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4G

LTE – A 4G SOLUTION

LTE meets – and in most cases exceeds – the requirements for a 4G technology. Through a range of innovative functionalities, LTE enables operators to manage more traffic and meet growing data-rate demands – and is consequently a key enabler for future mobile broadband delivery.

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FUTURE MOBILE BROADBAND – EXPECTED DEMANDS

New services and improved device capabilities mean that mobile broadband traffic and consumer data-rate demands are growing at an unprecedented rate. In particular, mobile broadband traffic has seen almost exponential increases, and in late 2009 overtook voice as the dominant traffic in mobile networks [1].

As illustrated in Figure 1, data-traffic levels in mobile networks are expected to double every year up until 2014 [2], thus far surpassing voice traffic. Extrapolating this trend indicates that the amount of data-traffic can be expected to increase several hundred times in the longer term.

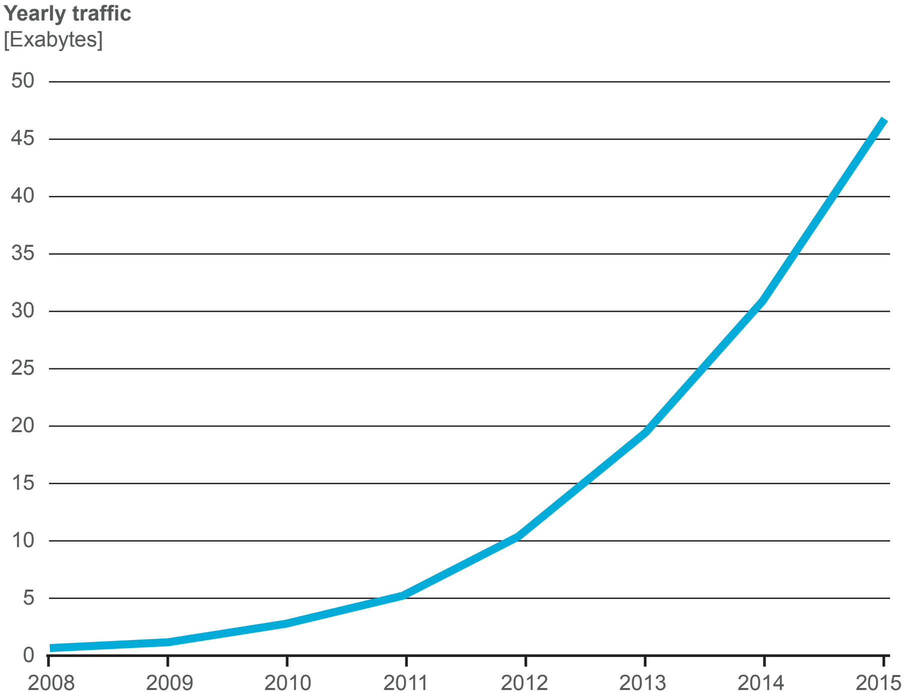

Figure 1: Forecast yearly traffic – data

LTE – ENABLING FUTURE MOBILE BROADBAND

TECHNOLOGIES FOR MOBILE BROADBAND

Mobile broadband networks need to handle the predicted traffic volumes and meet ever-increasing consumer data-rate demands in a responsive manner. An efficient radio-access technology is essential to achieve this – and several technologies are currently available.

3G evolution based on HSPA is one approach. Today, there are more than 330 HSPA-capable mobile broadband networks serving more than 375 million users worldwide [3]. Data rates of several Mbps are generally available and peak data rates as high as 80Mbps are supported by the latest HSPA specifications. HSPA continues to evolve, and it will remain a highly capable and competitive radio-access solution.

In parallel with HSPA, LTE radio-access technology has been developed by 3GPP to offer a fully 4G-capable mobile broadband platform. LTE is an OFDM-based radio-access technology that supports a scalable transmission bandwidth up to 20MHz and advanced multi-antenna transmission including beam-forming and spatial multiplexing with up to four transmit antennas in the downlink direction.

As illustrated in Figure 2, LTE is based on a flat network architecture with base stations (eNodeBs in LTE terminology) connected directly to the Enhanced Packet Core (EPC) network. In the case of the user plane the connection is to the Serving GateWay (SGW), and to the Mobility Management Entity (MME) in the case of the control plane.

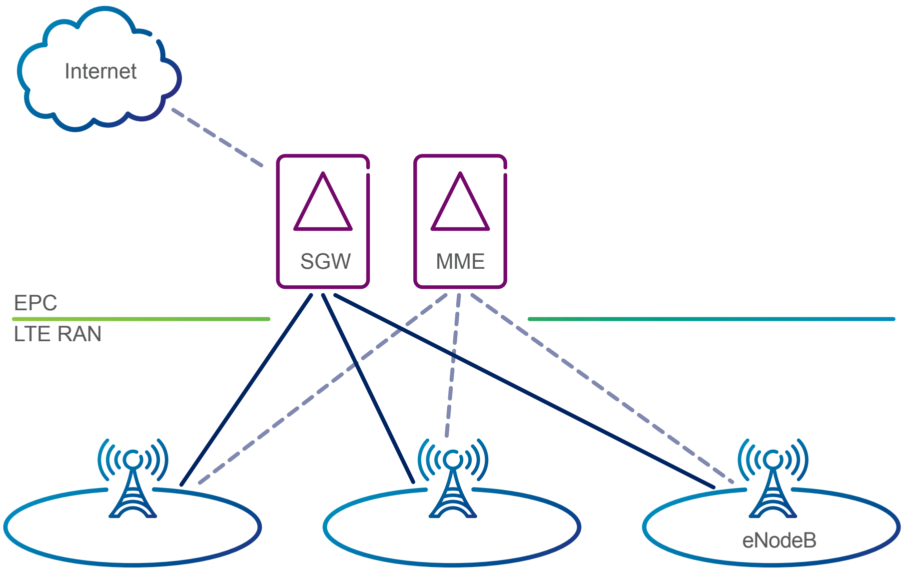

Figure 2: LTE network architecture

LTE EVOLUTION

LTE has gone through a number of evolutionary stages since its initial Release 8. To further extend the performance and capabilities of the LTE radio-access technology, 3GPP initiated work on LTE Release 10 in April 2008. One target was to ensure that LTE fully complies with the requirements for the IMT-Advanced 4G standard as defined by the International Telecommunication Union (ITU) – meaning that LTE can be referred to as a true 4G technology. For this reason, LTE Release 10 is also referred to as LTE-Advanced, although it is important to emphasize that LTE-Advanced is not a new radio-access technology, but simply the name given to LTE Release 10 and beyond.

LTE Release 10 extends the capabilities of LTE in several respects. Through these innovative functionalities, LTE networks can enable operators to manage more traffic and provide higher data rates – and are thus key enablers for future mobile broadband delivery. So how does LTE Release 10 make the difference?

BANDWIDTH EXTENSION AND SPECTRUM AGGREGATION

Operators are increasingly faced with the need to deliver higher end-user data rates. To achieve this, LTE Release 10 facilitates carrier aggregation, allowing for the parallel transmission of multiple LTE carriers to and from a single terminal – thereby enabling increased overall bandwidth and corresponding end-user data rates. Up to five 20MHz carriers can be aggregated, resulting in overall bandwidth of up to 100MHz for both downlink and uplink, as shown on the left in Figure 3.

In addition to aggregation of contiguous carriers within a single frequency band, LTE also supports aggregation of carriers in different frequency bands. Such out-of-band carrier aggregation, or spectrum aggregation, as illustrated on the right in Figure 3, allows operators with fragmented spectra to provide wider bandwidths, enabling higher end-user data rates and more efficient utilization of the overall available spectrum.

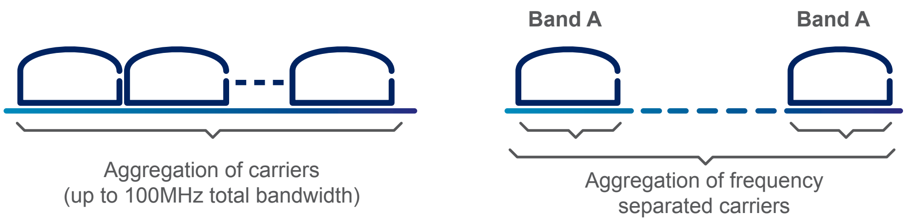

Figure 3: Carrier aggregation with contiguous carriers (left) and frequency-separated carriers (right)

EXTENDED MULTI-ANTENNA TRANSMISSION

LTE Release 10 extends the LTE downlink multi-antenna transmission capabilities to support spatial multiplexing with up to eight transmit antennas and eight corresponding transmission layers. Together with the bandwidth extension up to 100MHz enabled by carrier aggregation, this allows for peak data rates in the order of 3Gbps or 30bps/Hz.

LTE Release 10 also supports uplink multi-antenna transmission, with up to four transmit antennas and four corresponding transmission layers. This facilitates uplink peak data rates in the order of 1.5Gbps in 100MHz or 15bps/Hz.

RELAYING FUNCTIONALITY

LTE Release 10 supports relaying functionality, allowing mobile terminals to communicate with the network via a relay node wirelessly connected to a donor-eNodeB using the LTE radio-access technology and LTE spectrum, as Figure 4 illustrates. From a terminal point of view, the relay node will appear as a “normal” base station, meaning that earlier-release terminals can also access the network via the relay node.

Relaying functionality may provide a fast and cost-efficient way to extend the coverage of an LTE network. This includes coverage-area extensions as well as data-rate extensions.

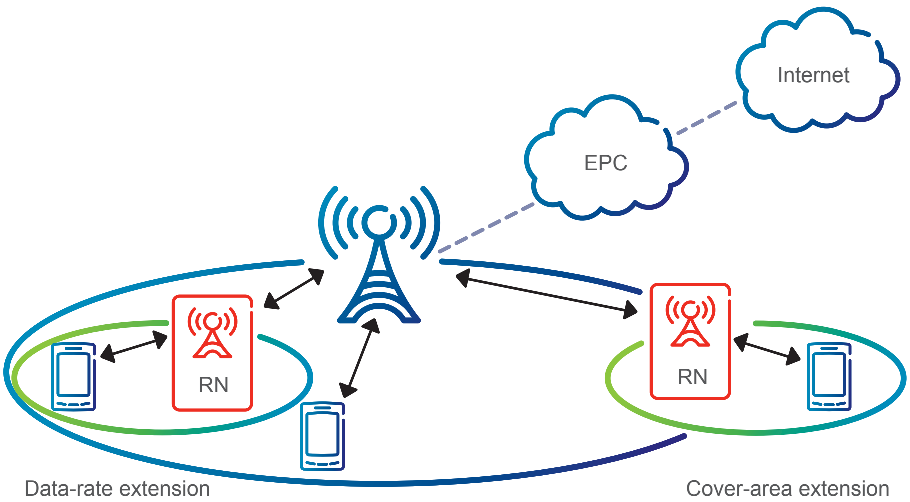

Figure 4: LTE relaying functionality

ENHANCED SUPPORT FOR HETEROGENEOUS NETWORK DEPLOYMENTS

Densification of the radio-access network can assist in fulfilling future traffic and data-rate demands. As Figure 5 shows, this includes complementing a macro-cell layer with additional low-power pico cells which extend traffic and data-rate capabilities when needed.

Such heterogeneous network (HetNet) deployments are already possible in currently implemented mobile communication networks, including the first release of LTE. However, LTE Release 10 includes features that can be used to further mitigate interference between the different cell layers, thereby extending the potential scope of HetNet deployments.

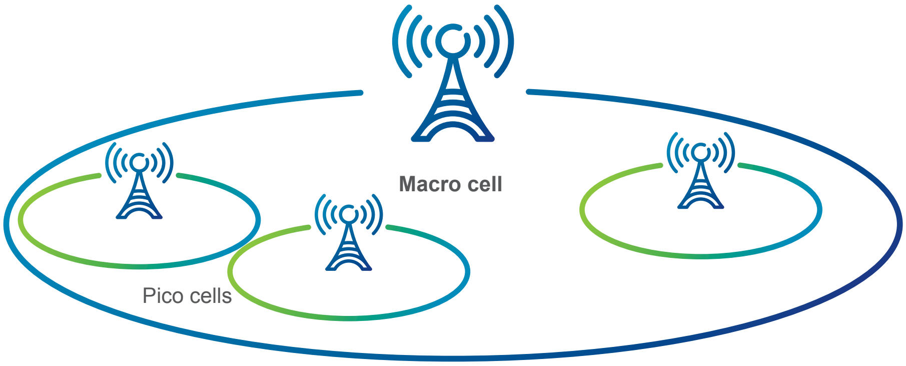

Figure 5: HetNet deployment

SPECTRUM CONVERGENCE

A key benefit of all LTE releases is that they provide convergence in terms of radio access for paired and unpaired spectrum, allowing for more efficient spectrum utilization.

There are two duplex alternatives for mobile communication: FDD for paired spectrum and TDD for unpaired spectrum. Until now, these duplex schemes have been supported by different 3GPP radio-access technologies, namely GSM and WCDMA/HSPA for FDD and TD-SCDMA for TDD. Although FDD has historically been the dominant duplex scheme for mobile communication, interest in TDD is growing. One of the reasons for this is the availability of unpaired spectrum, the efficient use of which requires a highly capable and globally accepted TDD technology.

By supporting both FDD and TDD within the same radio-access technology, LTE provides convergence of radio access for paired and unpaired spectrum into a single globally accepted technology. This is especially beneficial for TDD and utilization of unpaired spectrum, which have until now suffered from limited terminal availability and market momentum.

RELATION OF LTE TO ITU AND 4G

IMT-Advanced is a next-generation mobile communication technology defined by ITU that includes capabilities exceeding those of IMT-2000 (3G) mobile communication. ITU refers to IMT-Advanced as a fourth generation (4G) mobile communication technology, although it should be noted that there is no universally accepted definition of the term 4G.

ITU has defined a set of requirements that a 4G radio-access technology should fulfill [4]. Some of the more important requirements are presented in Figure 6, together with the corresponding capabilities of LTE.

	ITU REQUIREMENT FOR IMT-ADVANCED	CURRENT LTE CAPABILITY
Maximum bandwidth	At least 40MHz	100MHz
Peak spectral efficiency **– Downlink** **– Uplink**	 At least 15bps/Hz At least 6.75bps/Hz	 30bps/Hz 15bps/Hz
Control-plane latency	Less than 100ms	Less than 100ms
User-plane latency	Less than 10ms	Less than 10ms

Figure 6: Key ITU requirements for IMT-Advanced and current LTE capabilities

ITU has also defined a set of average- and cell-edge-throughput requirements for various well-specified deployment scenarios. These requirements are illustrated in Figure 7, together with the corresponding performance of the LTE radio-access technology.

As can be seen from Figures 6 and 7, LTE not only meets the requirements for IMT-Advanced/4G radio-access, but exceeds them.

RELATION OF LTE TO HSPA AND ITS EVOLUTION

HSPA performs as well as LTE in many areas and for many applications. It also has the benefit of being a well-proven technology with a large footprint. When compared with LTE, the data rates that can currently be provided by HSPA are limited by narrower bandwidths and multi-antenna capabilities imposed by the specification. However, it is likely that some of these limitations will be relaxed in the future, and 3GPP has already initiated work on further extending HSPA bandwidth capabilities to reach the IMT-Advanced requirement of 40MHz.

This means that 3GPP today provides two highly capable radio-access technologies for mobile broadband: 3G evolution based on HSPA and 4G LTE. Just as GSM and its evolution exists in parallel to 3G systems, 3G evolution based on HSPA will exist and flourish in parallel with LTE for many years to come.

MARKET SITUATION

The first fully-commercial LTE network was launched by TeliaSonera in Sweden in December 2009 and today provides coverage for almost 30 Swedish cities [6], delivering typical data rates of several tens of Mbps with close to 100Mbps being achieved in some scenarios.

Several other operators are currently in the process of deploying commercial mobile broadband networks based on LTE. These include AT&T, Verizon and MetroPCS in North America, T-Mobile in Europe, and NTT DoCoMo and KDDI in Japan. LTE has become the main migration path not only for network operators using 3GPP-based technologies, but also for many operators using the 3GPP2-based radio-access technology CDMA2000/1x-EV-DO. In fact, 3GPP2-based operators such as MetroPCS, Verizon and KDDI are among the first to commercially deploy LTE on a large scale.

A number of WiMAX operators are also moving towards LTE. These include the Russian operator Yota [7], which has announced that it will deploy an LTE network, and the North American operator Clearwire [8], which is investigating the introduction of such a network. A further indication that LTE is a preferred long-term solution for mobile broadband is the decision of the Next Generation Mobile Networks (NGMN) alliance to select LTE as its choice of radio-access technology for next-generation mobile broadband [9].

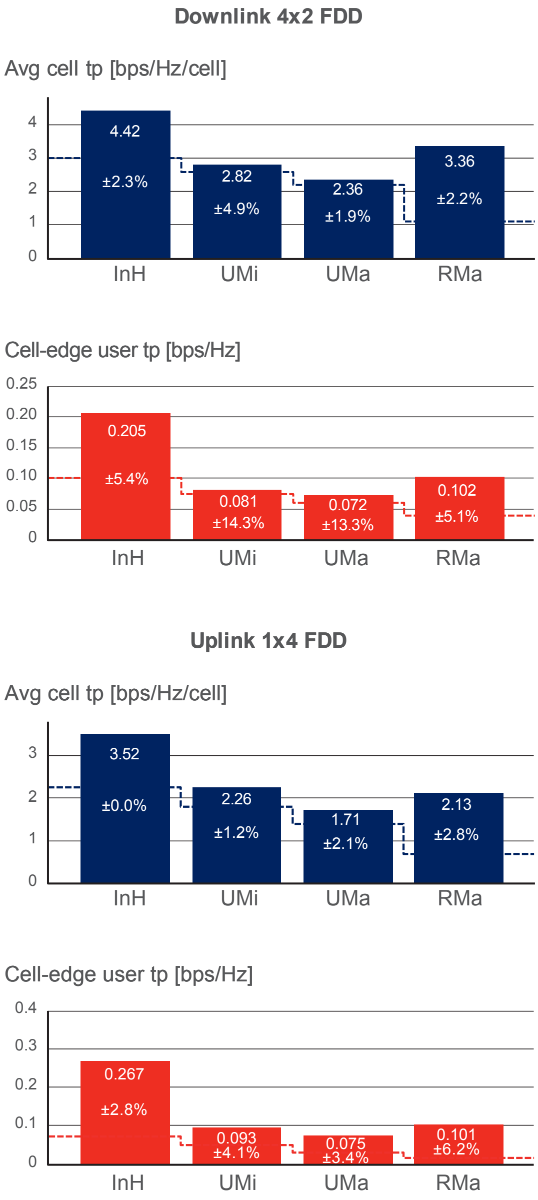

Figure 7: Performance of LTE (bars) compared with the requirements for IMT-Advanced (lines)

CONCLUSION

LTE networks are now in commercial operation alongside HSPA networks. The evolution of LTE, also referred to as LTE-Advanced or LTE Release 10, provides bandwidth extension and spectrum aggregation, extended multi-antenna transmission, relaying functionality and enhanced support for HetNet deployments.

The performance and capabilities of LTE meet, and in many cases exceed, the requirements of IMT-Advanced as defined by ITU. Consequently, LTE is a 4G technology positioned to meet the ever-growing requirements of not only today's mobile broadband networks, but also those of the future.

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GLOSSARY

3G	3rd Generation
3GPP	3rd Generation Partnership Program
3GPP2	3rd Generation Partnership Program 2
4G	4th Generation
CDMA	Code Division Multiple Access
CDMA2000	Code Division Multiple Access 2000
EPC	Enhanced Packet Core
EV-DO	Evolution-Data Optimized
FDD	Frequency Division Duplex
GSM	Global System for Mobile Communication
GSMA	GSM Association
HetNet	Heterogeneous Network
HSPA	High-Speed Packet Access
IMT-2000	International Mobile Telecommunications-2000, better known as 3G
IMT-Advanced	International Mobile Telecommunications Advanced
ITU	International Telecommunication Union
LTE	Long Term Evolution
MME	Mobility Management Entity
NGMN	Next Generation Mobile Networks
OFDM	Orthogonal Frequency Division Multiplexing
RAN	Radio Access Network
SGW	Serving GateWay
TDD	Time Division Duplex
TD-SCDMA	Time Division Synchronous Code Division Multiple Access
WCDMA	Wideband Code Division Multiple Access