LTE-Advanced UE Capabilities - 450 Mbps and Beyond !

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Summary

LTE networks get more mature and new terminals of different capabilities are being introduced. 3GPP just defined the new LTE-A UE categories to support terminals with peak data rates of up to 450 Mbps in the downlink. This white paper provides an overview of all existing LTE/LTE-A UE categories and presents the new Release 11 capabilities that have just been standardized. Furthermore it describes key scenarios and use cases such as the support for downlink carrier aggregation with 3 downlink carriers with up to 60 MHz of total bandwidth.

Introduction UE Categories

LTE defines UE categories that group terminals' capabilities in classes supporting certain data rates in downlink and in uplink. Such UE categories reduce the base station complexity (less options and scheduler restrictions), limit over the air signalling overhead and avoid a too strong terminal market fragmentation.

Table 1 provides an overview of the defined UE categories [2]. As can be seen the supported peak data rates increase with the UE category. The requirements on physical layer processing concerning the maximum number of bits to be processed per 1 ms transmission time interval will scale accordingly. All UEs have to support the maximum bandwidth of up to 20 MHz. Class 5 is unlikely to appear on the market. It supports 4x4 MIMO in downlink and 64QAM on uplink which is extremely demanding.

Table 1: Rel.8/9 UE Categories

		Class 1	Class 2	Class 3	Class 4	Class 5
Peak Rate Mbps	DL	10	50	100	150	300
	UL	5	25	50	50	75
RF		support of 20MHz Bandwidth				
Modulation	DL	QPSK, 16QAM, 64QAM				
	UL	QPSK, 16QAM				.., 64QAM
eNB Tx		UE support of 1,2 and 4 Tx antenna diversity mandatory				
UE Rx		Performance based on 2 Rx diversity				
2x2 MIMO		Optional	Mandatory			
4x4 MIMO		Optional				Mandatory

The peak data rates should not be misunderstood as user data rates that are achievable in a regularly loaded system. They represent the maximum rate a UE can be allocated by a base station in a 1 ms scheduling interval and sometimes even represent the maximum possible cell capacity. It means, they can only be achieved in the rare event that all resources are given to a single user and that this user experiences the best possible channel state.

At initial attach, a terminal will report its capabilities with the RRC procedure [3] shown in Figure 1. Amongst others the UE categories, supported LTE Release, supported access technologies and frequency bands etc. are signalled. Due to the ever growing number of optionally supported features of different releases, the message size has been growing significantly. Once received by the base station, the Mobility Management Entity will store the UE capabilities of all UEs registered in its tracking

area. It will provide this information to the base station each time the terminal will reconnect to the network.

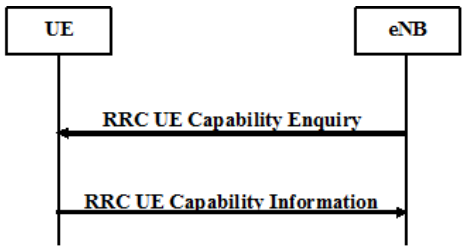

Figure 1: UE Capability Exchange

Initial LTE terminals were of Class 3 providing peak date rates up to 100 Mbps and are being replaced by Class 4 terminal of a maximum data rate of 150 Mbps.

LTE-Advance UE Categories

LTE-A introduced a new set of advanced functions like Carrier Aggregation [1] and MIMO with spatial multiplexing of up to 8x8 SU-MIMO. The theoretically achievable peak data rates will scale with the number of supported carriers and supported MIMO streams.

Three additional UE categories have been defined in LTE-Advanced Release 10 [4] as shown in Table 2 below:

Table 2: Rel.10 UE Categories

		Class 6	Class 7	Class 8
Peak rate Mbps	DL	300	300	3.000
	UL	50	100	1.500
RF Bandwidth		CA capabilities signalled separately		
Modula-tion	DL	QPSK, 16QAM, 64QAM		
	UL	QPSK, 16QAM		..., 64QAM
MIMO Layer DL		2 or 4	2 or 4	8
MIMO Layer UL		2	2	4

Besides the supported UE class, the supported band combinations for Carrier Aggregation and the supported number of layers for MIMO spatial multiplexing are signalled as part of the capability exchange.

One of the use cases of Class 6 for instance is the support of 2 carriers each having 20 MHz bandwidth with 2x2 SU-MIMO. Once again a high end class, Class 8, was introduced supporting 5 carriers with an aggregated downlink bandwidth of up to 100 MHz, 8x8 SU-MIMO (4x4 SU-MIMO in uplink) as well as 64QAM. It can be understood that due to complexity reasons these capabilities will not be practical for quite some time to come, besides the unavailability of an respective RF specification or available band allocation of 100 MHz. Class 8 was defined in the specification to fulfil the ITU-R requirements for 4G with respect to the maximum peak data rate and maximum bandwidth supported.

As a matter of fact, besides the LTE-A categories, LTE-A capabilities are also signalled separately. Therefore existing Rel.8 LTE UE categories can also be extended by LTE-A features. This would for instance allow for higher data rates at lower bandwidth allocation. The first LTE-Advanced terminals on the market are likely to be Class 4 terminals supporting Carrier Aggregation of two times 10 MHz bandwidth.

Introducing 450 Mbps

The marketing race on announcing higher and higher peak data rates to the customers is ongoing. New bands and Carrier Aggregation band combinations are being standardized and will be allocated in the different regions around the globe to serve the ever growing data demand.

Only this month Release 11 Change Requests for the introduction of two new capabilities have been approved at 3GPP RAN plenary #63 [5][6]. This functionality introduces UE categories supporting the following downlink/uplink rates:

- UE category 9 - 450/50 Mbps
- UE category 10 - 450/100 Mbps

The new 450Mbps classes address a deployment scenario of 3 downlink CA component carriers

with total aggregated bandwidth of 60 MHz. Neglecting the various SU-MIMO configurations, Carrier Aggregation scenarios as depicted in Figure 2 are now supported by the different LTE releases. According to the Carrier Aggregation RF band specifications, intra-band contiguous, intra-band non-contiguous and inter-band combinations will be supported [7]. Even before specifications was available, several vendors and operators announced tests and trials of respective equipment in their labs [8][9][10]. The announced equipment seem to support FDD and TDD variants of LTE-A.

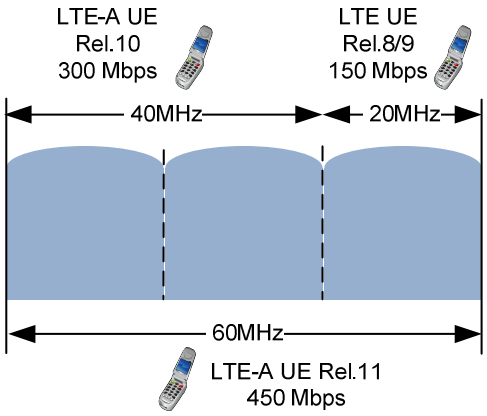

Figure 2: Supported CA Bandwidths

First markets to be addressed by such technology will be Korea or US. Of course it remains questionable which of the operators is actually owning multiple 20 MHz blocks that can be combined to an aggregated spectrum of 60 MHz bandwidth. In an upcoming White Paper NoMoR will provide an overview of standardized band combinations.

Although heavily marketed to the customer the technology does not increase spectrum efficiency as such. Still significant gain due to instantaneous load balancing between carriers can be expected at low to medium load. This assumes a sufficient penetration of Carrier Aggregation enabled terminals of course.

Future LTE-Advance UE Categories

We can expect more UE categories to come in future releases. Physical layer peak data rates will increase by aggregation of more and more carriers and by multi-layer MIMO transmission. As part of Release 12, 3GPP is currently defining the use of 256QAM in the downlink. A scenario to use such high modulation order might for instance be an isolated indoor small cell.

After Release 12 functionality is fixed (completion is targeted for end of 2014), we might see new classes with downlink/uplink rates like

- UE category xx - 600/ 50 or 100 Mbps
- UE category xx - 750 / 50 or 100 Mbps

Today's practically used uplink peak data rates are 50 Mbps. Uplink MIMO with transmissions on multiple antennas or uplink carrier aggregation with transmission in multiple bands might be a major step in UE implementation complexity. Furthermore, considering a defined overall UE maximum output power of the LTE/LTE-A power class of 23 dBm (±2dB) also limits the possible gain compared to the downlink. The use of 64QAM as UE modulation scheme might be an alternative to reach higher uplink rates.

Today the use of uplink 64QAM is linked to the not used high end classes, class 5 and class 8. A more flexible use of uplink 64QAM, independent of the UE categories, has been discussed already in 3GPP and is seen as feasible [11]. The optional support of uplink 64QAM, providing peak data rates of 75Mbps, at least for UE categories 6, 7, 9 and 10 was thus agreed at the RAN plenary last month.

Uplink 64QAM might have some impact on RF specification and thus per signalling band per band combination might be required, same as for MIMO and Carrier Aggregation. Next RAN plenary will decide if this functionality will become part of Release 11 or part of Release 12.

Backwards Compatibility

Of course backwards compatibility of LTE-A equipment with LTE equipment is of high importance and so far this backwards compatibility was never broken.

As illustrated in the first case in Figure 3, an LTE-A eNB will look like an LTE eNB to a LTE UE by sending backwards compatible system information.

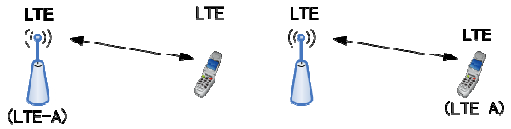

Figure 3: UE and eNB Backwards Compatibility

Conversely, an LTE-A UE will also signal its LTE capabilities to the network in case there are LTE only capable eNBs. This means that by now the UE will signal its capabilities for every release. Actually a single UE will support different UE classes for the different Releases.

References

[1] NOMOR 3GPP Newsletter, "LTE-A Carrier Aggregation Enhancements", Eiko Seidel, August 2012

[2] 3GPP TS36.306 Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities – Release 8

[3] 3GPP TS36.331 Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification

[4] 3GPP TS36.306 Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities – Release 10

[5] RP-140290 CRs to 36.213 on new UE categories for DL 450Mbps class RAN1 CR36.213 Rel.11

[6] RP-140364 RAN2 agreed CRs on New UE categories for DL 450Mbps class RAN2 REL-11

[7] 3GPP TS36.101 Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception

[8] NSN breaks new ground with LTE-Advanced for superior performance #MWC14, Espoo, Finland, February 4, 2014
http://nsn.com/news-events/press-room/press-releases

[9] Huawei and LG Uplus Demo World's First Three-Carrier CA for 450 Mbps LTE-A at MWC 2014, Barcelona, Spain, February 25, 2014
http://www.huawei.com/ilink/en/about-huawei/newsroom/

[10] SK Telecom: World's First Development of Four Time Faster 3band LTE-A, January 23, 2014
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[11] R2-131940, "Decouple UL 64QAM from UE category"; Huawei, HiSilicon, Clearwire, CMCC; 3GPP TSG RAN WG2 meeting #82, Barcelona, Spain, August 19 – 23, 2013

[12] RP-140490, "Way forward on introducing capability of UL 64QAM"; Huawei, HiSilicon, KDDI, Qualcomm Incorporated, CMCC, China Unicom, Verizon, Deutsche Telekom, China Telecom, TeliaSonera, Soft bank mobile Corporation, eAccess Ltd, AT&T, Samsung, Telecom Italia, NEC; 3GPP TSG RAN meeting #64, Fukuoka, Japan, March 3 – 6, 2014

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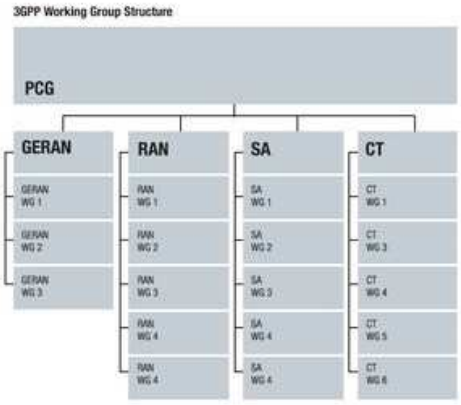

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