LTE Release 14 Outlook

Christian Hoymann, David Astely, Magnus Stattin, Gustav Wikström, Jung-Fu (Thomas) Cheng, Henning Wiemann, Niklas Johansson, Mattias Frenne, Ricardo Blasco, Joerg Huschke, Andreas Höglund, Fredrik Gunnarsson

Ericsson Research

1 Abstract

Today's fourth generation LTE systems bring unprecedented mobile broadband performance to over a billion of users across the globe. Recently, the work on a 5G mobile communication system started, and next to a new 5G air interface, LTE will be an essential component. The evolution of LTE will therefore strive to meet 5G requirements and to address 5G use cases.

In this article, we provide an overview of foreseen key technology areas and components for Release 14, including latency reductions, enhancements for machine-type communication, operation in unlicensed spectrum, massive multiple antenna systems, broadcast multicast systems, and positioning as well as intelligent transportation systems.

2 Introduction

The first release of the LTE specifications, release 8, was completed in 2008, and commercial network operation began already in December 2009. This was soon followed by deployments on a global scale and since then there has been an unprecedented adoption on a global scale. In the first six years of commercial availability, more than 440 LTE networks have been launched in over 145 countries, and at the end of 2015, the number of LTE subscriptions reached one billion.

Ever since the first release 8, the specifications have been regularly updated with releases 9 through 13, introducing enhancements and new features to improve efficiency and to boost both user and system performances. This includes carrier aggregation for spectrum flexibility, advanced antenna techniques and advanced receivers to increase spectral efficiency, small cell enhancements to address densification as well as WiFi interworking and licensed assisted access to exploit unlicensed spectrum. At the same time, support for voice calls, public warning systems, positioning and multimedia broadcast multicast services have been added in addition to enhancements for Internet of Things (IoT) with optimization of machine type communications and support for public safety with device-to-device communication.

In short, LTE is continuously evolving, addressing not only mobile broadband, but also new areas and use cases beyond mobile broadband. In light of the advancements, release 13 and onwards is also referred to as LTE-Advanced Pro, and at the time of writing, the work on release 14 has started with the target to be finalized in March 2017.

At the same time, the work on future 5G radio access is ongoing in industry and academia as well as in fora such as ITU and 3GPP, see e.g.[1],[2] and [3]. LTE is currently seen to be an essential part of future radio access beyond 2020, and 3GPP has concluded to continue a strong evolution of LTE in parallel with the development of a new radio interface and also to submit the two to IMT-2020. Hence, the further evolution of LTE evolution in Release 14 and beyond will strive to meet and address corresponding requirements and use cases, respectively.

In the present article, we review the requirements on future 5G radio access in Section 3 to identify some main technology areas and components for the LTE evolution in Release 14 and beyond. These include

- Latency reduction
- Enhanced operation with unlicensed spectrum
- Machine type communication
- Massive multi antenna systems
- Intelligent transportation systems
- Enhanced multimedia broadcast and multicast services (eMBMS),and
- Enhanced positioning

The different areas are discussed Sections 4 through 10, followed by a conclusion in Section 11. It is important to understand that work in 3GPP is contribution driven, and additional features may become part of LTE as work progresses.

3 Requirements on Future Radio Access

There is an industry consensus that the most important use cases for radio access in the 2020 and beyond timeframe can be categorized in three families [2] also reflected in the ongoing 3GPP work on requirements [3]:

- Enhanced mobile broadband (eMBB)
- Massive machine type communication (mMTC)
- Ultra-reliable and low latency communication (URLLC),

eMBB will require massive system capacity to meet the predicted future traffic growth. At the same time, future systems will not only offer higher peak rates up to 20 Gbps but more importantly offer much higher data rates in real-life deployments, for example 10Mbps everywhere, several 100Mbps in dense urban environments and even higher in hot-spot environments. Densification with more network nodes, use of more spectrum, both licensed and un-licensed, as well as spectral efficiency enhancements are needed. This motivates further evolution of Licensed Assisted Access and massive multiple antenna systems as described in Sections 5 and 7. With eight layer transmission defined in Release 10 and carrier aggregation of up to 32 carriers introduced in Release 13, the peak data rate in LTE is around 25Gbps. However, very high data rates will also call for latency reductions due to the properties of internet protocols as outlined in Section 4. Furthermore, media content streaming constitutes a major part of the future traffic volumes, and this motivates further evolution of eMBMS as described in Section 9.

mMTC addresses applications with a very large number of sensors, actuators and similar devices typically associated with little traffic as well as requirements on low device cost and very long battery life. Together with network enhancements, such as improved coverage and signaling reductions, the vision of a networked society with billions of connected things is enabled. Challenges in terms of coverage, device cost, and battery-life have been addressed in previous standard releases as described in Section 6, where also further evolution is outlined.

URLLC implies a wide range of requirements including reliability, availability and latency in order to offer connectivity that is not only typically available but essentially always available with required characteristics. Examples include health applications, traffic safety and control, control of critical infrastructures and connectivity for industrial processes. More specifically, in Release 14 timeframe, an ITS solution based on LTE will be developed as described in Section 8. We also note that latency reduction will enable even more low latency applications.

Furthermore, positioning enhancements will not only add value to all the above mentioned use cases but also be needed for emergency calls. In Section 10, enhancements for indoor positioning are outlined.

Already today, LTE offers support for many diverse use cases and from above it is clear that the LTE capabilities will be significantly extended allowing LTE to address even more challenging use cases.

4 Latency reduction

While much attention has been paid to improve LTE data rates, little effort has been spent on reducing packet latency. However, the perceived throughput will be affected by both aspects, and especially for smaller packets the impact of latency becomes visible. Also for TCP traffic, a reduced latency is essential since, in particular during the TCP slow start phase, the rate of TCP acknowledgments determines the achievable rate. Furthermore, low latency is of key importance to enable future URLLC use cases with tight delay requirements. Latency reduction techniques are currently being considered in 3GPP in forms of an extension of semi-persistent scheduling for faster UL access, reduction of handover interruption time, as well as shorter transmission time intervals (TTIs) and processing times [4]. For TDD operation, it may be of interest to study latency reductions by increasing the number of UL-DL switches which currently is at most one per 5ms.

In the uplink (UL), medium access is based on scheduling requests (SR) that are sent by the terminal to request resources if data need to be sent. This introduces delay since the terminal must wait for SR opportunity as well as the extra round trip time needed to grant the transmission. By instead configuring a terminal with a periodic UL grant with a 1ms periodicity, referred to as a Fast UL grant [4], the UE is allowed to transmit without the SR related delay. The existing SR-based UL access as well as UL access using a Fast UL grant are depicted in Figure 1. To avoid unnecessary battery consumption and interference, the terminal should only use the UL resources configured if it has data to send. Additionally, to avoid that resources are under-utilized they could be overbooked and assigned to multiple UEs with different reference signal settings to allow the network to distinguish them

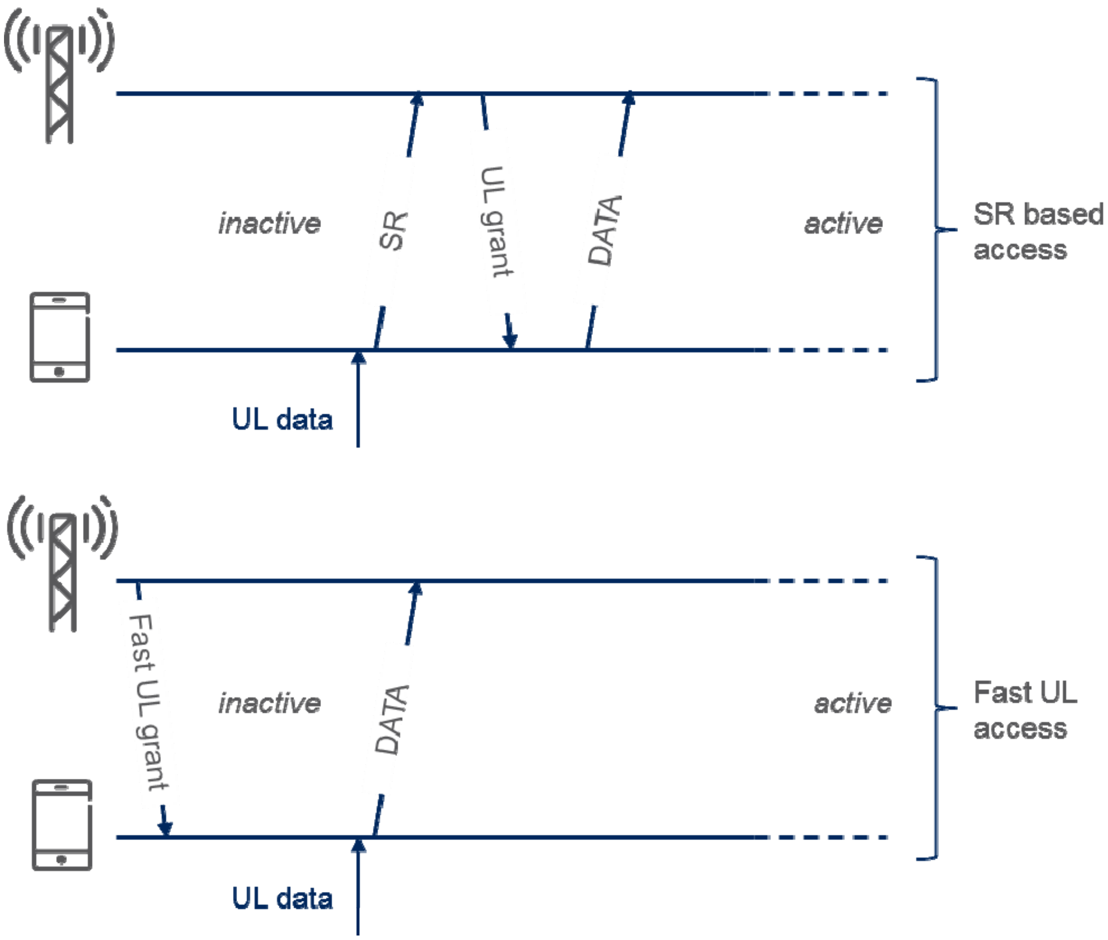

Figure 1: Conventional scheduling request based access (top) and access with Fast UL grant (bottom)

On the physical layer, the introduction of a shorter scheduling period, as compared to the current 1ms TTI, allows to dramatically reduce the RAN latency. This since the scheduling delay as well as the transmission and processing delays can be reduced. It is essential, though, to also reduce the period of control signaling in both UL and DL for scheduling commands and HARQ feedback and also consider reference signals for demodulation. TTI durations down to a single symbol is considered, but since the additional control and reference signal overhead grows with decreasing TTI, the final design needs to strike a tradeoff. It should also be noted that the solution is backwards compatible in the sense that legacy terminals can be served by the same carrier.

These enhancements have the potential to significantly reduce user plane latency. With Fast UL the latency for a sporadic UL transmission can be reduced from 12.5ms down to the DL level of 7.5ms for the current TTI duration. For a reduction of the TTI length down to say two symbols, the potential reduction in one-way latency is up to a further factor of seven, corresponding to a one-way latency of around 1ms.

5 Licensed-Assisted Access

Existing and new spectrum licensed for use by International Mobile Telecommunications (IMT) technologies will remain fundamental for providing seamless wide-area coverage, achieving the highest spectral efficiency, and ensuring reliability of cellular networks. To meet ever increasing data traffic demand, more spectrum will be needed. Given the large amount of spectrum available in the unlicensed bands, it is therefore of interest to use it as a complement to licensed spectrum. After a study [5], 3GPP introduced licensed assisted access (LAA) in Release 13 to enable LTE DL transmissions in secondary cells (SCells) operated in unlicensed spectrum. These transmissions are controlled and coordinated from primary cells (PCells) operating in licensed spectrum using the carrier aggregation framework (see Figure 2). This approach enables operators to enhance the seamless coverage in the LTE network with additional bandwidth and capacity. To achieve coexistence with other technologies (such as IEEE 802.11) operating in the same band, eNB listen-before-talk (LBT) procedures and discontinuous transmission with limited maximum channel occupancy time were introduced

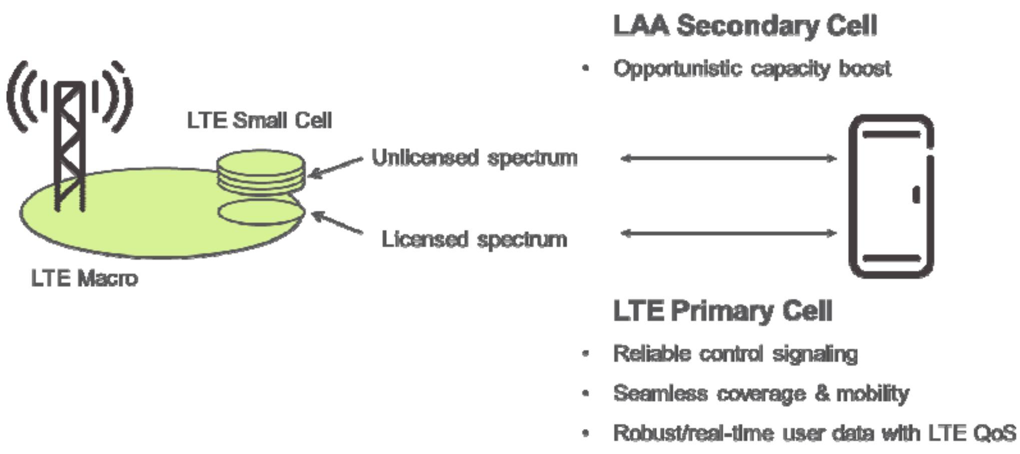

Figure 2: LAA enabling transmissions on secondary cell(s) operated in unlicensed spectrum controlled from a primary cell operating in licensed spectrum using carrier aggregation

To further enhance the capabilities of LAA operations, uplink channel access for the unlicensed band SCells will be introduced in Release 14. Due to LBT procedures several protocol enhancements may be introduced to improve LAA UL operation efficiency. Enabling one DL subframe to send grants for several UL subframes can reduce the overhead and significantly increase the throughput of LAA UL transmissions. Due to the uncertainty in channel access opportunities on carriers in unlicensed spectrum, it is more efficient for LAA UL HARQ to follow an asynchronous protocol, similar to LAA DL HARQ. The UL retransmission can be scheduled by an UL grant and occur at any time relative to the initial transmission.

On the physical layer side, 256QAM support will be introduced to bring LTE UL capability on par with other small cell technologies. Another potential enhancement to consider is the dual connectivity framework wherein the UE may simultaneously receive and transmit to a master eNB (MeNB) and a secondary eNB (SeNB) also when the two network nodes are connected via non-ideal backhaul. The combination of the dual connectivity and LAA features will extend unlicensed band LTE operations to even more deployment scenarios.

The LTE-WLAN aggregation (LWA) feature introduced in Release 13 is another area that will receive several protocol enhancements in Release 14. Release 13 supports LTE-WLAN aggregation for the DL. In Release 14 LTE-WLAN aggregation also for the UL is envisioned. Additional information collection and feedback (e.g. better estimation of available WLAN capacity) as well as automatic neighbor relation (ANR) procedures are to be introduced to improve LWA performance.

Due to the discontinuous transmission with limited maximum channel occupancy time designs, LAA carriers can support very dynamic muting of otherwise persistent broadcast signals (such as the cell specific reference signals). Such lean operations can lead to reduced inter-cell interference and enhanced energy efficiency. It is therefore noted that such designs and benefits can also be extended to carriers in the licensed spectrum with significant user throughput improvements, especially in combination with higher order modulation such as 256QAM.

6 Machine Type Communication

Significant enhancements of LTE have been introduced to efficiently handle machine type communications, and to allow very simple devices to be connected in a power efficient manner. In Release 13, the existing track of MTC improvements (eMTC) [6] has been further evolved, by reducing the device bandwidth to 1.4 MHz and the output power to 20 dBm, achieving even lower device cost. Furthermore, coverage enhancements up 15-20 dB were introduced. These devices will still operate in all existing LTE system bandwidths.

In Release 13, another LTE-based MTC solution, NB-IoT, is also being standardized [7], with similar targets when it comes to coverage, power consumption, and device complexity. The smaller device bandwidth of 200 kHz reduces data rates and increases latency, but also offers greater deployment flexibility as shown in Figure 3. Such devices can be supported using one resource block inside an LTE carrier, but can also be operated in a standalone system with 200 kHz bandwidth in an existing GSM network replacing one or a few GSM carriers, or alternatively in the guard band of an LTE carrier or another system. Whereas currently eMTC supports operation in TDD spectrum, NB-IoT does not. It may be of interest to address this in release 14.

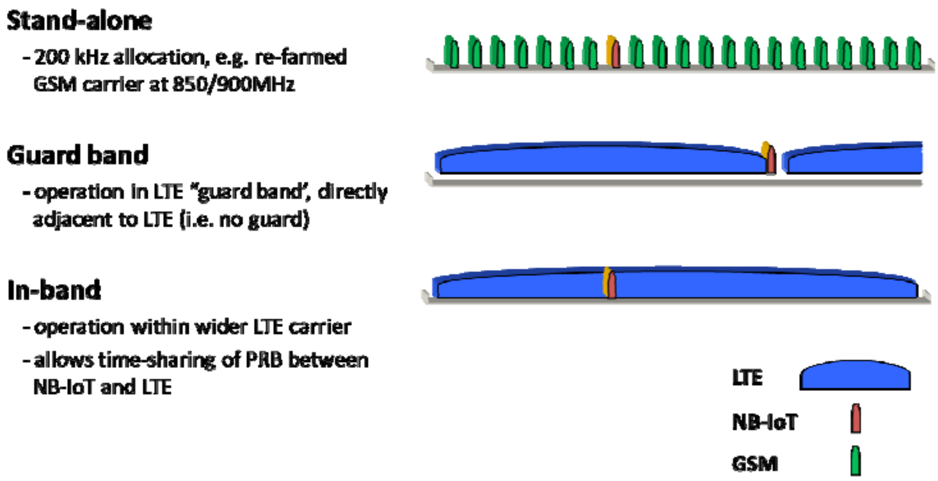

Figure 3: NB-IoT deployment modes.

The evolution of LTE will include enhancements common to both the eMTC and NB-IoT solutions. More specifically

- Point-to-multipoint broadcast for MTC enables e.g. efficient software/firmware updates or addressing of many actuators, e.g. light-switches, for thousands of devices simultaneously.
- Cost-efficient and easily deployable relays can reduce the transmission times, especially in challenging coverage conditions, and improve battery life, increase capacity, reduce latency, and enhance the coverage simultaneously. One application for which this of particular interest is for smart wearables which will also be considered in the Rel-14 timeframe [8].
- Positioning brings benefits to many different MTC use cases. There is already support for positioning in Rel-13 but improving the positioning accuracy is desirable by introducing dedicated signals, procedures and requirements for enhanced positioning performance in Rel-14.

Furthermore, higher layer enhancements for signaling reductions and extended DRX cycles introduced in release 13 improve battery life for devices and improve network capacity. Longer DRX cycles in connected mode makes it possible to keep UEs with moderate needs for long battery life or high requirements on DL reachability in connected mode, but also puts new requirements on, e.g., mobility handling and congestion control in connected state. Work in release 14 is foreseen to address these aspects and to consider to further reduce the radio and network interfaces signaling overhead, further extend battery life and reduce the access latency for all types of devices, see e.g.[9].

Another potential release 14 addition is NB-IoT operation in unpaired spectrum; currently supported for eMTC but not for NB-IoT.

As a final remark, due to the deployment flexibility of NB-IoT, this solution may be well suited for migration into future 5G networks, complementing the new networks with the ability to support massive amounts of low-cost MTC devices.

7 Massive Multi Antenna Systems

In Release 13, a study of MIMO enhancements to extend the current support of eight transmit antennas up to 64 transmit antennas was concluded, thus targeting a massive number of controllable antenna elements [10]. The study considered simultaneous horizontal and vertical adaptive transmission, utilizing two dimensional antenna arrays with both closed loop and open loop (beamforming) operation modes. Significant performance benefit for both single user and multi user MIMO was found leading to standard enhancements for 12 and 16 antennas. This included feedback and small cell sounding enhancements for both closed and open loop operation in addition to an extension of the number of co-scheduled terminals to eight for multi user MIMO.

The closed loop mode is suitable for both FDD and TDD. It uses measurement reference signals (CSI-RS) per antenna a precoder codebook for terminal feedback, see Figure 4. A large number of UEs can be served in a cell without increasing the CSI-RS overhead as the CSI-RSs are cell specific. However for an increased number of antennas the increasing CSI-RS overhead will at some point neutralize any possible massive MIMO gain. Open loop beamforming operation, on the other hand, has increased efficiency for large number of transmit antennas, since the CSI-RS are UE specific and beamformed, see Figure 5. However, when the number of served UEs becomes large, the overhead gets problematic. Hence the closed loop and open loop modes are complementary and further enhancements to both of them will increase coverage and capacity further.

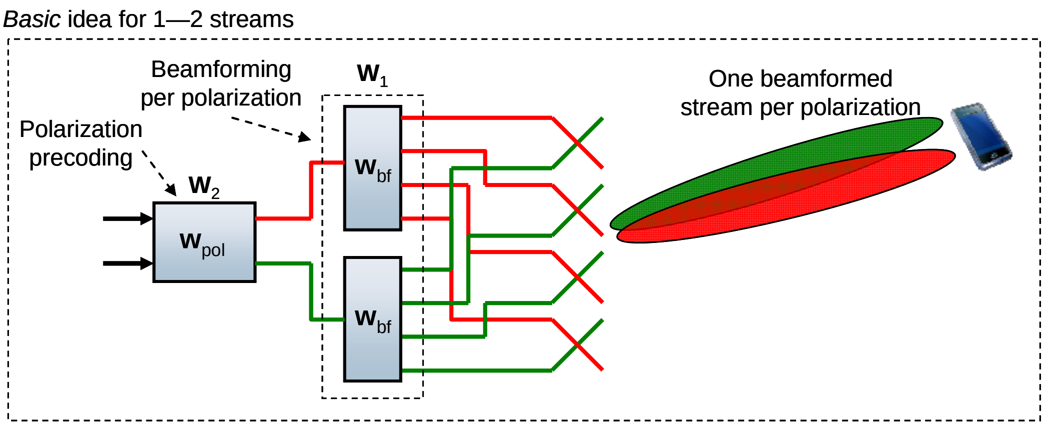

Figure 4: Closed loop MIMO where the UE controls the precoders W1 and W2 for robust operation

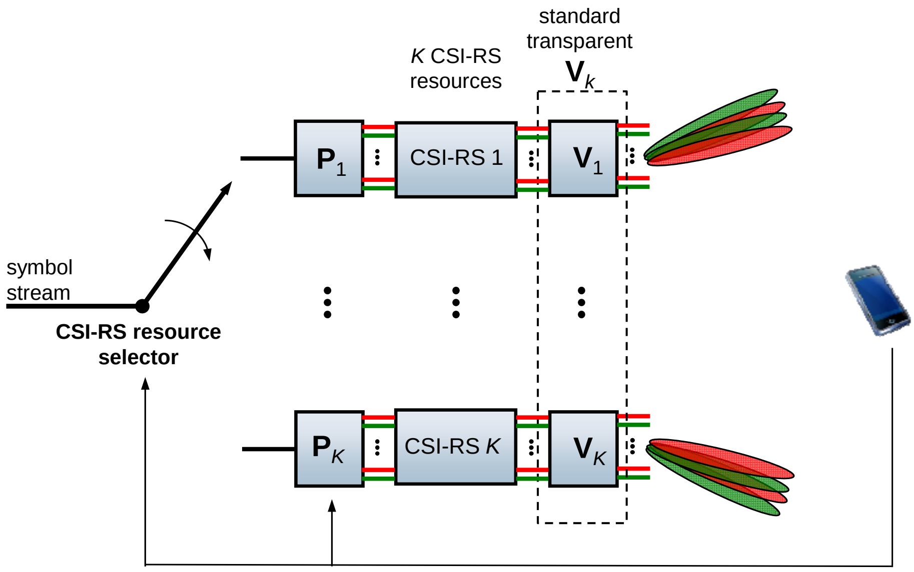

Figure 5: Beamforming MIMO operation, where the UE selects one out of K beams formed by the standard transparent precoders Vk determined by eNB without explicit feedback from the UE.

In Release 14, the massive MIMO evolution will continue [11], targeting up to 32 transmit antennas. Currently MU-MIMO performance is seen to be limited by quality of channel knowledge at the transmitter and this motivates investigation of new feedback methodologies for high resolution feedback in addition to the existing precoding codebook based scheme. The challenge is how to ensure sufficiently good transmitter channel knowledge for the FDD system and in TDD system when reciprocity needs to be complemented, for instance when the UE has fewer TX antennas than RX antennas. Having this in place will also benefit SU-MIMO operation in rich scattering environments.

In addition, support for at least 32 antennas is targeted for Release 14 including the high resolution channel feedback. For the open loop operation, further beamforming enhancements are envisioned, introducing dynamic CSI-RS allocation, allowing for efficient pooling of reference signals resources. This would then both manage the reference signal overhead with beamforming with a larger number of simultaneous UEs as well as provide robustness for the open loop mode.

Finally, studies on further enhanced downlink coordinated multipoint operation, including FD-MIMO beamforming coordination between multiple eNBs using massive MIMO, is also foreseen.

8 Intelligent Transportation Systems

Radio communications are instrumental in enabling the deployment of Intelligent Transportation Systems (ITS), which have been identified as a way of improving traffic safety and efficiency. To support these as well as many other applications, 3GPP is developing an ITS solution based on LTE targeting different vehicle-to-anything (V2X) connectivity scenarios, including vehicle-to-vehicle (V2V), vehicle-to-roadside infrastructure (V2I), vehicle-to-pedestrian (V2P), and vehicle-to-network (V2N), see Figure 6. LTE V2X intends to reuse the higher layers and services specified by ETSI, specifying only the lower layers. An LTE solution will benefit from the existence of an already-deployed network infrastructure to support many of the use cases and to provide increased level of security over distributed systems.

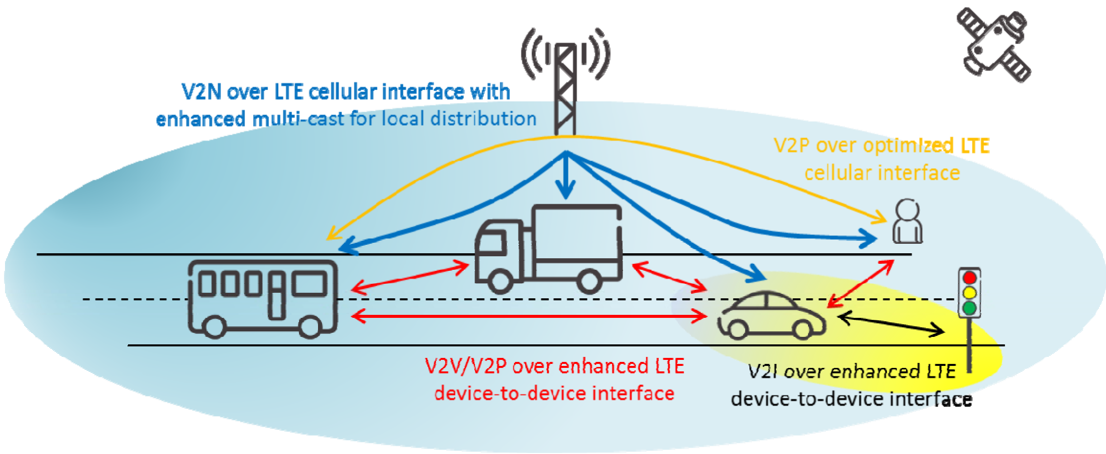

Figure 6: Illustration of the different ITS connectivity scenarios and the different LTE interfaces.

The standardization started in Release 13 by identifying the uses cases of V2X services along with their requirements. This is followed by enhancing the existing interfaces that are necessary to support the connectivity scenarios [12].

The direct link interface, used for example in V2V or V2P, need to support increased terminal mobility. At typical vehicle speeds, the transmitted signals are significantly degraded, especially at high carrier frequencies where, e.g., the coherence time of the channel is much shorter than in traditional cellular communications. Thus, it is necessary to introduce a new LTE subframe structure with increased pilot-symbol density that allows for accurate channel estimation. Similarly, the cellular methods for obtaining frequency synchronization do not perform well in these scenarios. One possibility to overcome this problem is to derive synchronization from an absolute time reference obtained from positioning satellites. An enhanced pilot structure may also allow for resolving larger frequency misalignments between transmitter and receiver.

Other enhancements are motivated by the high user densities that are typical of urban environments. For example, improvements to the resource allocation algorithms are necessary to improve system capacity. Sensing-based distributed resource allocation may alleviate congestion in scenarios with moderate loads, whereas centralized resource allocation may be necessary in the most challenging cases such as in traffic jams. Location information may be used to improve spatial reuse of radio resources.

For the cellular interface, e.g., used for V2N, the motivations are similar. For example, in scenarios with high densities of users, multi-cast transmission with local distribution of the traffic may be used to alleviate network. This can be realized by performing a local breakout of the traffic before it reaches the core network and redistributing the packets locally. In this way latency is minimized, which is critical for safety applications. Similarly, optimizations to the scheduling protocols are necessary to reduce the overhead and to enable low-latency transmissions. Enhancements to the signaling protocols are also necessary to provide support for high mobility. For example, in urban scenarios, service continuity needs to be ensured for terminals that may change the serving cell frequently. Other general enhancements for ITS include higher-layer protocol optimizations and security solutions for V2X.

9 Multimedia Broadcast and Multicast Services

Evolved Multimedia Broadcast Multicast Service (eMBMS) provides an efficient way to deliver download as well as streaming content to multiple users. Especially mobile video streaming is generating a major volume of network data traffic in the future. Commercial deployments of eMBMS or "LTE Broadcast" are generating increasing interest and to meet the industry and operators' demand it is important to enhance eMBMS further, especially with a focus on use cases including linear TV, Live, Video on Demand, smart TV, and over-the-top content.

eMBMS uses the Multimedia Broadcast Single Frequency Network (MBSFN) transmission mode, where all cells in an area transmit the broadcast signal synchronously. Interference does not occur from any cell in the area where the signal arrives with a delay shorter than the Cyclic Prefix (CP). The CP available today for eMBMS is 16.7us but this is not large eough to offer higher spectral efficency of 2 bps/Hz in relevant deploymnet sceanarios such as lower 700 and 800 MHz frequency bands and rural scenarios with smaller indoor losses or outdoor rooftop antennas for TV reception, This motivates the introduction of SFN transmission with a longer CP, up to 100-200µs to cater for larger ISDs of 15km or more. In order to keep the relative overhead of the CP constant, the OFDM symbol length and thereby the number of subcarriers needs to be increased proportionally.

Furthermore, currently only six subframes out of the ten of a radio frame can be allocated to eMBMS. By extending this number, the broadcast capacity can be increased, for example when eMBMS is deployed on a supplementary downlink carrier. A further broadcast capacity enhancement is the support for MBSFN subframes without any unicast control region. This since with almost all subframes allocated to eMBMS, there is hardly any use for the control region.

The above mentioned enhancements are being addressed in release 14 [13], and may ultimately lead to an LTE carrier that is dedicated to eMBMS.

10 Positioning Enhancements

Recently, FCC introduced new positioning requirements with dedicated focus on indoor users [14]. It has been concluded that the baseline positioning functionalities introduced in release 9 meets the horizontal accuracy requirements in adequately densely deployed networks [15]. The exact metric for evaluating vertical accuracy is still under discussion [14]. Some solution components for vertical positioning was introduced in release 13 such as UE reporting of WiFi and Bluetooth nodes, and uncompensated barometric pressure, which will be further addressed with network assistance aspects in release 14.

In addition, release 14 enhancements include more general means to generate positioning reference signals (PRSs). This is motivated by the need to generate different PRSs from different remote radio heads associated to the same cell, as well as to enable better interference suppression. Moreover, the focus will also be on terrestrial beacon systems with PRS beacons on a dedicated carrier to support positioning. Furthermore, the reporting format and requirements of observed time difference of arrival (OTDOA) will be revisited to enable finer granularity reporting. UE receivers have become more accurate since the requirements were specified and a finer reporting prevents the positioning performance from be limited by the report quantization.

11 Summary and Conclusion

This article has provided a high-level overview of some of the major technology areas considered for the further evolution of LTE in release 14, including support for reduced latency, enhancements to LTE in unlicensed spectrum, enhancements to machine type communication, further enhancements for using multiple antennas, support for intelligent transportation systems, e.g. by means of direct vehicle-to-vehicle communication, and enhanced support for TV services.

With the above enhancements, the LTE evolution will strive to meet the 5G requirements and to address 5G use cases. As a complement to the new 5G air interface LTE will remain an essential component of any future wireless access network.

12 References

[1] A. Osseiran et.al, “Scenarios for 5G mobile wireless communications: the vision of the METIS project,” IEEE Communication Magazine, vol. 52, no. 5, pp. 26—35, May 2014

[2] ITU-R, “IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond,” Recommendation ITU-R M.2083-0 (09/2015)

[3] 3GPP TR 38.913, “Study on scenarios and requirements for next generation access technologies;” V0.2.0, (2016-02)

[4] 3GPP TR 36.881, “Study on latency reduction techniques for LTE,” V0.6.0 (2016-02)

[5] 3GPP TR 36.889, "Study on licensed-assisted access to unlicensed spectrum", V13.0.0 (2015-06)

[6] 3GPP TR 36.888, “Study on provision of low-cost machine-type communication (MTC) user equipments (UE),” V12.0.0 (2013-06)

[7] RP-151621, “New work item: Narrowband IOT (NB-IOT),” Qualcomm, 3GPP TSG RAN Meeting #69, Phoenix, USA, Sept. 14-16, 2015

[8] RP-160677, “New SI: Further enhancements to LTE device to device, UE to network relays for IoT and wearables”, Qualcomm Incorporated, Intel, Huawei, HiSilicon, LG Electronics Inc.

[9] RP-160540, “Signaling reduction to enable light connection for LTE”, Huawei, Intel Corporation, China Telecom.
[10] 3GPP TR 36.897, “Study on elevation beamforming/full-dimension (FD) multiple input multiple output (MIMO) for LTE (Release 13)”, v 13.0.0 (2015-06)
[11] RP-160623, “New WID proposal: Enhancements on full-dimension (FD) MIMO for LTE,” Samsung, 3GPP TSG RAN Meeting #71, Göteborg, Sweden, March 7-10, 2016
[12] 3GPP TR 36.885, “Study on LTE-based V2X services,” V1.0.0 (2016-03)
[13] RP-160675, “New WID: eMBMS enhancements for LTE,” Ericsson, Qualcomm Inc., Nokia Networks, EBU, 3GPP TSG RAN Meeting #71, Göteborg, Sweden, March 7-10, 2016
[14] FCC 15-9 “Wireless E911 location accuracy requirements, fourth report and order,” February 2015.
[15] 3GPP TR 37.857 “Study on indoor positioning enhancements for UTRA and LTE,” V.13.1.0 (2015-12)