1

Introduction

Harri Holma

1.1 Introduction

Mobile broadband technology has experienced an incredibly fast evolution during the last 10 years. The first High-Speed Downlink Packet Access (HSDPA) network was launched 2005 enabling the high-speed mobile broadband and the first iPhone was launched 2007 creating the massive need for the mobile broadband. The data rates have increased more than 100-fold and the data volumes by more than 1000-fold during the last 10 years. The HSDPA started with 3.6 Mbps while the latest Long-Term Evolution (LTE)-Advanced networks deliver user data rates of 300 Mbps during 2014 and 450 Mbps during 2015. But still, we have just seen the first part of the mobile broadband era – the fast evolution continues forward. Also, the number of mobile broadband subscribers is increasing rapidly with affordable new smartphones providing the internet access for the next billions of users.

This chapter shortly introduces the status of LTE networks globally, the traffic growth, LTE in Third Generation Partnership Project (3GPP) and the spectrum aspects. The chapter also discusses the importance of the small cell deployments, the network optimization and the LTE.

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Edited by Harri Holma, Antti Toskala and Jussi Reunanen.

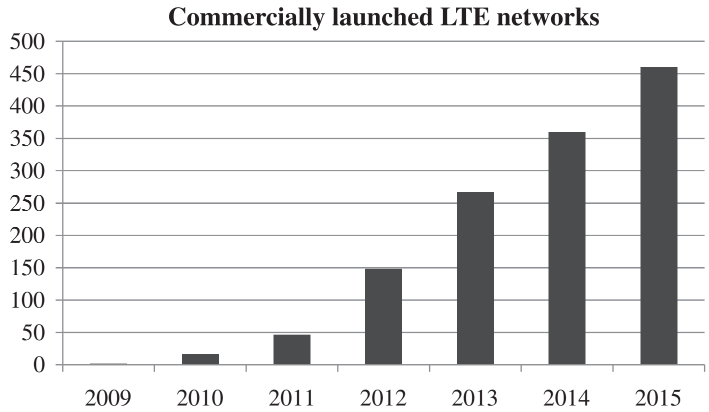

Figure 1.1 Commercially launched LTE networks [1]

1.2 LTE Global Deployments and Devices

The first commercial LTE network was opened by Teliasonera in Sweden in December 2009 marking the new era of high-speed mobile communications. The number of commercial LTE networks has already increased to 460 in more than 140 countries by end 2015. The fast growth of launches has happened during 2012–2015. It is expected that more than 500 operators in more than 150 countries will soon have commercial LTE network running. The number of launched networks is shown in Figure 1.1.

The very first LTE devices supported 100 Mbps in the form factor of Universal Serial Bus (USB) modem. Soon LTE capability was introduced into high end and mid-priced smartphones with the bit rate up to 150 Mbps. By 2015, LTE radio is found in most smartphones excluding the very low end segment at 50-USD. The data rate capability is increased to 300 Mbps, and 450 Mbps, in the latest devices. An example drive test throughput is shown in Figure 1.2 illustrating that it is possible to get very close to 300 Mbps in the good channel conditions in

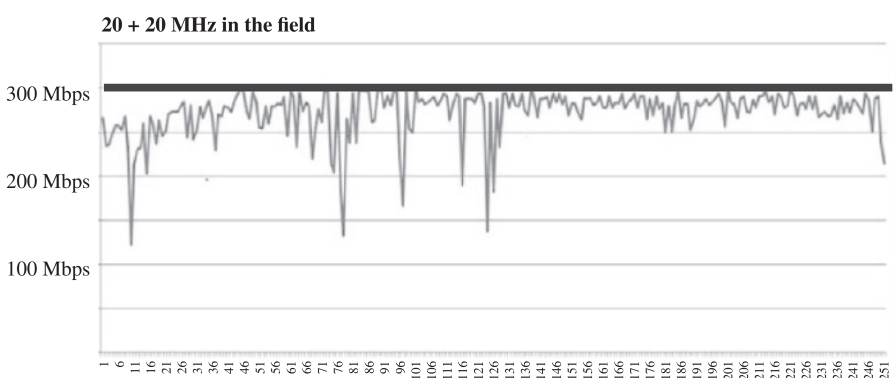

Figure 1.2 Drive test data rate with Category 6 LTE device

Figure 1.3 Example Category 6 LTE device supporting 300 Mbps

the field with Category 6 devices. An example of such a device is shown in Figure 1.3. Also, the support for Voice over LTE (VoLTE) is included, which allows to use LTE network not only for data connections but also for voice connections.

1.3 Mobile Data Traffic Growth

The mobile data traffic has grown rapidly during the last few years driven by the new smartphones, large displays, higher data rates and higher number of mobile broadband subscribers. The mobile data growth for 2-year period is illustrated in Figure 1.4. These data are collected from more than 100 major operators globally. The absolute data volume in this graph is more than million terabytes, that is, exabytes, per year. The data traffic has grown by a factor of 3.6× during the 2-year period, which corresponds to 90% annual growth. The fast growth of mobile data is expected to continue. The data growth is one of the reasons why more LTE networks are required, more spectra are needed, radio optimization is necessary and why small cells will be deployed. All this data growth must happen without increase in the operator revenues. Therefore, the cost per bit must decrease and the network efficiency must increase correspondingly.

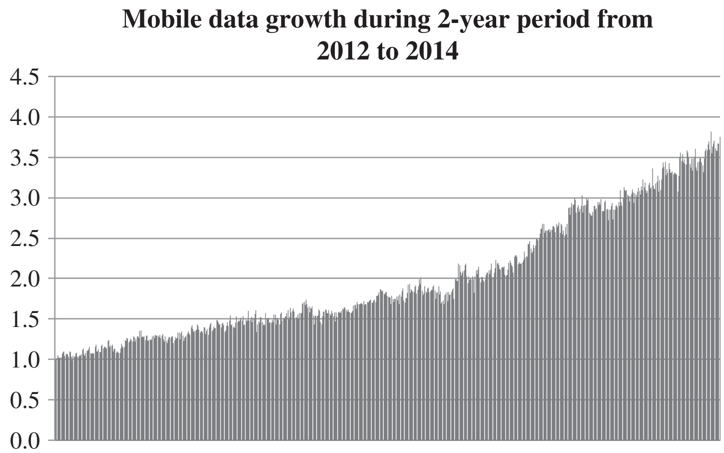

Figure 1.4 Mobile data growth during 2-year period

1.4 LTE Technology Evolution

The LTE technology has been standardized by Third Generation Partnership Project (3GPP). The LTE was introduced in 3GPP Release 8. The specifications were completed and the backwards compatibility started in March 2009. Release 8 enabled peak rate of 150 Mbps with 2×2 MIMO, low latency, flat network architecture and the support for 4-antenna base station transmission and reception. Release 8 enabled in theory also 300 Mbps with 4×4 MIMO but the practical devices so far have two antennas limiting the data rate to 150 Mbps. Release 9 was a relatively small update on top of Release 8. Release 9 was completed 1 year after Release 8 and the first deployments started during 2011. Release 9 brought enhanced Multimedia Broadcast Multicast Solution (eMBMS) also known as LTE-Broadcast, emergency call support for VoLTE, femto base station handovers and first set of Self-Organizing Network (SON) functionalities. Release 10 provided a major step in terms of data rates and capacity with Carrier Aggregation (CA), higher order MIMO up to eight antennas in downlink and four antennas in uplink. The support for Heterogeneous Network (HetNet) was included in Release 10 with the feature enhanced Inter-Cell Interference Coordination (eICIC). Release 10 was completed in June 2011 and the first commercial carrier aggregation network started in June 2013. Release 10 is also known as LTE-Advanced. Release 11 enhanced LTE-Advanced with Coordinated Multipoint (CoMP) transmission and reception, with further enhanced ICIC (feICIC), advanced UE interference cancellation and carrier aggregation improvements. First Release 11 commercial implementation was available during 2015. Release 12 was completed in 3GPP in March 2015 and the deployments are expected by 2017. Release 12 includes dual connectivity between macro and small cells, enhanced CoMP (eCoMP), machine-to-machine (M2M) optimization and device-to-device (D2D) communication. Release 13 work started during second half of 2014 and is expected to be completed during 2016. Release 13 brings Licensed Assisted Access (LAA) also known as LTE for Unlicensed bands (LTE-U), Authorized Shared Access (ASA), 3-dimensional (3D) beamforming and D2D enhancements.

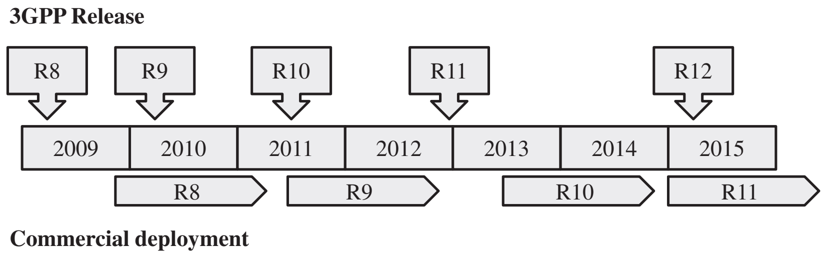

Figure 1.5 3GPP Release availability dates

The timing of 3GPP releases in standardization and in first commercial networks is shown in Figure 1.5. The main contents of each release are summarized in Figure 1.6.

The radio data rate has increased very fast with LTE and LTE-Advanced and 150 Mbps was available with Release 8 commercially during 2010 when using continuous 20 MHz spectrum allocation and 2×2 MIMO. The carrier aggregation with 10 + 10 MHz during 2013 enabled 150 Mbps also for those operators having just 10 MHz continuous spectrum. The aggregation of 20 + 20 MHz during 2014 pushed the peak rate to 300 Mbps and three-carrier aggregation (3CA) further increased the data rate up to 450 Mbps during 2015. The evolution is expected to continue rapidly in the near future with commercial devices supporting 1 Gbps with 100 MHz of total bandwidth. The evolution of device data rate capabilities is illustrated in Figure 1.7. The terminals used to be the limiting factor in terms of data rates but now the limiting factor is rather the amount of spectrum that can be allocated for the connection. Those operators having more spectrum resources available will have an advantage in terms of data rate capabilities. The carrier aggregation aspects are discussed in Reference [2].

1.5 LTE Spectrum

The LTE-Advanced needs lot of spectrum to deliver high capacity and data rates. The typical spectrum resources in European or some Asian markets are shown in Figure 1.8. All the

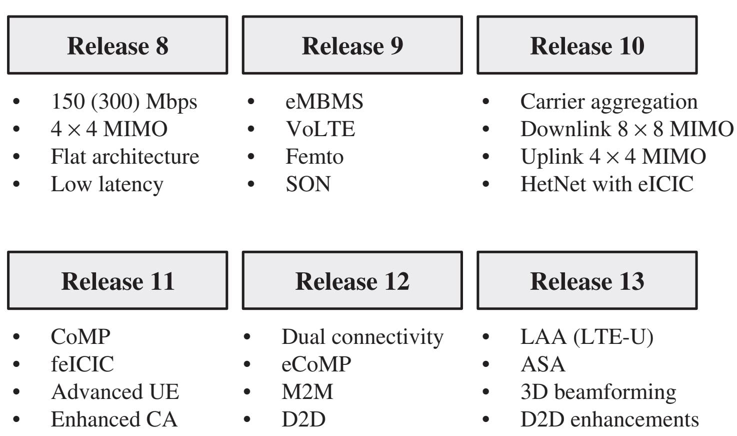

Figure 1.6 Main contents of each release

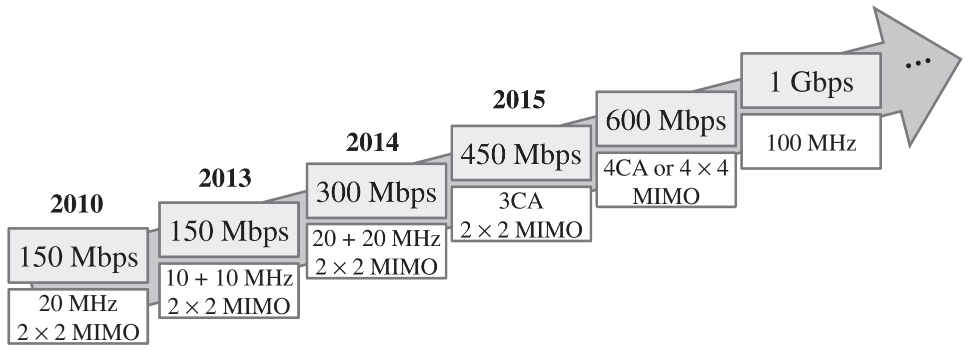

Figure 1.7 Peak data rate evolution in commercial devices

spectrum between 700 and 2600 MHz will be aggregated together. The carrier aggregation of the multiple spectrum blocks together helps in terms of network traffic management and load balancing in addition to providing more capacity and higher data rates. The higher frequency at 3.5 GHz can also be aggregated in the macro cells especially if the site density is high in the urban areas. Another option is to use 3.5 GHz band in the small cell layer. The unlicensed band at 5 GHz can be utilized in the small cells for more spectrum [3]. In the best case, more than 1 GHz of licensed spectrum is available for the mobile operators and more when considering the unlicensed spectrum.

1.6 Small Cell Deployments

The small cell deployments are driven by the need for improved network quality, higher data rates and more capacity. So far most of the base stations have been high power macro base

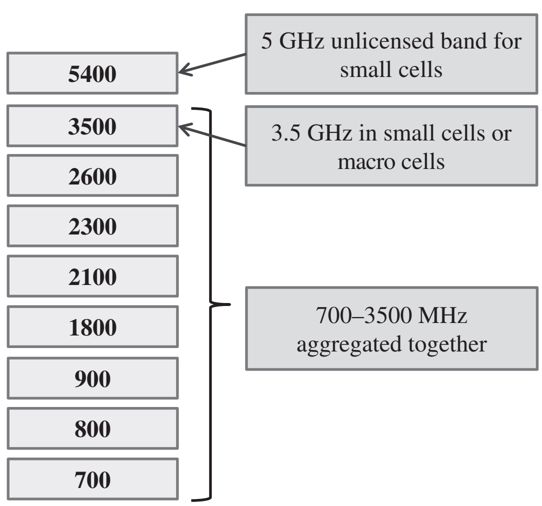

Figure 1.8 Example spectrum resources for LTE usage

Figure 1.9 The LTE micro cell base station with 5 kg, 5 L and 5+5 W

stations while some small cells are being deployed in the advanced LTE networks. The small cell rollouts have come simpler than earlier because the new products are compact and include SON features for automatic configuration and optimization. An example micro base station product is shown in Figure 1.9: Nokia FlexiZone micro with 5+5 W of output power in 5 kg and 5 L outdoor capable package. The lower power indoor products are even smaller and more compact.

The small cell deployment is different from the traditional macro cells and requires new competences and tools. For example, the location of the cell is important for the maximal benefit of the small cell. If the small cell is located close to the hotspot users, it can offload lot of macro cell traffic. But if the small cell location is less optimal, it collects hardly any traffic and increases interference. The interference management is also critical between macro and small cells in the co-channel deployment.

The 3GPP brings a number of enhancements for HetNet cases in LTE-Advanced for interference management, for multi-cell reception and for higher order modulation.

1.7 Network Optimization

The LTE networks need optimization in order to deliver the full potential of LTE technology. The Key Performance Indicators (KPIs) like success rates and drop rates must reach sufficient levels, the data rates should match the expectations for 4G technology and the coverage must fulfil the operator promises. These basic optimizations not only include traditional RF and antenna optimization but also LTE-specific parameter and planning solutions like cell identity planning, link adaptation and power control parameterization and scheduler optimization. The hotspot areas and especially mass events call for more advanced optimization to deliver stable

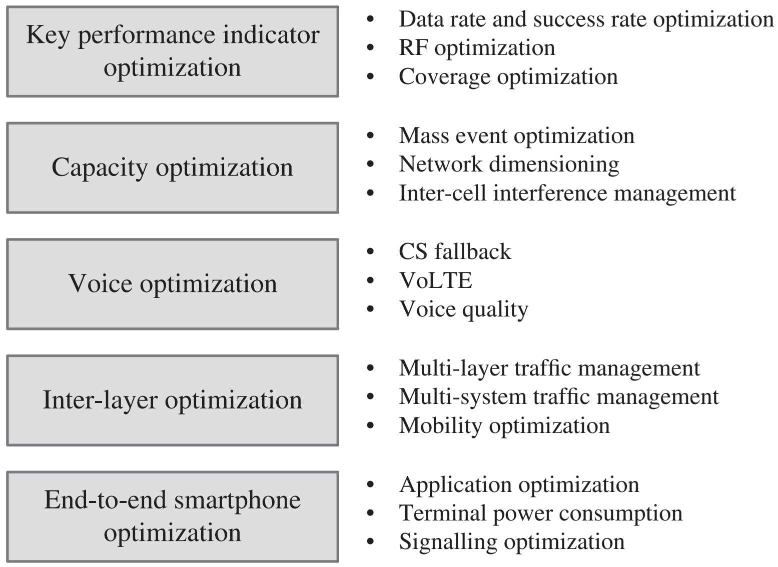

Figure 1.10 Key areas of LTE network optimization

network operator during the extreme loading when tens of thousands of customers are in the same location like sports stadiums. The interference management and control channels are the critical areas in those venues.

The initial LTE networks did not support voice but CS voice in the legacy 2G and 3G networks was used instead. The CS fallback requires some optimization while VoLTE needs further optimization steps to deliver the same or higher quality voice than with CS voice.

Both 2G and 3G networks typically had two frequency bands in use for each operator while LTE networks can have more than six LTE bands. Such complex spectrum allocation requires careful planning how the multiple frequencies are used together. The interworking to the underlying 3G network is also needed for both voice and data until LTE deployment reaches full coverage and VoLTE is used by all customers.

The end-user experience is impacted also by the terminal power consumption, by the application performance and by the device operating system. The end-to-end application optimization needs to consider all these aspects to deliver an attractive user experience to the customer's smartphone or other device.

The key areas of LTE network optimization are summarized in Figure 1.10 and will be explained in detail in this book.

1.8 LTE Evolution Beyond Release 13

The 3GPP is busy working with Release 13 during 2015 and 2016, but it will not be the end of LTE technology. The target is to utilize the massive ecosystem of the LTE radio also for other use cases and applications. Figure 1.11 illustrates new services that can be supported by the LTE radio and the corresponding technical solution. There are more than 7 billion

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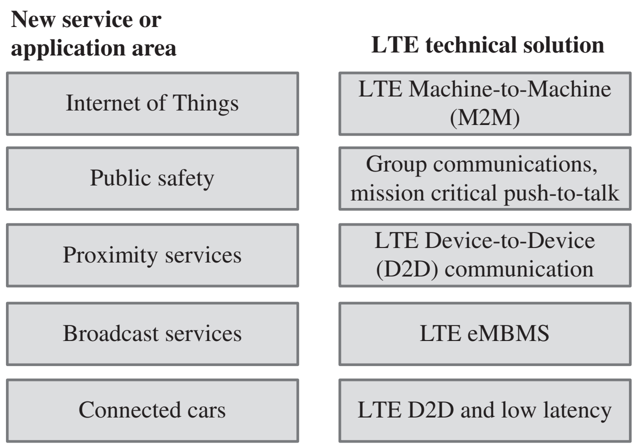

Figure 1.11 New application areas for LTE radio

mobile connections globally during 2016 but a lot more connected devices are expected in the future when many objects will have an internet connection – that is called Internet of Things (IoT). The LTE M2M optimization is targeting on that application area. The LTE can also be utilized for the public safety networks, like police and firemen. When the public safety applications utilize LTE technology, the performance will be far better than in the traditional public safety radios and the communication can even run on top of commercial networks making the solution also more cost efficient. The public safety applications need direct D2D communication. The same D2D functionality can also be utilized for many new proximity services between devices. The LTE broadcast service could eventually replace terrestrial TV by using eMBMS. Other new application areas can be connected cars for traffic safety and for entertainment or backhauling the Wi-Fi access points in the airplanes. The new service capabilities are illustrated in Reference [4].

1.9 Summary

The mobile broadband technology has experienced an impressive evolution during the last 10 years in terms of data usage, data rates and connected smartphones, tablet and computers. The data volumes have increased more than by a factor of 1000× and the data rates have increased by more than a factor of 100×. The further evolution continues in 3GPP and in commercial LTE networks. A number of optimization steps are required to take full benefit of LTE technology capabilities including network optimization and small cells. This book focuses on these topics: 3GPP evolution, LTE small cells and LTE network optimization.

References

[1] GSA – The Global Mobile Suppliers Association, July 2015.
[2] 'LTE-Advanced Carrier Aggregation Optimization', Nokia white paper, 2014.
[3] 'LTE for Unlicensed Spectrum', Nokia white paper, 2014.
[4] 'LTE-Advanced Evolution in Releases 12 – 14', Nokia white paper, 2015.