3GPP LTE-A Standardisation in Release 12 and Beyond

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Summary

Quite some time ago major improvements have been made to LTE with LTE-Advanced as part of 3GPP Release 10. Unquestionably, LTE-A will be the leading global 4G standard fulfilling the defined ITU-R requirements [1] on IMT-Advanced such as peak data rates beyond 1Gbps. While further enhancements to LTE-Advanced have just been completed in 3GPP Release 11, the new technology trends become visible to serve the continuously growing traffic demand. This White Paper, based on Nomor's attendance of 3GPP, provides an outlook on 3GPP standardisation for the forthcoming years. Besides a summary of general trends and a projected release schedule, it includes an overview of the work and study items of Release 12 in the Radio Working Groups. New key technologies that Release 12 will address are: Small Cell Enhancements, a New Carrier Type, 3D-MIMO Beamforming, Machine-Type-Communication, LTE-WiFi Integration at radio level and Public Safety incl. Device-to-Device communication. While the completion of Release 12 is expected mid of 2014, deployments might be seen around the end of 2015 and later. NoMoR is active in different related research projects and offers consultancy services for related research, standardisation, simulation, early prototyping and technology training.

Workshop on LTE Release 12 and Beyond

In June 2012 a 3GPP workshop [2] was held to get an overview of the priorities within the industry concerning future standardisation work. There was a very large interest in the workshop with about 250 participants attending in Ljubljana, Slovenia. Although no decisions or binding conclusions were drawn, the workshop provided quite a good picture of the ideas of the companies for future releases.

Traffic is increasing further and even with technology improvements it appears to be clear that the traffic demand cannot be satisfied with the proposed technologies.

Technology enhancements can roughly be clustered into

- Improvements of Spectral Efficiency
- Bandwidth Expansion
- Cell Densification
- Minor Issues or Enhancements

Improvement of spectral efficiency is hard to achieve given the maturity of this field, especially gains that are transferable to noticeable system-level gains. Furthermore, such improvements often require major changes to the standard. Possible technological enhancements are the introduction of OFDMA in the uplink that will provide gain in not power limited situations, the introduction of 256QAM in the downlink, the support for flexible downlink power control, advanced receivers with interference cancellation and also enhancements of Cooperative Multi-Point techniques (CoMP) for real-life scenarios (e.g. non ideal backhaul).

Spectrum availability will grow in the future, mostly in higher frequency bands, and future LTE systems need to support this. Bandwidth extensions will be done continuously in every release according to market demand. Frequencies in the range of 3.5 GHz will need to be supported soon. Local access assisted by wide area macro cells providing basic coverage have been mentioned by many key companies. Very high frequencies (>10 GHz) might be allocated in the World Radio conference 2015 and might be served with a completely new access scheme potentially standardized as part of Rel.-14. Access technologies making extensive use of beam forming will be candidates since the beam forming gain might compensate for the increased pathloss at higher frequencies. Although an increase in available and useful spectrum is expected to be at least threefold until 2020 this is by far not sufficient to keep pace with the expected growth of traffic.

One of the key areas for improvement of the next releases is surely the full integration of small cells into Heterogeneous Networks. Cell splitting provides the only way to have significant capacity increase at the cost of higher deployment costs. High SINR regions are generated by the introduction of small cells (possibly on a separate frequency layer) and might offer a further increase in peak data rates. This goes hand in hand with advanced interference management between macro and pico layer or the extension of Carrier Aggregation (CA) to support multi-site CA or multi-RAT CA (FDD/TDD or LTE/HSPA). Mobility management will have to be enhanced and the network should assist the UEs in discovering low power nodes with minimum power consumption. Wireless backhaul was often mentioned by operators as one of the requirements. They also proposed to use higher frequency bands for the backhaul.

Other issues and enhancements are interworking with WiFi (e.g. tight integration at RAN level) and the support of Device to Device communication. Work is also likely to be split into two fields: proximity or device detection and direct transmission. Continuous enhancements for Machine Type Communication, Self-Organizing Networks and Minimization of Drive Test will happen, but will not cause major changes to specification.

Once again it is emphasized that this only represents company views during the 3GPP workshop. No actual conclusions have been drawn or decisions have been made.

Potential 3GPP Release Timing

Standardisation work and release timing in 3GPP is split into three stages.

- Stage 1: Requirements and Service Aspects
- Stage 2: Architecture and Technical Design
- Stage 3: Detailed Specification

Release 12

Stage-1 of Release 12 work already started in 2011. Nevertheless in the radio groups little time was spent on it due to a 3 month delay of Release 11 completion. The following are the official completion dates of Release 12 as of today:

- Stage 1: March 2013 RAN
- Stage 2: December 2013 RAN
- Stage 3: June 2014 RAN
- ASN.1 freeze likely in September 2014

First products should not be expected sooner than 15 to 18 months after ASN.1 freeze. Therefore actual deployment could be expected end of 2015 and later.

Release 13

From the workshop it can be deduced there will be another release to further enhance LTE-A technology, a Release 13. Dates of Release 13 are still hypothetical and not official, yet.

- Start: June 2014 RAN
- Completion: December 2015

Surely the content and timing of Release 13 will depend on progress in Release 12.

Release 14/15

The timing of Release 14/15 is likely to be influenced by the World Radio Conference (WRC) 2015 scheduled to take place in September

2015. Potential candidate bands allocated at WRC 2015 might include:

- 1427-1525 MHz
- 3.4-3.6 GHz
- 3800-4200 MHz

As consequence a completely new access technology might be defined in the Rel.14/15 time frame for commercial deployment at the end of this decade. Up to today most companies call this technology Beyond 4G.

Release 12 Work and Study Items

At 3GPP RAN Plenary#58 in December 2012 in Barcelona [3] major decisions concerning the content of Release 12 where made. In this section the respective decisions are summarized and the technology proposals are explained in detail.

MIMO DL Enhancements / 3D-MIMO [4]

By continued progress of antenna technologies, enhancements of the macro cell eNBs can be realized mostly by exploiting an increased frequency reuse and reduced interference in the spatial domain.

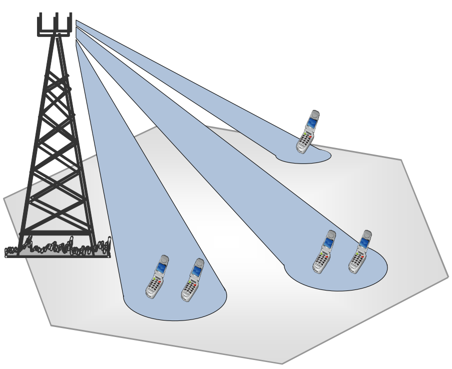

Figure 1: 3D MIMO Beam Forming

Due to the reuse of the existing cell sites and transport network, operators are provided attractive means of capacity enhancements at reasonable costs. Potential changes to the specifications will mostly impact Channel State Information (CSI) feedback. Amongst others Pre-coding Matrix Indicator (PMI) codebook enhancements might allow for a finer spatial domain granularity and might support different eNB antenna configurations. New CSI feedback modes might also be introduced.

There is also a Rel.12 study item [7] that will standardise a new 3D channel model to allow for accurate system-level simulations of such antenna technologies.

Low Cost Machine Type Communication [5]

A massive growth of Machine to Machine (M2M) communication, devices and traffic is expected to support smart grid, transport, logistics, e-health, energy, safety applications etc. Therefore the LTE radio interface shall be prepared to efficiently support the massive transfer of small, infrequent packets using very low cost, low complexity and low power devices. Quite some work on Machine Type Communication (MTC) was already standardized in Release 11. The work covers service requirements, architecture and security issues. Among others, a MTC Interworking Function and Service Capability Server [14] are defined in Release 11.

Significant link budget enhancements are targeted in this work to improve indoor penetration. The use case is that some MTC UEs are installed in the basements of residential buildings or locations shielded by foil-backed insulation, metalized windows or traditional thick-walled building construction, and these UEs would experience significantly greater penetration losses on the radio interface than normal LTE devices. Most promising and simple techniques are around adding time diversity (e.g. TTI bundling), extensive use of HARQ repetition as well as power boosting.

New Carrier Type (NCT) [6]

So far LTE-A standardisation has always been restricted to backward-compatible carriers only. On the one hand, this enables a smooth transition to new releases; on the other hand, there are limitations to the introduction of new technologies. One of the consequences of backward compatibility is the need to continuously transmit Common Reference Symbols in every subframe across the bandwidth as shown in Figure 2.

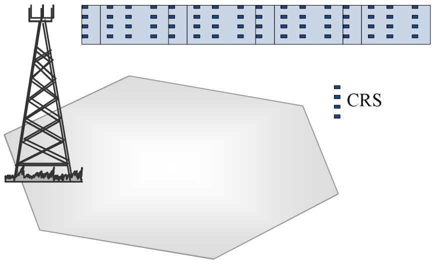

Figure 2: LTE/LTE-A Carrier with Common Reference Symbols

This precludes switching off a cell temporarily and represents unnecessary overhead particularly in case of non-codebook based beam forming using dedicated reference symbols.

A new carrier type allows switching off cells, at least temporarily, and will reduce the overhead and interference from Common Reference Symbols by maximizing the use of dedicated Demodulation Reference Symbols required for advanced antenna technologies.

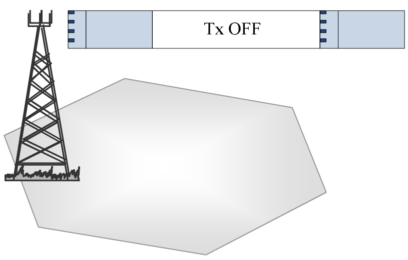

Figure 3: New Carrier Type with Discontinuous Transmission

Furthermore new bandwidth formats might be introduced to support all kinds of bandwidths. The New Carrier Type might be operated as a kind of extension carrier along with another LTE/LTE-A carrier or alternatively as standalone non-backward compatible carrier.

Small Cell Enhancements [8], [9]

Further network densification is seen as one of the key elements to increase spectrum efficiency. Although initially started as a study item, this work is expected to get the largest attention in Release 12. By bringing the UEs closer to the network nodes the SINR improves, increasing overall performance by use of adaptive coding/modulation and MIMO. Similarly to 3D beam forming system performance can be increased through the reuse of frequency resource, so-called cell splitting. The impact of Heterogeneous Networks on operation is manifold e.g. large traffic and user variations in the cells are expected, larger SINR dynamics, increased handover rate etc.

As illustrated in Figure 4 two scenarios can be envisioned in this work. The first is a frequency separated local access, where different frequency layers are being used for the small cells. And secondly, a frequency-integrated local access might be feasible, where macro and pico cells are using the same frequency and where the small cells are fully integrated into the network.

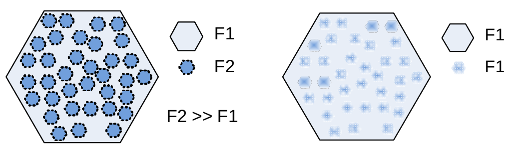

Figure 4: Scenarios of Network Densification

Depending on the scenario, different methods are required to assign cell identities and to support the UEs in finding and using the respective small cells. For the small cells, particularly when using higher frequencies, new regulatory requirements will be required and co-existence studies need to be conducted. The use of different TDD based duplex schemes can also become beneficial. A more dynamic uplink/downlink subframe allocation in isolated cell clusters could match the instantaneous, local traffic situation. Advanced sensing and resource reservation might be required to avoid severe interference scenarios.

Surely, the fully integrated local access of the second scenario looks like a very promising method for performance enhancements. The small cells just extend the macro cell with the same physical layer identification or with dynamically assigned virtual cell identities that are reused in spatial domain. Previously defined enhanced Inter-Cell Interference Coordination (eICIC) techniques are replaced by dynamic creation of such "virtual" cells or "soft" cells. Extensive traffic offload with any offset of cell range expansion (CRE) will be possible in such scenario.

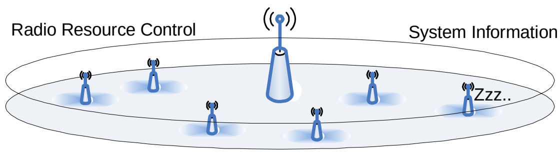

Figure 5: Split of User and Control Plane for Frequency Integrated Local Access

The small cells simply provide a fast data pipe with a largely improved link budget due to the close proximity of the network node. The macro cell on the other hand will provide cell wide system information as well as radio resource control including traffic steering, carrier selection and supporting the UE to detect a small cell close by (see Figure 5). Other benefits are that mobility in such HetNet scenarios will become more robust and that the operation of small cells might even be transparent to the UE, so the UE need not even be aware of the local access.

On the other hand, this architecture requires a tight integration of the small cells into the network by ultra-fast interfaces or preferable by a central baseband processing unit. This might prevent the selection of multiple vendors for marco cells and small cells in the same geographical area.

LTE Device to Device Communication [10]

Device to device communication allows direct communication between UEs that are in proximity to each other. Besides its potential to save energy, reduce interference and extend coverage, the key driver for this work is to ensure that 3GPP LTE meets the needs of Public Safety. Until today different technologies are used for public cellular networks and for dedicated public safety networks. LTE is already globally promoted as future public safety system. Once D2D is standardised the market might also see new proximity-based applications and services. Focus is mostly given to network controlled D2D communication as shown in Figure 6. In this case the control signalling (e.g. initial access, authentication, connection control) as well as resource reservation is handled by the network.

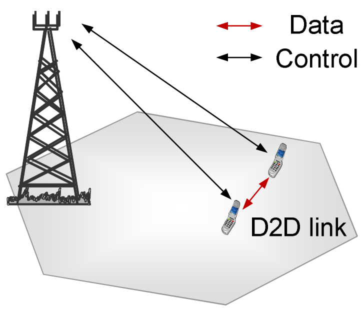

Figure 6: Network Controlled Device to Device Communication

This way Quality of Service can be guaranteed and the network operator still remains in control of the transmission. Although standardisation did not start yet, it can be assumed that schemes that are transparent to the user equipment will be preferred. Although not shown in Figure 6, it is also likely that a radio bearer for potential data transmission to the network is being maintained all the time.

Nevertheless there might be opposing requirements from the public safety area such as a disaster use case, where the network might be down and communication between security forces must still be possible. This might require that a new specification also supports an autonomous control by the UEs or a hybrid approach with a distributed control between network and UEs.

3GPP/WiFi Radio Interworking [11]

Base stations also supporting WiFi have been seen on the market for some time now, but interworking is mostly limited to core network functionality like user authentication / authorization and accounting. Although the specification also supports mobility, further optimization is seen as beneficial to improve load balancing, Quality of Service provisioning and an improved UE battery consumption when using WiFi technology in tight cooperation with cellular networks. In a first phase of this study item interworking at radio level will be studied and requirements will be defined to derive respective solutions. Today's WiFi network detection and selection functions are mostly UE based and future solutions might be operator controlled. This will allow for implementing more intelligent networks that consider cell load or transport network load, user Quality of Service or radio link quality for the different links during that operation.

HetNet Mobility Enhancements [12]

This work item has been created as a result of an ongoing study item in Release 11. The results of the study item have been captured in a technical report TR36.839 [13]. From simulation results it was concluded that handover performance of Heterogeneous Networks is not as good as for pure marco network deployments. Furthermore, it was shown that the UE speed has significant impact on the handover performance and that careful DRX settings are required to avoid negative impact on handover performance. The objective is thus to enhance handover performance in HetNet environments (e.g. failure rate, minimize ping-pong effects, recovery from radio link failure) also supporting UE mobility and longer DRX cycles. Small-cell enhancements related to mobility will also be discussed with the focus on inter-frequency scenarios.

RAN WG3 Work and Study Items with Impact on Network Architecture

RAN3 will continue to work on solutions that involve S1 and X2 signalling. In Release 12 the following related work and study items have been approved:

- Study on Next Generation Self-Organizing Networks (SON)
- Further Energy Saving Study
- Work item on X2-GW support for H(e)NB mobility (left over from Rel.11)
- Study on RAN Enhancements for UMTS/LTE Interworking

Theses work and study items are mostly enhancements of already existing technologies for specific scenarios or for better interworking between existing features. Surely the integrated support of a large number of small cells in HetNets will pose new requirements SON operation (e.g. load balancing, mobility robustness optimization) or to enable more efficient power saving on the network side.

RAN WG4 and WG5 Work and Study Items concerning RF and Testing

Please note that there is quite some work ongoing on radio frequency aspects and testing in Release 12 which are not within the scope of this white paper. Amongst others there are a large number of spectrum related work items to enable new frequency combinations for Carrier Aggregation.

References

[1] Report ITU-R M.2134 - Requirements related to technical performance for IMT-Advanced radio interface(s)

[2] RWS-120052, Report of 3GPP TSG RAN Workshop on Release 12 and onwards, Ljubljana, Slovenia, June 2012

[3] RP-13xxxx, Draft Report of 3GPP TSG RAN meeting#58, Barcelona, Spain, Dec. 2012

[4] RP-121416, Further Downlink MIMO Enhancement for LTE-Advanced

[5] RP-121648, Study on Provision of low-cost MTC UEs based on LTE

[6] RP-122028, Updated WI proposal: New Carrier Type for LTE

[7] RP-121788, Study on 3D-channel model for Elevation Beamforming and Massive MIMO studies for LTE

[8] RP-122005, New Study Item Proposal for Small Cell Enhancements for E-UTRA and E-UTRAN – Physical-layer Aspects

[9] RP-122033, New Study Item Description: Small Cell enhancements for E-UTRA and E-UTRAN – Higher-layer aspects

[10] RP-121699, Background on "LTE D2D Proximity Services" Study Item proposal

[11] RP-122038, New Study Item Proposal on WLAN/3GPP Radio Interworking

[12] RP-122007, New WI proposal: Hetnet Mobility Enhancements for LTE

[13] 3GPP TR 36.839 V11.1.0 (2012-12), (E-UTRA); Mobility enhancements in heterogeneous networks (Release 11)

[14] 3GPP TS23.682 "Architecture enhancements to facilitate communications with packet data networks and applications (Release 11)"

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- Flexible base station and user configurations and drop models
- Different transmitter and receiver chains incl. MIMO, ZF, MMSE
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- 2D and 3D antenna pattern and multi-antenna beam forming
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- Full user plane (MAC, RLC, PDCP) implementation
- Enhanced MBMS broadcast functionality

The simulator can be used on project basis or in customized simulation campaigns. The performance of the system level simulator has been calibrated to simulation results obtained in 3GPP standardisation or in research projects.

Research on advanced algorithms and features include, but are not limited to:

- Scheduling and resource allocation algorithms considering channel and buffer status, QoS etc.
- Inter-cell interference coordination, avoidance and cancellation
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- HetNet radio resource management and interference coordination
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- Application testing

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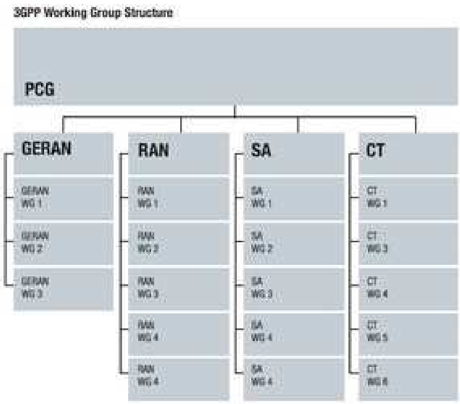

Consulting can include, but is not limited to:

- Regular standardisation updates,
- In-depth information on technical areas,
- Release analysis, feature roadmaps and complexity analysis,
- Contribute and influence standards activities,
- Represent your company at standardization,
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- LTE-Advanced
- LTE Self-Organizing Networks
- LTE Heterogeneous Networks

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