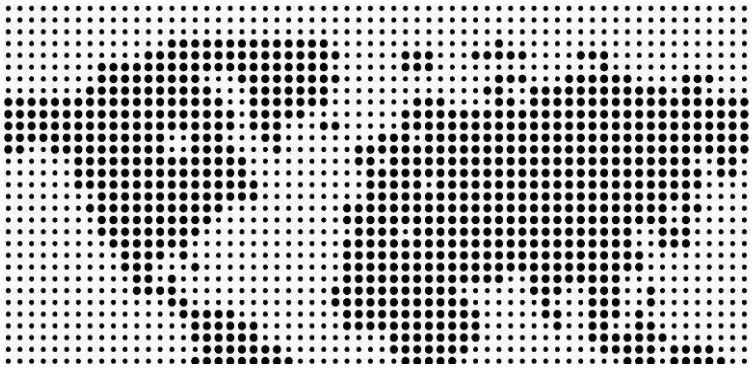
LTE – An Optimized OFDMA Solution for Wider Bandwidth Spectrum



Qualcomm Incorporated
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[1] Executive Summary

EV-DO- and HSPA-based mobile broadband services have been a tremendous success. 3G operators around the world are witnessing a phenomenal growth in broadband data subscriptions and revenues. This growth, fueled by the proliferation of broadband connectivity into many market and device segments is expected to continue. While bracing up to sustain growth, many operators, in addition to evolving their 3G networks, are embracing LTE (Long Term Evolution) to leverage new wider bandwidth spectrum.

LTE is an optimized mobile OFDMA solution standardized by the 3GPP. It leverages wider bandwidths to provide very high data rates and an enhanced user experience. LTE is a parallel evolution path that continues 3G's track record of mobility and high spectral efficiency. Deployed as an overlay on the existing 3G networks, LTE will effectively boost data capacity in high-demand dense urban areas. 3G and its evolutions will provide ubiquitous broadband service outside focused LTE coverage areas, as well as voice services throughout the network. 3G evolutions offer data rates and capacity similar to LTE, when using the same bandwidth and antenna configuration. LTE is designed to seamlessly interoperate with 3G through multimode devices, which will play a pivotal role in initial LTE deployments. Qualcomm, with its industry's first LTE/HSPA+/EV-DO multimode chipset solutions, is in a unique position to support timely LTE deployments.

LTE leverages 3G's large ecosystem and benefits from its extensive experience in designing, building and operating successful mobile systems. Many major operators have already announced plans to trial and commercially deploy LTE to augment data capacity of their existing 3G networks. LTE initial trials are slated for 2009, followed by commercial launches expected in the second half of 2010.

[2] LTE is an Optimized Mobile OFDMA Solution

LTE is designed from ground up for mobility and high capacity, following the footsteps of successful 3G development. The OFDMA modulation scheme adopted by LTE excels in leveraging wider bandwidths to offer high data rates. LTE's low overhead resource management design optimizes use of OFDMA to yield high spectral efficiency (data capacity). LTE's robust mobility features and seamless handoffs also demonstrate its superiority over other OFDMA solutions.

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LTE incorporates advanced antenna techniques such as MIMO (Multiple Input Multiple Output), SDMA (Spatial Diversity Multiple Access) and beamforming to offer enhanced performance. LTE also adopts a new flatter packet-only core network called EPC (Evolved Packet Core) to support IP-based applications and services.

The initial LTE commercial networks are expected to offer peak data rates up to 73 Mbps in the downlink and up to 36 Mbps in the uplink, using 10 MHz of spectrum with 2x2 downlink MIMO. Future phases of LTE will be able to provide even higher data rates using wider bandwidths (up to 20 MHz) and higher order MIMO.

LTE benefits from the large 3G ecosystem and its extensive experience in designing and managing successful mobile systems. Many major operators have already announced LTE trials and deployment plans supported by most of the leading device and infrastructure vendors. With strong momentum behind it, LTE has clearly emerged as the OFDMA technology of choice for many operators.

3GPP froze ASN.1 for Rel.8 in March 2009—a major milestone—in LTE commercialization that paves the way for building interoperable platforms. The first LTE trials are slated for 2009, followed by commercial launches expected in the second half of 2010. Initially, LTE networks will offer data services through devices such as USB dongles, PC cards and embedded data modules.

While LTE Rel.8 commercialization is underway, 3GPP is already busy exploring evolution toward LTE Advanced. Multicarrier techniques that allow harnessing even wider bandwidths (more than 20 MHz), and advanced topology networks that optimize and further improve performance of pico, micro and femtocells, are among the multitude of enhancements being considered for LTE Advanced. LTE Advanced will be a strong candidate for IMT Advanced, currently being defined by ITU.

[3] LTE Leverages New Wider Bandwidth Spectrum

LTE's OFDMA technology excels in leveraging wider bandwidths to provide very high data rates and thereby an excellent user experience, making it best suited for new spectrum with bandwidths 10 MHz or more.

For the existing, refarmed and new non-contiguous spectrum, HSPA+ and EV-DO Rev. B are the most cost-effective upgrade paths. While they provide

similar capacity as LTE with the same bandwidth and same number of antennas, HSPA+ and EV-DO Rev. B also capitalize on the investments that operators have already made.

As depicted in *Figure 1*, LTE supports bandwidths up to 20 MHz as well as both frequency division duplex (FDD) and time division duplex (TDD) modes, allowing operators to address all available spectrum resources.

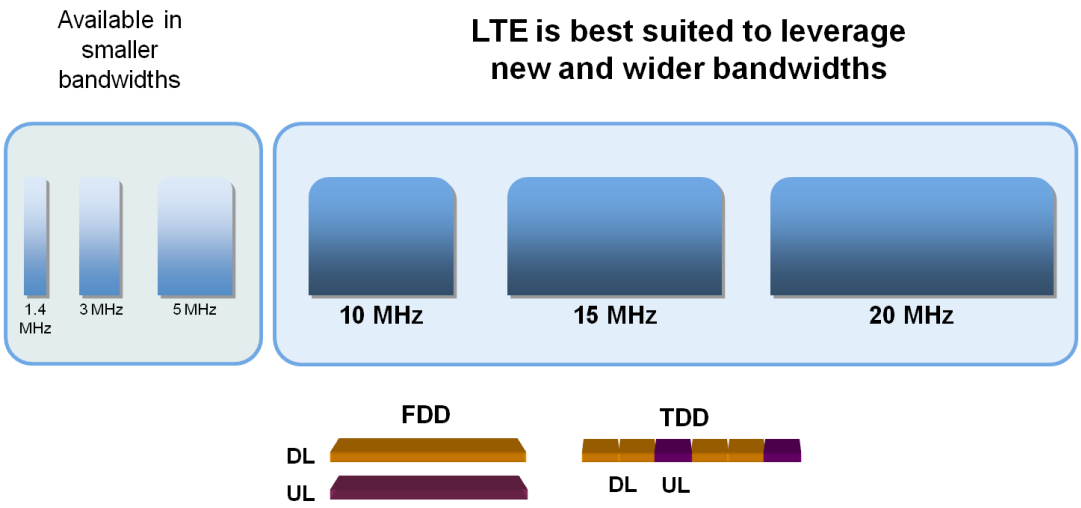

Figure 1: LTE leverages new wider bandwidths

[4] LTE Boosts Data Capacity in Dense Urban Areas

As evident from the recent subscriber and revenue growth registered by many major operators, HSPA- and EV-DO-based mobile broadband services have been a tremendous success. Users are demanding anytime anywhere access to broadband multimedia services. The demand for data services will be relatively high in dense urban areas. In such areas, LTE, with its ability to leverage new and wider bandwidths, can be employed to significantly increase data capacity, effectively augmenting the underlying 3G networks, as illustrated in *Figure 2.*

3G and its evolutions will continue to provide ubiquitous broadband service and a similar user experience outside LTE coverage areas as well as voice services throughout the network.

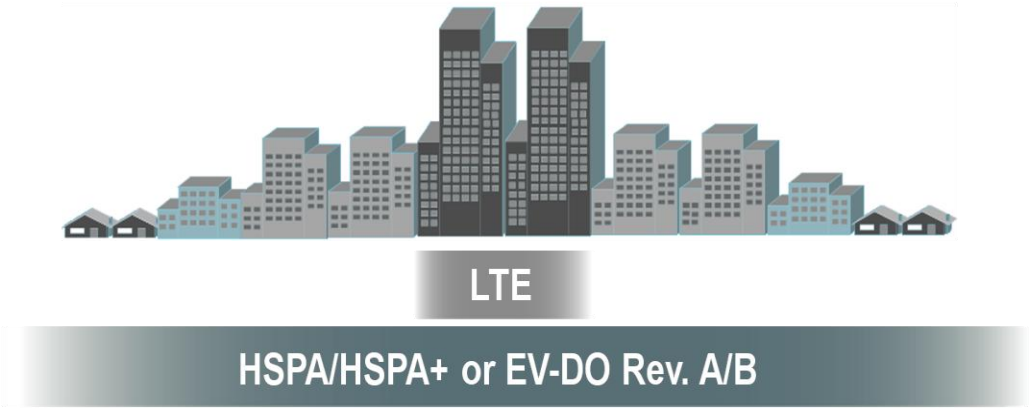

Figure 2: LTE overlay on a 3G network

LTE, with its low latency, low overheads, QoS (Quality of Service) support, and a new flat packet-only core network EPC, is designed to support the entire range of IP-based applications and services. Industry's initial commercial focus has been to offer LTE as a robust data solution through devices such as USB dongles, PC Cards and embedded modules. Full support for voice through VoIP is expected in the future.

[5] LTE is Evolving in Parallel to 3G's Evolution

3G already provides excellent mobile broadband through HSPA and EV-DO. Its low latency and efficient QoS features support the entire range of IP-based services such as VoIP, video telephony, push-to-media, low latency interactive games and others.

In the quest to reach new heights of user experience, both LTE and 3G are evolving in parallel, as illustrated in *Figure 3.* HSPA+ and EV-DO Rev. B/DO Advanced are the natural evolution paths for HSPA and EV-DO networks. They improve performance through incremental cost-effective upgrades that leverage existing assets.

HSPA+ Rel. 7, which is already commercial, doubles peak data rates and capacity over HSPA and more than doubles voice capacity over WCDMA. HSPA+ Rel.8 expands HSPA+ to 10 MHz spectrum through multicarrier, enhancing the broadband experience. Multicarrier doubles data rates for all users in the cell and doubles capacity for bursty applications such as web browsing. Similarly, the EV-DO Rev. B Phase I software upgrade, expected to be commercial in second half of 2009, triples data rates for all users and more than doubles capacity for bursty applications through multicarrier. The

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CSM6850-based channel card upgrade, Rev. B Phase II, provides even higher data rates and capacity. Further, DO Advanced improves network capacity and user experience by exploiting inherent uneven loading in the networks. DO Advanced is a software upgrade that benefits both existing as well as new devices.

LTE, on the other hand, will be primarily driven by availability of new wider or TDD spectrum. It will be deployed as an overlay to augment data capacity of 3G networks and their evolutions.

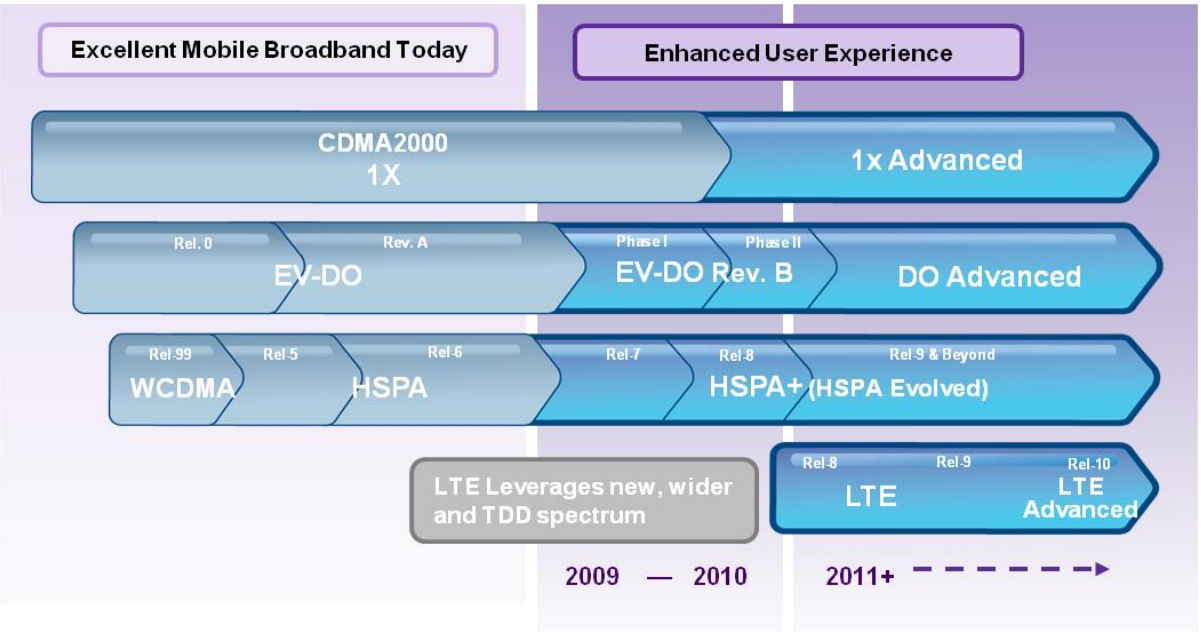


Figure 3: LTE and 3G are parallel evolution paths

Both LTE and 3G evolutions leverage the same enhancements to improve performance—shared data channel with adaptive modulation and coding, advanced antenna techniques, wider bandwidth, higher order modulation, advanced receivers, etc. Hence, they can provide very similar performance. As shown in *Figure 4*, LTE, and HSPA+ offer similar capacity (spectral efficiency) and peak rates while using the same amount of spectrum and antenna configuration.

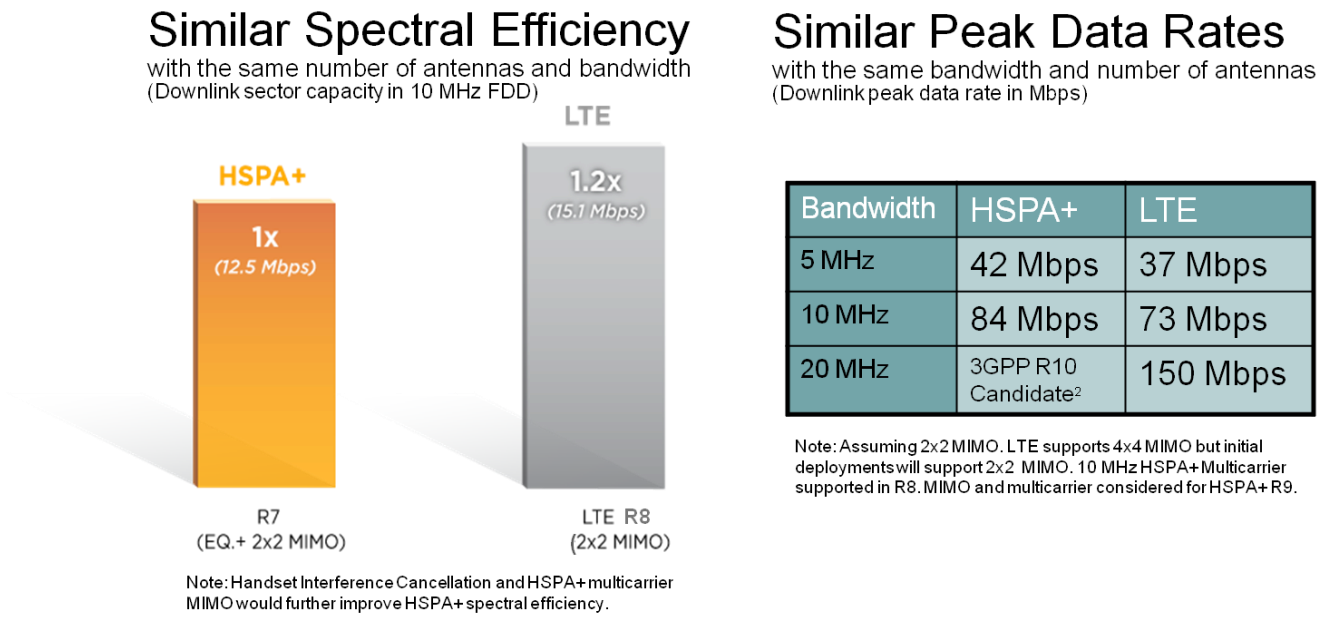


Figure 4: Similar LTE and HSPA+ performance[1]

[6] Qualcomm Provides Industry's First LTE/3G Multimode Chipsets

Qualcomm is at the forefront of LTE commercialization with its industry's first LTE/HSPA+/EV-DO multimode chipsets.

Qualcomm is one of the leading contributors to LTE technology and standards development. The company brings more than eight years of valuable OFDM/A experience, garnered through commercialization of MediaFLO™ (OFDM-based broadcast technology), Flash-OFDM and Platinum Multicasting (standardized in EV-DO). Qualcomm is also an active partner in industry initiatives such as LSTI (LTE/SAE Trial Initiative), which is helping accelerate commercialization and interoperability of LTE.

Qualcomm's LTE/3G multimode chipsets support LTE along with both major flavors of 3G technology—HSPA+ and EV-DO Rev. B—as well as their predecessors. The MDM™ family of chipsets that power data cards and USB modems are expected to be sampled in the middle of 2009. The MSM™

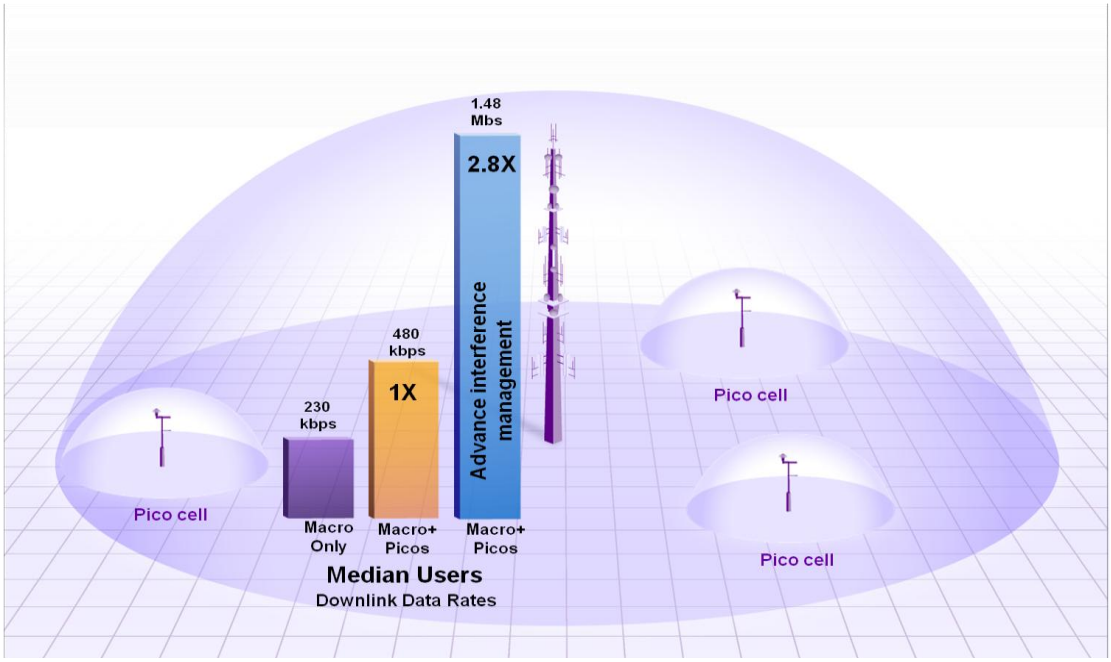
[1] Source: Qualcomm Simulation, details in 3GPP R1-070674. 500m ISD, HSPA+ R7 results scaled up from 10 MHz, HSPA+. HSPA+: 16QAM not considered for the UL and UE. Interference Cancellation not considered for the DL. HSPA+ multicarrier and DL Interference Cancellation would narrow the gap with LTE.
[2] Future HSPA+ release may support up to 20 MHz.

chipset targeted at smartphones and handheld terminals is expected to be sampled in the middle of 2010. Qualcomm's LTE chipsets support both FDD and TDD modes, providing flexibility for device vendors and operators.

[7] Topology Provides Gains beyond Technology

With the enhancements of LTE and the evolution of 3G, air link is approaching the theoretical limit of capacity. The next leap in performance improvement will likely come from topology enhancements—such as introducing femtocells—and not from technology. The additional nodes such as femto, micro and picocells bring the transmitter closer to the user, to significantly increase data rates and capacity.

Advanced topology networks optimize pico, micro and femtocell deployments to further improve performance. For example, advanced topology networks can do better user assignments—assigning users to more optimal cells and not always to the strongest cells—which can further double the data rates and improve overall capacity of the network, as shown in *Figure 5*. Such enhancements are one of the areas that technologies such as LTE Advanced, DO Advanced and future releases of HSPA+ are focusing on.



Note: Assuming 10 Picos per macro randomly dropped within macro coverage. Preliminary results based on simplified set of simulations and some advanced interference management techniques. Based on proposed LTE-A evaluation methodology in R1-08402610 MHz FDD, 2x2 MIMO

Figure 5: An example of advance topology networks further improving network performance by assigning users to more optimal cells, not always to strongest cells (advanced interference management)

[8] Conclusion

LTE is an optimized mobile OFDMA solution that continues 3G's track record of mobility and high spectral efficiency. It leverages new and wider bandwidth spectrum to boost data capacity in dense urban areas. 3G and its evolutions will continue to provide ubiquitous broadband coverage outside LTE areas as well as voice services throughout the network. LTE and 3G evolutions provide similar performance as they both leverage the same enhancements. Designed for seamless interoperability with 3G networks and their evolutions, LTE allows operators to capitalize on existing HSPA/EV-DO and future HSPA+/EV-DO Rev. B investments. LTE/3G multimode devices play a pivotal role in LTE deployments. Qualcomm with its industry's first multimode chipset solutions is in a unique position to support timely LTE deployments. The first LTE trials are planned for 2009, followed by commercial launches expected in the second half of 2010. The initial LTE networks will offer data services through devices such as USB dongles, PC Cards and embedded data modules.

The next leap in performance improvements will likely come from leveraging topology rather than technology. Advanced topology networks that further enhance the performance of mobile networks are a subject many forward-looking wireless players are now focusing on.