectively

The gain can also be expressed in terms of supported offered load for a given quality of service level. From this point of view, the gain of Multi-Carrier HSDPA is a decreasing function of fractional load. However, we believe that from an end-user experience point of view, the gain seen in user throughput at given offered load should in the context of mobile broadband access services be the most important to consider when assessing the gain of Multi-Carrier HSDPA. Moreover, it is interesting to note that Multi-Carrier HSDPA will increase the user throughput by a factor N -throughout the system coverage area; that is, even at the cell edge. This fact is illustrated in figure 5, which shows

the CDF of user throughput for a system composed of 2 carriers and an offered load of 6.4 Mbit/s/sector.

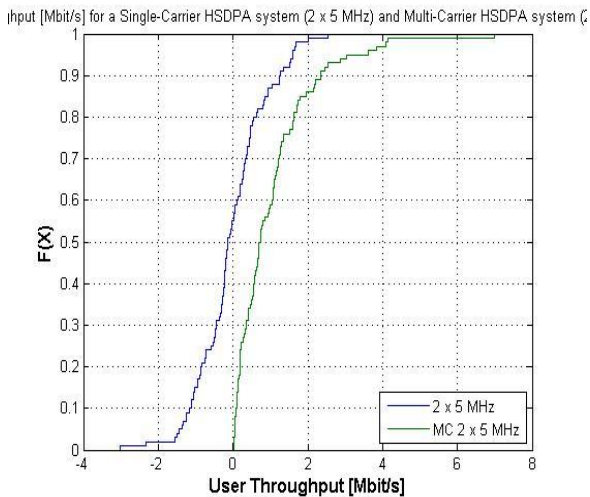


Figure 5: Empirical Cumulative Distribution Function (CDF) of user throughput [Mbit/s] for a Single-Carrier HSDPA system (2 x 5 MHz) and Multi-Carrier HSDPA system (2 x 5 MHz), respectively. The offered load equals 6.4 Mbit/s/sector.

In LTE downlink, according to the results shown in Figure 6, MIMO 4 x 4 scheme provides a clearly better performance than the other schemes for almost all the useful SINR margin. Nevertheless, MIMO 2x2 scheme does not provide an important performance improvement until SINR reaches a value of 15 dB. Also, it can be observed that improvement factor in peak throughput due to MIMO schemes is far from being equal to the number of antennas (2 or 4). Instead, peak throughput is multiplied by 1.7 and 3.6 in MIMO 2x2 and MIMO 4x4 respectively. This is basically due to the higher quantity of reference signals needed in the MIMO schemes.

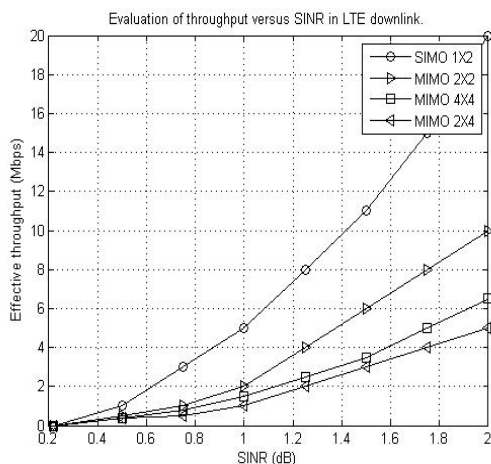


Figure 6: Link level evaluation of throughput versus SINR in LTE downlink.

IV. CONCLUSION

The evolution of HSPA towards higher rates has in this paper been discussed with emphasis on the possibility to use multiple carriers simultaneously for individual users; so-called multi-carrier operation, or Multi-Carrier HSPA. Based on these results, this paper concludes that LTE will offer peak rates of more than 150 Mbps in the downlink and 40 Mbps in the uplink with 10 MHz bandwidth. Besides, in the downlink the minimum average throughput will be around 30 Mbps, which represents a quite significant improvement in the cellular systems performance. As compared with current cellular systems, LTE entails an enhancement of more than six times the performance of HSDPA/HSUPA. This analysis allows those who are interested in wireless communications to get aligned with the research community towards the definition and optimization of next Fourth-Generation mobile.

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