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Introduction

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1.1 Introduction

The huge popularity of smartphones and tablet computers has pushed the need for mobile broadband networks. Users find increasing value in mobile devices combined with a wireless broadband connection. Users and new applications need faster access speeds and lower latency while operators need more capacity and higher efficiency. LTE is all about fulfilling these requirements. GSM made voice go wireless, HSPA made initial set of data connections go wireless and now LTE offers massive capabilities for the mobile broadband applications.

The first set of LTE specifications were completed in 3GPP in March 2009. The first commercial LTE network opened in December 2009. There were approximately 50 commercial LTE networks by the end of 2011 and over 100 networks are expected by the end of 2012. The first LTE smartphones were introduced in 2011 and a wide selection of devices hit the market during 2012. An example LTE smartphone is shown in Figure 1.1: the Nokia 900 with 100 Mbps LTE data rate and advanced multimedia capabilities. Overall, LTE technology deployment has been a success story. LTE shows attractive performance in the field in terms of data rates and latency and the technology acceptance has been very fast. The underlying technology capabilities evolve further which allows pushing also LTE technology to even higher data rates, higher base station densities and higher efficiencies. This book describes the next step in LTE evolution, called LTE-Advanced, which is set to increase the data rate even beyond 1 Gbps.

1.2 Radio Technology Convergence Towards LTE

The history of mobile communications has seen many competing radio standards for voice and for data. LTE changes the landscape because all the existing radios converge towards LTE. LTE is the evolution of not only GSM/HSPA operators but also CDMA and WiMAX operators. Therefore, LTE can achieve the largest possible ecosystem. LTE co-exists smoothly with the current radio networks. Most GSM/HSPA operators keep their existing

LTE-Advanced: 3GPP Solution for IMT-Advanced, First Edition. Edited by Harri Holma and Antti Toskala.

Figure 1.1 An example of an LTE smartphone – Nokia Lumia 900.

GSM and HSPA radio networks running for long time together with LTE, and they also keep enhancing the existing networks with GSM and HSPA evolutions. The LTE terminals are multimode capable supporting also GSM and HSPA. The radio network solution is based on multi-radio base station which is able to run simultaneously all three radios. Many operators introduce multi-radio products to their networks together with LTE rollouts to simplify the network management and to modernize the existing networks.

The starting point for CDMA and WiMAX operators is different since there is no real evolution for those radio technologies happening. Therefore, CDMA and WiMAX operators tend to have the most aggressive plans for LTE rollouts to get quickly to the main stream 3GPP radio technology to enjoy the LTE radio performance and to get access to the world market terminals.

The high level technology evolution is illustrated in Figure 1.2.

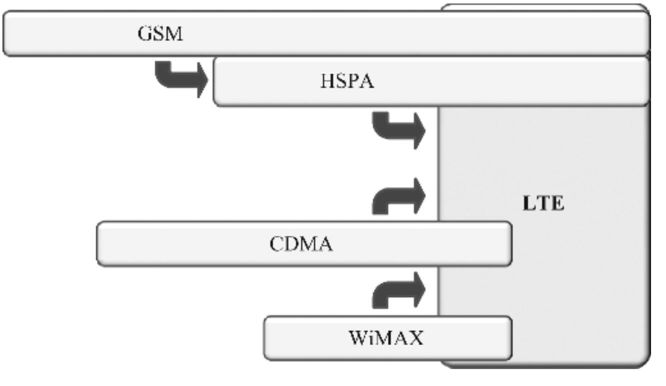

Figure 1.2 Radio technology convergence towards LTE.

1.3 LTE Capabilities

LTE Release 8 offers peak data rate of 150 Mbps in downlink by using 20 MHz of bandwidth and 2 × 2 MIMO. The first LTE devices support up to 100 Mbps while the network capability is up to 150 Mbps. The average data rates in the commercial networks range between 20 and 40 Mbps in downlink and 10–20 Mbps in uplink with 20 MHz bandwidth. Example drive test results are shown in Figure 1.3. Practical LTE data rates in many cases are higher than the available data rates in fixed Asymmetric Digital Subscriber Lines (ADSL). LTE has been deployed using number of different bandwidths: most networks use bandwidth from 5 to 20 MHz. If the LTE bandwidth is smaller than 20 MHz, the data rates scale down correspondingly. LTE has been rolled out both with Frequency Division Duplex (FDD) and Time Division Duplex) TDD variants. LTE has the benefit that both the FDD and TDD modes are highly harmonized in standardization.

The end user performance is also enhanced by low latency: the LTE networks can offer round trip times of 10–20 ms. The LTE connections support full mobility including seamless intra-frequency LTE handovers and inter-RAT (Radio Access Technology) mobility between LTE and legacy radio networks. The terminal power consumption is optimized by using discontinuous reception and transmission (DRX/DTX).

LTE also offers benefits for the operators in terms of simple network deployment. The flat architecture reduces the number of network elements and the interfaces. Self-Organizing Network (SON) has made the network configuration and optimization simpler enabling faster and more efficient network rollout.

LTE supports large number of different frequency bands to cater the needs of all global operators. The large number of RF bands makes it challenging to make universal LTE devices. The practical solution is to have several different device variants for the different markets. The roaming cases are handled mainly by legacy radios.

Initial LTE smartphones have a few different solutions for voice: Circuit Switched Fallback (CSFB) handover from LTE to legacy radio (GSM, HSPA, CDMA) or dual radio CDMA + LTE radio. Both options use the legacy circuit switched network for voice and

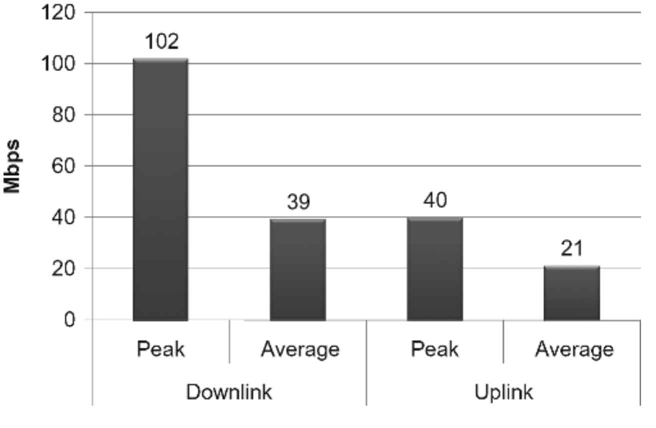

Figure 1.3 Example drive test data rates in LTE network with 20 MHz bandwidth.

LTE network for data. The Voice over LTE (VoLTE) solution with Voice over IP (VoIP) also started during 2012.

1.4 Underlying Technology Evolution

The radio technology improvements need to be supported by the evolution of the underlying technologies. The technology components – including mass storage, baseband, RF and batteries – keep evolving and help the radio improvements to materialize. The size of the mass storage is expected to have fastest growth during the next ten years which allows for storing more data on the device and which may fuel data download over the radio. The memory size can increase from tens of Gigabytes to several Terabytes. Also the digital processing has its strong evolution. The digital processing power has improved according to Moore's law for several decades. The evolution of the integration level will not be as easy as in earlier times, especially when we need to minimize the device power consumption. Still, the digital processing capabilities will improve during the 2010s, which allows for processing of higher data rates and more powerful interference cancellation techniques. Another area of improvement is the RF bandwidth which increases mainly because of innovations in digital front end processing. The terminal power consumption remains one of the challenges because the battery capacity is expected to have relatively slow evolution. Therefore, power saving features in the devices will still be needed. The technology evolution is illustrated in Figure 1.4.

LTE-Advanced devices and base stations will take benefit of the technology evolution. Higher data rates and wider bandwidth require baseband and RF evolution. The attractive LTE-Advanced devices also benefit from larger memory sizes and from improved battery capacity.

1.5 Traffic Growth

The data volumes in mobile networks have increased considerably during the last few years and the growth is expected to continue. The traffic growth since 2007 and the expected growth until 2015 are illustrated in Figure 1.5. The graph shows the total global mobile network data volume in Exabytes; that is, millions of Terabytes. The traffic is split into voice traffic and data traffic from laptops, tablets and smartphones. The data traffic exceeded the voice traffic during 2009 in terms of carried bytes. The initial data growth was driven by

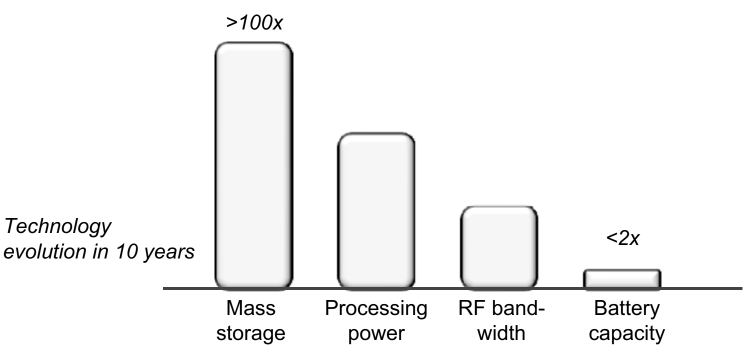

Figure 1.4 Evolution of underlying technology components.

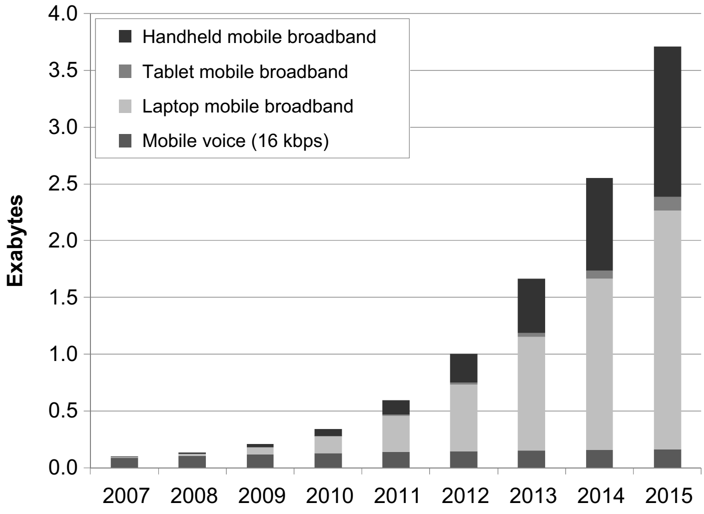

Figure 1.5 Expected traffic growth (Nokia Siemens Network estimate 2011).

the laptop modems; see an example in Figure 1.6. It is also expected that the LTE-Advanced capabilities, like higher data rates, are first introduced for the laptop modems. The relatively fastest growth from 2012 to 2015 is expected to come from smartphones. The smartphones make nearly half of the traffic by 2015. The total traffic by 2015 will be approximately 40 times more than the traffic 2007. The share of voice traffic is expected to shrink to less than 5% by 2015. Some of the advanced markets already have the total traffic 50 times more than the voice traffic; that means voice is less than 2% of total traffic.

It is not only the data volume that is growing in the networks but also the amount of signalling grows and the number of connected devices grows. The radio evolution work needs to address all these growth factors.

Figure 1.6 Example of a 100 Mbps USB modem – Nokia Siemens Networks 7210.

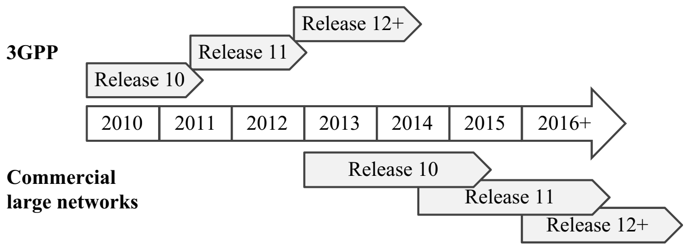

Figure 1.7 3GPP timing of LTE-Advanced.

1.6 LTE-Advanced Schedule

The first set of LTE-Advanced is specified in 3GPP Release 10. That release was completed in June 2011. The target date for Release 11 is December 2012. The typical release cycle in 3GPP has been 1.5 years – except for some smaller releases like Release 9 that was completed in a year. It tends to take another 1.5 years from the specification's completion until the first commercial networks and devices are available. Some small features can be implemented faster while some major features requiring heavy redesign may take more time. We could then expect that the first LTE-Advanced features are commercially available during 2013, and Release 11 features towards end of 2014. The LTE-Advanced schedule is shown in Figure 1.7.

1.7 LTE-Advanced Overview

The main features of LTE-Advanced are summarized in Figure 1.8.

- Downlink carrier aggregation to push the data rate initially to 300 Mbps with $20 + 20$ MHz spectrum and 2×2 MIMO, and later to even 3 Gbps by using 100 MHz bandwidth and 8×8 MIMO. More bandwidth is the handy solution to increase the data rates.
- Multiantenna MIMO evolution to 8×8 in downlink and 4×4 in uplink. The multiantenna MIMO can also be used at the base station while keeping the number of terminal antennas low. This approach offers the beamforming benefits increasing the network capacity while

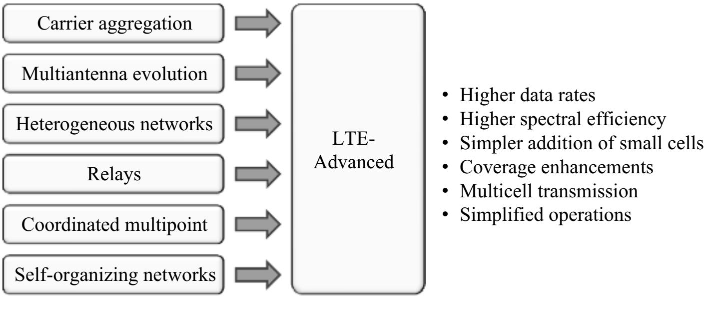

Figure 1.8 Overview of LTE-Advanced main features.

keeping the terminal complexity low. Multiantennas increase the data rates and the network capacity.
- Heterogeneous network (HetNet) for the co-channel deployment of macrocells and small cells. HetNet features enable interference coordination between the cell layers. Those features enhance the network capacity and coverage with high density of small cells while sharing the frequency with large macrocells.
- Relay nodes for backhauling the base stations via LTE radio interface. The transmission link can use inband or outband transmission. Relays are practical for increasing network coverage if the backhaul connections are not available.
- Coordinated multipoint transmission and reception allows using several cells for the data connection towards one terminal. Coordinated multipoint improves especially the cell edge data rates that are limited by inter-cell interference.
- Self-organizing network features make the network rollout faster and simpler, and improves the end user performance by providing correct configurations and optimized parameter setting.

LTE-Advanced features in Release 10 can be upgraded flexibly on top of Release 8 network on the same frequencies while still supporting all legacy Release 8 terminals. Therefore, the evolution from LTE to LTE-Advanced will be a smooth one. All these features will be described in detail in this book.

1.8 Summary

LTE Release 8 has turned out to be a successful technology in terms of practical performance and in terms of commercial network and terminal launches. At the same time the high popularity of smartphones pushes the need for further mobile broadband evolution. LTE-Advanced is designed to enhance LTE capabilities in terms of data rates, capacity, coverage and operational simplicity. The first set of LTE-Advanced specifications was completed in 3GPP during 2011 and the features are expected to be commercially available 2013. LTE-Advanced is backwards compatible with LTE and can co-exist with LTE Release 8 terminals on the same frequency.