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Strategies to win in LTE and evolve to LTE Advanced

September 2013

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1 Executive summary

With the critical milestones of 100 Million connections[1] reached and more than 200 networks deployed[2], LTE is on a strong growth path. Then consider that large regions such as China and India are just getting started on LTE; it is even more evident that the technology has much more potential.

From the technology and standards perspective, being a common global standard resulting in a common ecosystem, LTE has had a unifying effect and is lining up the whole industry behind one common goal.

While LTE is still proliferating rapidly, industry leaders have already gotten a head start in LTE's next step—LTE Advanced. The first step of LTE Advanced—carrier aggregation—was launched in June 2013, powered by third-generation Qualcomm Gobi™ modems integrated into Qualcomm Snapdragon™ 800 chipsets. LTE Advanced is shaping up to be a pervasive technology with solutions that not only meet the ever-increasing data demand of traditional mobile broadband services, but also open up opportunities to transform new industries. Direct device-to-device proximity based services, addressing unconventional spectrum, are some such examples. This paper analyzes the success factors of LTE and the many dimensions that LTE Advanced is poised to explore.

Qualcomm, being an industry leader, is at the forefront of LTE evolution, not only envisioning the impossible, but also inventing, developing and commercializing technologies that bring our vision to fruition. Our quest to develop solutions to increase the data capacity of today's networks by 1000-times (what we call the "1000x mobile data challenge"), and being first to commercialize LTE/3G multimode and now LTE Advanced (carrier aggregation) are vivid and recent proof-points of such thought leadership.

2 The success factors of LTE

The global success of LTE is the result of a well thought-out, methodical approach to a complex challenge. Although, most of the initial LTE deployments were in developed regions using paired spectrum (LTE FDD), the success factors and the valuable lessons are universal and can be applied to emerging regions such as China and others, as well as to unpaired spectrum deployments (LTE TDD). In this section we will explore some of the important success factors.

2.1 Providing ubiquitous, un-interrupted data and voice experience

As with any new technology and a new network, the initial LTE deployment focus is going to be in high-traffic areas such as urban centers, with suburban and rural areas coming later. But, mobile device users like to use their phones everywhere, and they expect the same and consistent experience all the time. To offer such seamless experiences, LTE/3G multimode devices that enable tighter interworking with 3G for data/voice and with 2G for voice are of paramount importance. Voice is gradually evolving to packet-switched VoLTE (Voice over LTE), but during the transition, LTE will still rely on 3G/2G voice through a feature called Circuit-Switched Fall Back (or through an option that requires dual-radios, one exclusively used for 3G/2G voice). With LTE brand fragmentation, 3G will also remain as the means for global roaming for LTE devices.

[1]LTE/3G connections reached 100 Million in May 2013, source – Wireless Intelligence; [2] as of Aug, 2013, source www.gsacom.com

Qualcomm was the first in the world to introduce LTE/3G multimode modems back in 2010, and the first to implement CSFB and to test VoLTE with SRVCC (Single Radio Voice Call Continuity, required for handoff from VoLTE to 3G/2G).

2.2 Ability to address LTE band fragmentation and all smartphone tiers

As evident, global LTE deployments are spread across many bands, including paired and unpaired spectrum, in additional to many bands that 3G/2G technologies are deployed. All of this amounts to a situation where there may be a requirement to support 40 more bands. This indeed is a formidable hurdle for device makers hoping to leverage their devices across global LTE networks.

Envisioning this challenge early on, Qualcomm has been diligently working on the solution. In April 2013, we introduced a unique solution that we call Qualcomm RF360™, which realizes the dream of a single SKU LTE world phone. Qualcomm RF360 will enable vendors to bring their devices to the global market quickly and cost-effectively.

Undoubtedly, smartphones define the present and the foreseeable future of mobile broadband networks. It would not be an overstatement to say that having an extensive smartphone deployment plan is as important as the LTE deployment itself. The faster the operators and vendors can bring their smartphones, tablets and other mobile computing devices to more users, the closer they are to success. This, in turn, means the ability to offer a range of devices in all the product segments—extremely high-end, to high-volume tiers—while still providing an excellent user experience across the board is key. Qualcomm's Snapdragon family of chipsets with integrated Qualcomm's Gobi LTE/3G modems is designed to do exactly that—from Qualcomm Snapdragon 800 in the premium-tier to Qualcomm Snapdragon 400 in the high-volume tier.

2.3 Tight interworking between FDD and TDD

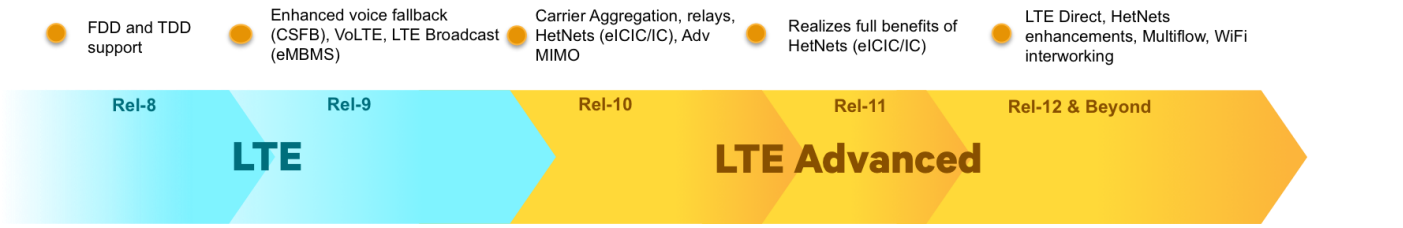
LTE is a common global standard with a common global ecosystem. It has two modes—FDD and TDD—addressing paired and unpaired spectrum bands respectively. The initial decision between the two is purely based on spectrum availability. However, in the future we believe that most of the operators will have both the networks to leverage all the spectrum resources they have.

A common LTE standard also means there is inherent FDD/TDD interworking support. Since there are already operators with both FDD and TDD networks, interworking is more of a requirement than an option. LTE FDD/TDD interworking is going to expand and become even tighter as carrier aggregation evolves.

Another important aspect is the ability to utilize the same devices for both FDD and TDD networks. Qualcomm's Gobi modems support both FDD and TDD on the same chip and fully support seamless interworking from the first generation itself.

3 LTE Advanced is here!

LTE Advanced is the next milestone in the evolution of LTE, starting from 3GPP Rel. 10, as shown in Fig. 3.1



[1] Peak rates for 10 MHz or 20 MHz FDD using 2x2 MIMO, standard supports 4x4 MIMO enabling peak rates of 300 Mbps.; [2] Peak data rate can exceed 1 Gbps using 4x4 MIMO and at least 80 MHz of spectrum (carrier aggregation), or 3GBps with 8x8 MIMO and 100MHz of spectrum. Similarly, the uplink can reach 1.5Gbps with 4x4 MIMO.

Fig. 3.1: Strong LTE evolution

True to its name, LTE Advanced incorporates multiple dimensions of enhancements which can be grouped into three major categories:

1) Carrier aggregation to leverage more spectrum
2) Advanced antenna techniques to increase spectral efficiency
3) HetNets to bring most benefit out of small cells

Although, each of these enhancements has its role to play to increase capacity and improve the user experience, the most gain comes from optimizing HetNets.

The first step of LTE Advanced—carrier aggregation—was commercially launched in June 2013. It was powered by third-generation Qualcomm Gobi modems, integrated into Qualcomm Snapdragon 800 solutions.

3.1 Carrier aggregation and its evolution

Carrier aggregation, as the name suggests, combines multiple carriers (a.k.a. channels) at the device to provide a bigger data pipe to the user. A bigger data pipe means higher data rates, both peak data rates (as high as over 1 Gbps) and, more importantly, higher user date rates across the cell coverage area. The higher data rates can be traded off to get increased capacity for bursty applications such as browsing, social media apps, smartphone usage and more.

As a first step, the commercial launch supported aggregation of two 10 MHz carriers, enabling a 150 Mbps peak data rate (Cat 4 terminals). This also doubles the user data rates across the cell, whether the user is close to the cell or at the cell edge. As mentioned before, this higher data rate can also be traded off to provide twice (or more) the capacity for bursty apps, under typical loading conditions.

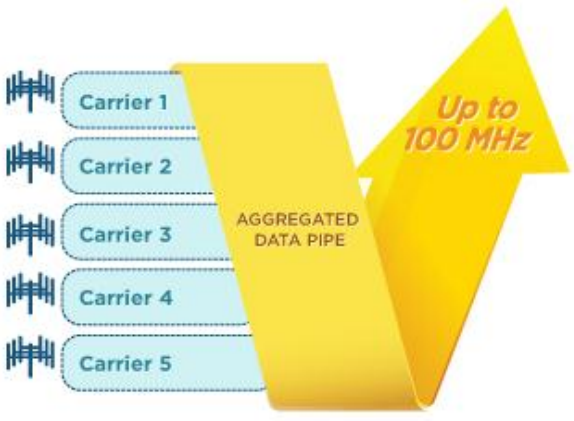


Fig. 3.2: LTE Advanced supports carrier aggregation of up to 5 carriers (100 MHz)

Carrier aggregation continues to evolve to utilize all spectrum resources that operators have access to. There could be aggregation across more carriers (up to five defined in LTE Advanced) and more band combinations (more than 45 being defined in 3GPP). There will be many different types

of aggregation: SDL - aggregating paired and unpaired spectrum; MultiFlow – aggregation across cells on the same carrier; aggregation across LTE FDD and TDD; uplink aggregation and many more. It is safe to say that the current aggregation across two 10 MHz carriers is only the beginning.

3.2 Advanced antenna techniques for higher spectral efficiency

A popular axiom is “the more antennas, the better it is.” But the challenge is to fit all of those antennas for all the technologies, in a small device form factor. We believe that the natural next step from today’s commercial 2x2 MIMO configuration is to go to four antennas, specifically, four-way receive diversity, and probably 4x4 MIMO thereafter. Four-way receive diversity provides most of the gains that can be achieved with four antennas. What makes four-way receive diversity worthwhile is that it’s a device-only feature that does not require any standard change or change in network infrastructure. This makes it much easier for operators to deploy and reap the benefits. Of course, the capacity gains scale with the penetration of such devices in the system.

Another interesting technique called CoMP (Coordinated MultiPoint) is also available for fiber installations with a centralized processing and scheduling facility. What CoMP essentially does is to coordinate the scheduling and transmission of resources between various cells (or Remote Radio Heads) so that the interference is minimized, thereby increasing capacity and improving the user experience. Since all the processing and scheduling is centralized, it indeed needs low-latency fiber connections between the processing/scheduling facility and the cells

3.3 HetNets – bringing more out of small cells

As mentioned before, optimizing HetNets is the most important component of LTE Advanced. It is becoming increasingly more evident to most of the industry; small cells are the future—all different kinds, shapes, and technologies—deployed everywhere, wherever people and machines use broadband. Small cells are simply a convenient way to add capacity wherever and whenever needed.

Adding small cells to the network seems like a simple thing to do. But each cell added has a profound effect on the overall network, both with the increased capacity it brings as well as the interference it generates. This effect is even larger when you consider the hyper-dense small networks being envisaged for the future.

LTE Advanced brings a robust suit of interference management tools to address the interference; resulting in what we call “Range Expansion.” Range Expansion is essentially a way to extend the reach of small cells so that they cover more and more users in their vicinity. It is critical for two equally important reasons: 1) you can offload more users from macro network; 2) users who can be better served by small cells (than the macro) are being connected to them.

Consequently, both of these actions increase the data rates that users can get, thereby improving their experience as well as increasing overall network capacity. Range Expansion can double the capacity of HetNets without any additional spectrum or infrastructure.

Range Expansion is enabled by two key features—eICIC (enhanced Inter Cell Interference Coordination)3 from the network side, and IC (Interference Cancellation) from the device side. The former is, essentially, cells coordinating resources among them to minimize interference and the latter is devices with advanced receivers cancelling overhead/signaling channels to minimize interference. Together these two make sure that every added cell brings in more capacity, while minimizing interference. In essence, LTE Advanced ensures that the overall network capacity scales with the densification of small cells, as shown in Fig. 3.3

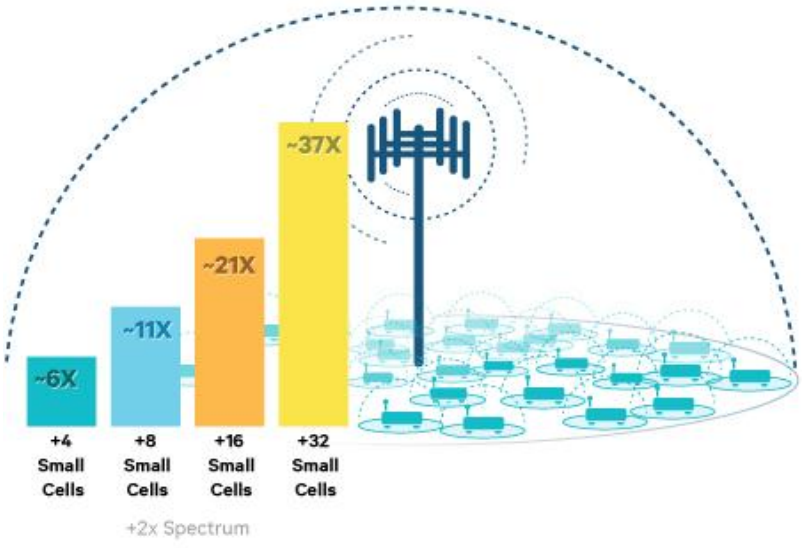


Fig. 3.3: LTE Advanced ensures capacity that scales with small cell densification

Qualcomm has an established leadership in the HetNets space. We envisioned the key role that HetNets will play in the future of wireless and have been steadfastly developing, prototyping and demonstrating innovative technologies since 2011, the time when the industry was still buzzing around the promise of 1 Gbps peak rates that LTE Advanced imparts. We have used our state-of-art over-the-air LTE Advanced small cell network in our San Diego campus to show the benefits of HetNets at many global events through live demonstrations. Qualcomm is also a main contributor to the LTE Advanced standards and, of course, as evidenced many times, is usually the first to bring these technologies to commercial reality

4 LTE Advanced evolution – Rel. 12 and beyond

LTE Advanced is continuing to evolve. From a standards perspective, LTE Advanced starts from 3GPP Rel. 10 and extends beyond. Rel. 12. The first phase of Rel. 12 is already complete and the second phase is in full swing and expected to be completed by end of 2013. The evolution includes on many organic, evolutionary components as well as revolutionary approaches that transform industries that LTE hasn't touched yet.

The focus is on further improving the performance of HetNets, enhancements to address the burgeoning machine-to-machine market, as well as seamless interworking between 3G/4G and Wi-Fi.

Above all, LTE technology is poised to extend its influence into many new horizons beyond mobile broadband, be it new industries, new applications/services or new, unexplored spectrum bands. LTE technology is versatile and robust enough to morph itself to suit the needs of these areas, while still maintaining its basic tenets of high efficiency and excellent user experience. Early indicative examples of such upcoming transformations are LTE Direct, a new proximity-based device-to-device technology, and LTE Broadcast enhancements for more efficient mass media distribution.

So, LTE Advanced is not a mere collection of 3GPP releases, but a well-planned technology evolution that will continue to play a pivotal role in the future of wireless for years to come.

5 Conclusion

LTE's successful run and its growth continue unabated. There are clear trends emerging on what it takes to be successful in LTE, based on the deployments so far—interworking with 3G/2G for seamless user experience; ability to address the LTE brand fragmentation; developing a robust smartphone strategy to reaching all segments—seem to be some of the most important ones. Although the initial LTE deployments are in the developed regions using paired spectrum (FDD), the learnings seem to be universal and applicable to emerging regions and unpaired (TDD) deployments as well.

On the heels of a successful LTE launch, LTE Advanced is making its foray. Its first step—carrier aggregation—was launched in Jun 2013 using Qualcomm Snapdragon chipsets, integrated with third-generation Qualcomm Gobi LTE modems. Apart from carrier aggregation, which helps to leverage wider bandwidths, LTE Advanced brings multiple dimensions of improvements, including advanced techniques, and HetNet optimizations that bring the most out of small cells. LTE Advanced continues to evolve, ensuring that it is a preferred wireless technology for years to come.

Qualcomm is the leader in LTE and LTE Advanced on multiple fronts. Right from the beginning with the Qualcomm Gobi world-first LTE/3G multimode modems to the most recent carrier aggregation support. The Qualcomm RF360 solution enables vendors to address LTE band fragmentation and makes a single-SKU global-LTE phone possible. Qualcomm is a main contributor to LTE Advanced standards and has developed, prototyped and demonstrated many HetNet optimizations at global events. To sum it up, building on our heritage, Qualcomm is in the forefront of LTE development, with a clear vision, robust roadmap and a proven track record.

To get most updated information about LTE Advanced, please visit *www.qualcomm.com/lte_advanced*