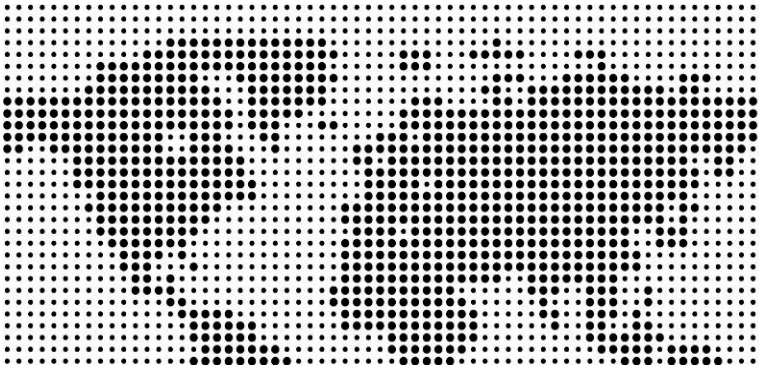
HSPA+ is Here! What's Next?



Qualcomm Incorporated
May 2010

Table of Contents

[1] Executive Summary

HSPA operators around the world are witnessing a phenomenal success with their mobile broadband services. The proliferation of broadband connectivity into many market and device segments is fueling unprecedented data growth. To sustain this growth, and enhance the broadband experience, operators are cost-effectively evolving their HSPA networks to HSPA+. In addition to HSPA+, many operators are also embracing LTE (Long Term Evolution), if they have access to new wider bandwidth spectrum.

As the natural evolution to HSPA, HSPA+ further enhances the mobile broadband experience and improves capacity. It is a cost-effective upgrade that leverages infrastctrue. Already commercial, HSPA+ Release 7 (Rel. 7) doubles the data capacity of HSPA and more than doubles the voice capacity of WCDMA. The higher data capacity enables operators to offer mobile broadband services at a lower cost, while the increased voice capacity allows them to free up resources to support more data. HSPA+ Release 8 (Rel. 8) introduces the first step of the multicarrier feature (a.k.a. dual-carrier), aggregating two 5 MHz carriers, which doubles the data rates to all users in the cell. Rel.8 will be commercial in 2010. The standardization of HSPA+ Release 9 (Rel. 9), which expands multicarrier support in 10 MHz, is expected to be complete in the early part of 2010. The standardization of HSPA+ Release 10 (Rel. 10) has already started. Rel. 10 will support aggregation of 4 carriers (20 MHz) in the downlink, offering an impressive 168 Mbps peak data rate.

Operators that have access to wider bandwidth spectrum are planning to overlay their 3G networks with LTE. LTE 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. LTE can be used to effectively boost data capacity in high-demand dense urban areas while 3G and its evolutions will provide ubiquitous broadband outside of focused LTE coverage areas, as well as voice services throughout the network. LTE is designed to seamlessly interoperate with 3G through multimode devices from day one. Hence, multimode devices will play a pivotal role in initial LTE deployments. The multimode LTE commercial launches are expected in the second half of 2010.

HSPA+ and LTE offer similar data rates and capacity when using the same antenna configuration and same amount of bandwidth, as both of the technologies depend on the same enhancements to improve performance. Furthermore, both HSPA+ and LTE leverage a large ecosystem of operators, infrastructure and device vendors.

With LTE and HSPA+ offering same performance, leveraging topology—the introduction of low-power nodes like pico and femtocells close to users— will bring gains beyond what technology alone could provide. Advanced topology networks further improve performance of these nodes, and hence is a focus areas of LTE Advanced. HSPA operators are already introducing commercial 3G femtocells. HSPA+ Rel. 8 brings in standardized support for them as well as some aspects of advanced topology networks.

Qualcomm is supporting both 3G and LTE evolution paths with its industry-first HSPA+ and LTE/HSPA+/EV-DO multimode chipset solutions.

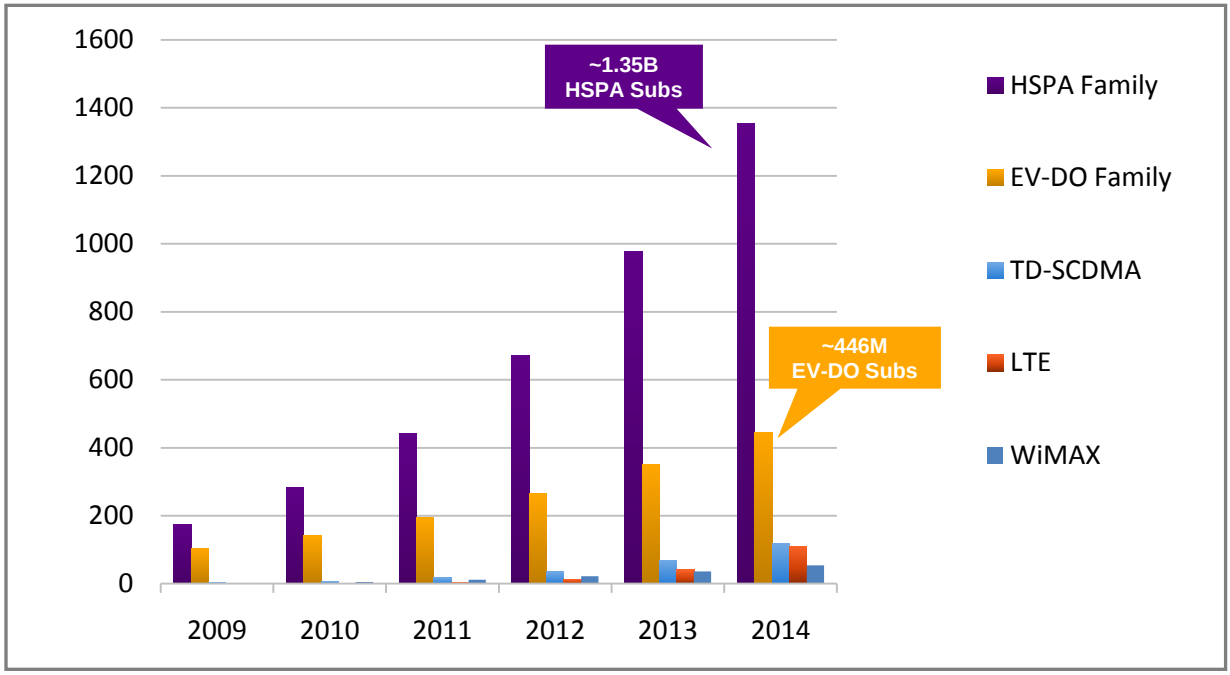
[2] HSPA along with HSPA+ Rel. 7 is Offering Excellent Mobile Broadband Today

HSPA has emerged as one of fastest growing mobile broadband technologies, making it a popular choice among both developing and emerging markets. HSPA's high-capacity uplink and downlink enable operators to offer cost-effective ubiquitous broadband service to the masses. The integrated QoS and low latency can support the entire range of IP services, including delay-sensitive applications such as VoIP and interactive multiplayer gaming. HSPA+ evolution further enhances the user experience and makes these services more affordable by lowering costs through increased capacity.

As of Feb. 2010**,** there were more than 300 operators offering HSPA based broadband services to estimated more than 190 million subscribers in 133 countries. HSPA+ Rel. 7 has seen rapid adoption with 41 operators currently offering it and about 40 more showing strong interest, indicating the way forward for the remaining HSPA operators. As of Feb. 2010, there were more than 32 HSPA+ Rel. 7 device models in the market produced by 11 vendors (source www.gsacom.com).

[3] HSPA+'s Mobile Broadband Dominance Continues

The strong momentum behind the HSPA+ evolution is expected to continue in this decade. Based on analyst estimates, HSPA/HSPA+ will command about 70 percent of the total mobile broadband market in 2013, as shown in *Fig. 1*.



Source: : Informa Telecoms & Media (Jan 2010), *WiMax Subscriptions: Avg. of ABI (Mar10) and Yankee Group (Sep09)

Figure 1: HSPA+'s dominance in mobile broadband continues

3.1 Strong HSPA+ Evolution

HSPA+ has a strong and well established evolution path, as shown in *Fig*. 2, that continues to enhance network performance and enables wireless operators to cost-effectively fulfill the ever-increasing demand for data.

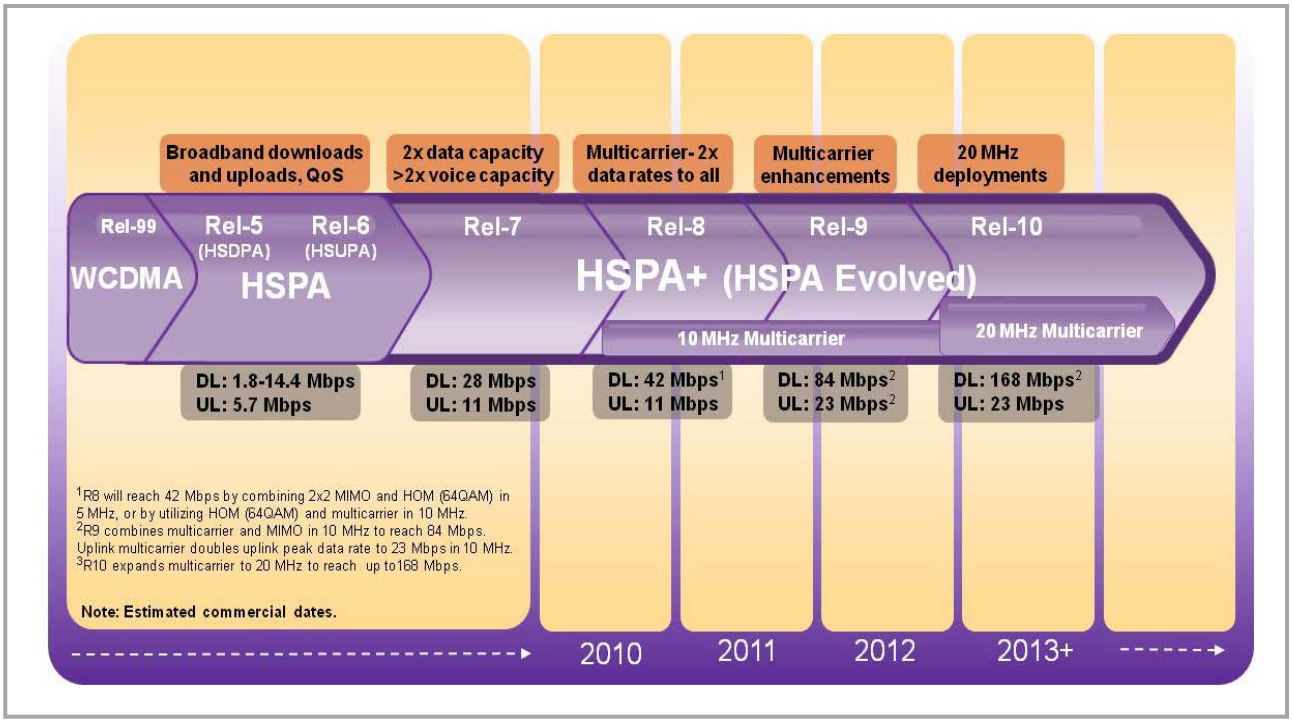


Figure 2: Strong HSPA+ Evolution path

As mentioned earlier, Rel. 7 is already commercial. The commercialization and wide spread adoption of Rel. 8 will be in 2010. The standardization of Rel. 9 is near completion in 3GPP with specification freeze expected in early 2010. Furthermore, the standardization process of Rel. 10 has already started.

3.2 HSPA+ Rel. 7 Doubles Data and More than Doubles Voice Capacity

Rel. 7 is the first step in the HSPA+ evolution. It increases the downlink peak data rates to 28 Mbps using 2x2 MIMO, or to 21 Mbps through higher order modulation 64 QAM, and increases the data and voice capacity offered by the network.

Rel. 7 doubles capacity over HSPA, together with advanced receivers that support standard independent features such as UE Equalizer and Node B interference cancellation.

High-quality voice is a key service that has traditionally been the core of wireless business. HSPA+ enables two options, CS (circuit-switched) voice-over HSPA or VoIP, both of which more than double the WCDMA R99 voice capacity and provide up to 50% more talk time, while maintaining the same quality and codec. Users will continue to enjoy simultaneous voice and high-speed data services while operators now can flexibly mix voice and data services on the same HSPA+ carrier. *Fig. 3* shows the voice-over HSPA options and the more than doubled voice capacity over WCDMA.

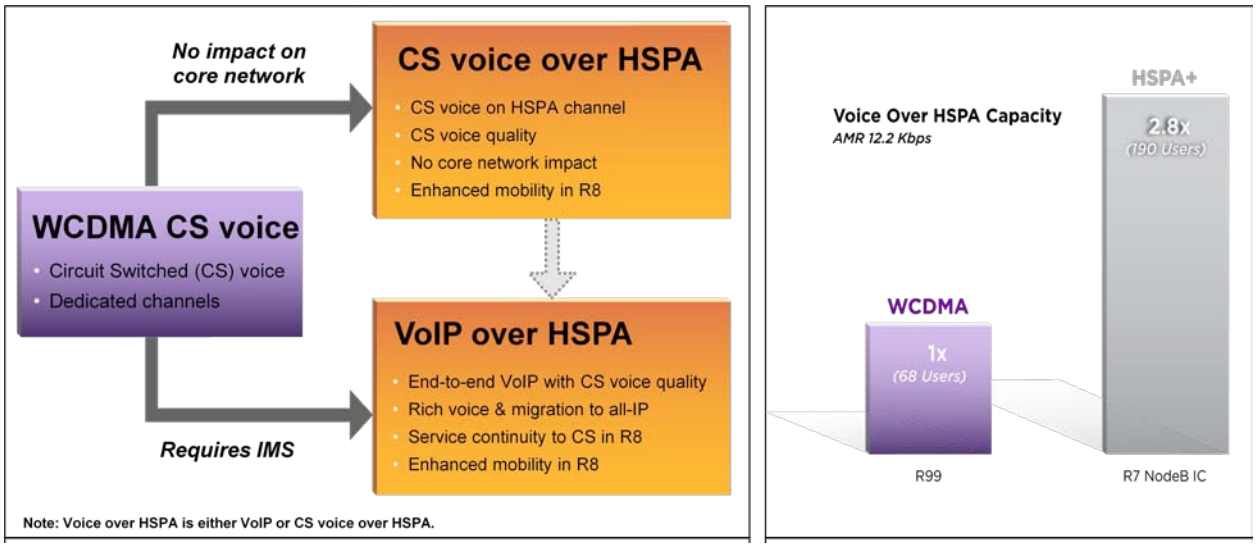


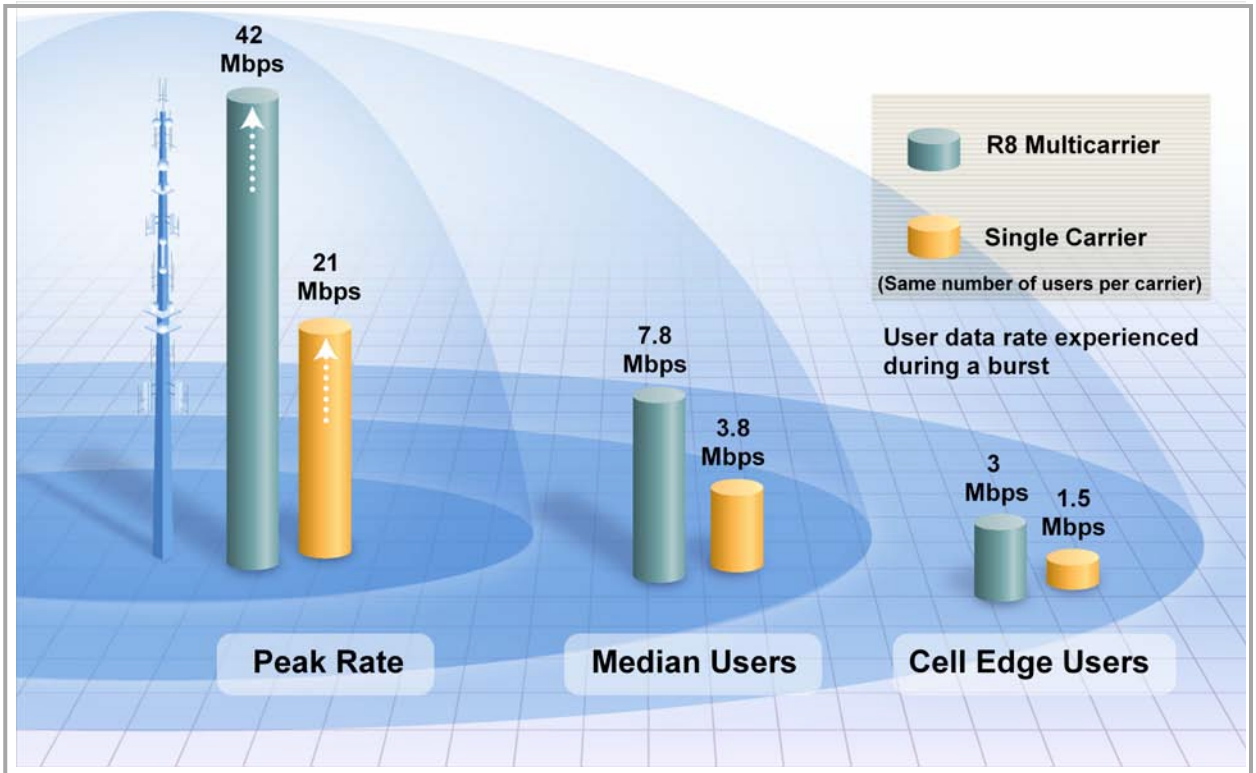
Figure 3: Voice over HSPA more than doubles voice capacity over WCDMA

CS voice-over HSPA, also known as CSoHS, leaves the core network intact, allowing operators to leverage their existing core network investments, while use of VoIP requires the deployment of IMS core network. CS voice-over HSPA is therefore the natural upgrade for most operators but could also be an intermediate step toward the long-term goal of migrating to VoIP. CSoHS is expected to be commercial in 2010.

3.3 HSPA+ Rel.8 Multicarrier Enhances Broadband Experience for *All* Users

The multicarrier feature aggregates multiple 5 MHz HSPA carriers, creating a fatter data pipe and thus providing an enhanced mobile broadband experience to all users in the cell. The Rel. 8 implementation of multicarrier (a.k.a. dual-carrier) supports two aggregated downlink

carriers that will double the user data rates to all users across the cell—all the way to the cell edge. Furthermore, peak data rates scale with the bandwidth and double to 42 Mbps in the downlink in 10 MHz spectrum (without MIMO), as shown in *Fig. 4*.



Qualcomm simulations. Each scenario is based on the same total number of users (eight users) per carrier, see 3GPP R1-081890 for details. Shows the theoretical peak data rata and the burst data rate for the median users and the 10% worst (cell edge) users. No MIMO with Multicarrier in R8. Peak data rates are scaled down by a factor of 2 in the picture.

Figure 4: Rel. 8 Multicarrier doubles data rates for all users in the cell

Multicarrier thus allows subscribers to enjoy an enhanced broadband experience with quicker overall network responses thanks to the higher data rates. This is especially beneficial for bursty applications like Web browsing in which the user can be served twice as fast compared to a single carrier and experience 50% reduced over-the-air latency.

Multicarrier is typically a cost-effective software upgrade to the Node B that allows for incremental introduction. It can be introduced in high-demand areas or even for single sites in the beginning, followed by a network wide deployment, as multicarrier devices operate seamlessly between singe and multicarrier networks.

Multicarrier leverages spectrum resources better through dynamic load balancing across carriers and improved trunking efficiency, providing higher network performance.

Multicarrier, apart from enhancing broadband experience, can also provide significant capacity improvement for bursty applications over partially loaded carriers. As shown in *Fig.5*, multicarrier can support significantly more bursty applications users, like Web browsing, compared to two single carriers for the same user experience (latency) in partially loaded networks.

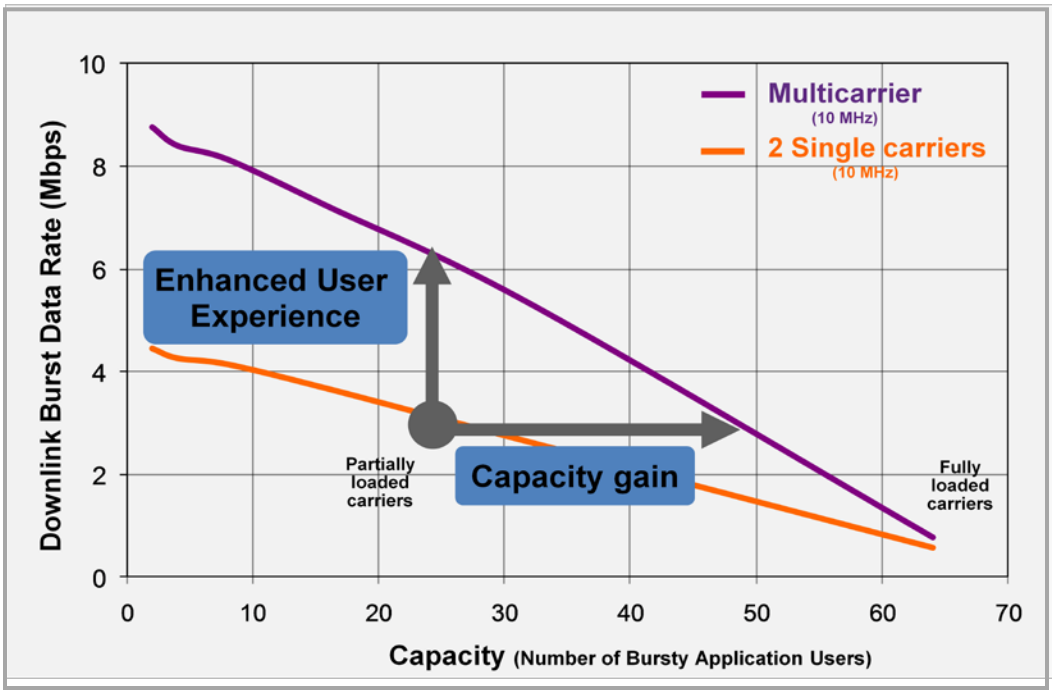


Figure 5: Rel. 8 Multicarrier can double capacity for bursty applications

Networks are not typically fully loaded all the time and multicarrier could double the bursty application capacity compared to two single carriers. A multicarrier deployment approaching a fully loaded network scenario will resemble the full buffer scenario and provide limited capacity gain even for bursty applications.

3.4 HSPA+ Rel. 9 and Rel. 10 Expand Multicarrier

HSPA+'s strong evolution continues with Rel. 9 and Rel.10. The primary focus of Rel. 9 has been to facilitate multicarrier across bands; for example, a combination of 2.1 GHz and 900 MHz bands. Rel. 9 is also designed to support multicarrier on the uplink. These features, while substantially improving the capacity and user experience, allow operators to leverage all the available spectrum resources, including simultaneous use of multiple bands. As shown in *Fig.6*, Rel.9 can provide 84 Mbps peak data rate in the downlink by combing 2x2 MIMO and Multicarrier, as well as offer 23 Mbps peak rate on the uplink through UL Multicarrier.

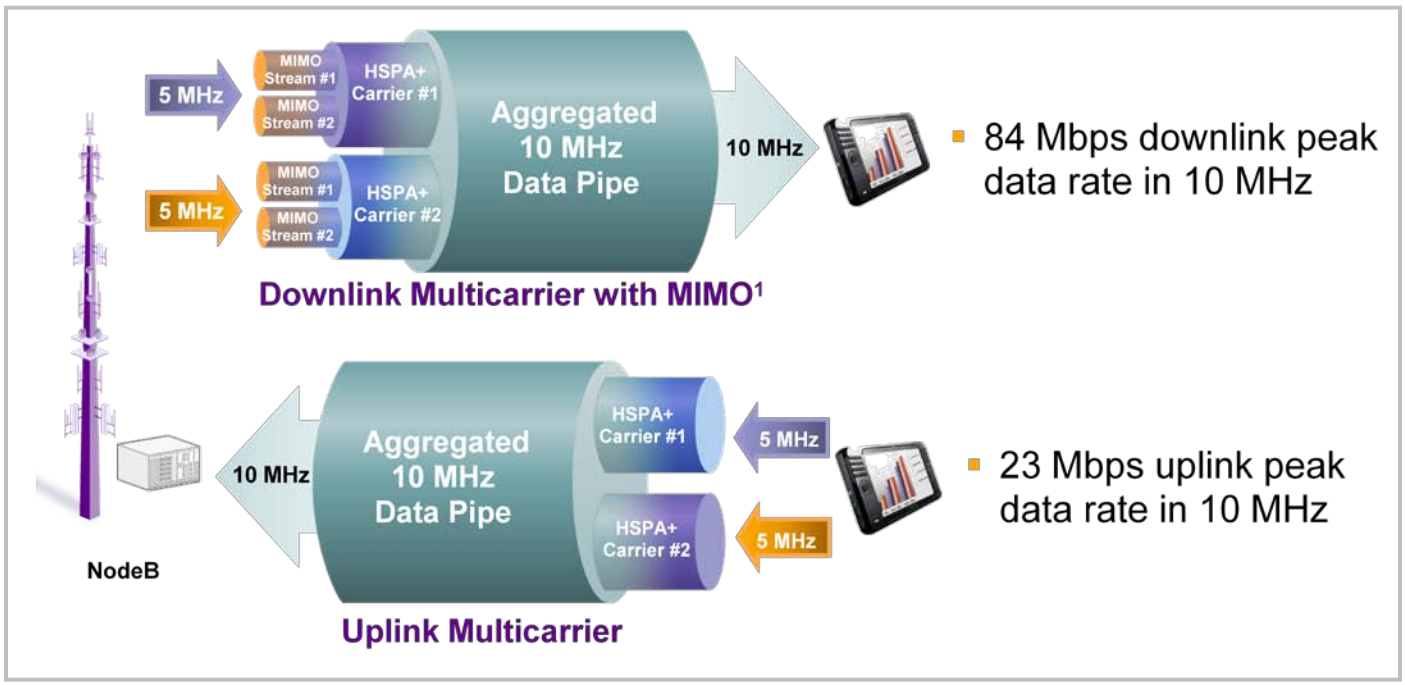


Figure 6: Rel. 9 supports Multicarrier and MIMO in the downlink and Multicarrier in the uplink

MIMO provides about 20% increases in the spectral efficiency. UL Multicarrier can double the uplink data capacity for bursty applications, similar to that of downlink multicarrier, as shown in *Fig.5*.

The increased uplink capacity is very beneficial for operators to support the recent surge in user generated content primarily driven by popularity of mobile social networks. Also, any improvement in the uplink data rates improves the downlink performance of bursty applications such as Web browsing.

Rel. 10 takes the multicarrier even further by aggregating 4 carriers supporting 20 MHz to provide am impressive 168 Mbps downlink peak data rate, as shown in *Fig*. 7.

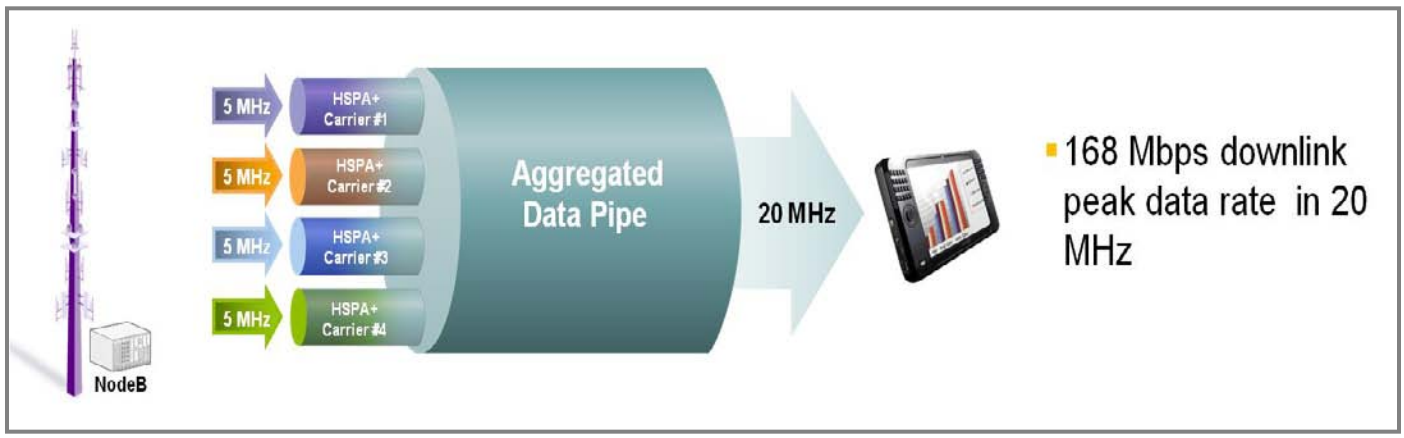


Figure 7: Rel. 9 supports Multicarrier and MIMO in the downlink and Multicarrier in the uplink

3.5 HSPA+ Enhances the User Experience

HSPA+ not only improves the user data rates for enhanced mobile broadband, it also enhances the end-user experience in other ways:

- Improved "always-on" experience by allowing user to stay longer in connected mode without compromising battery life through Continuous Packet Connectivity (CPC) feature.
- More responsive user experience thanks to lower latency with 50% reduced transition time between inactive and connected states and 50% reduced over-the-air call setup time compared with HSPA R6 (enhanced Cell_FACH/PCH).
- Up to 50% extended talk time through voice-over HSPA (VoIP or CS voice-over HSPA) compared to WCDMA.

CPC improves the "always-on" experience by allowing packet data users to stay in the connected mode longer with extended battery life. A user has to move to the inactive state after some inactivity time, but CPC enables the user to stay in connected mode longer and potentially already be in connected mode when the user becomes active again. In addition, the enhanced Cell_FACH (a.k.a. HS-RACH/HS-FACH) allows for 50% reduced transition time between active and inactive states.

All the features together provide an enhanced user experience with a better "always-on" connectivity and more responsive services. *Fig*. 8 illustrates the improved user experience for an application such as Google Maps.

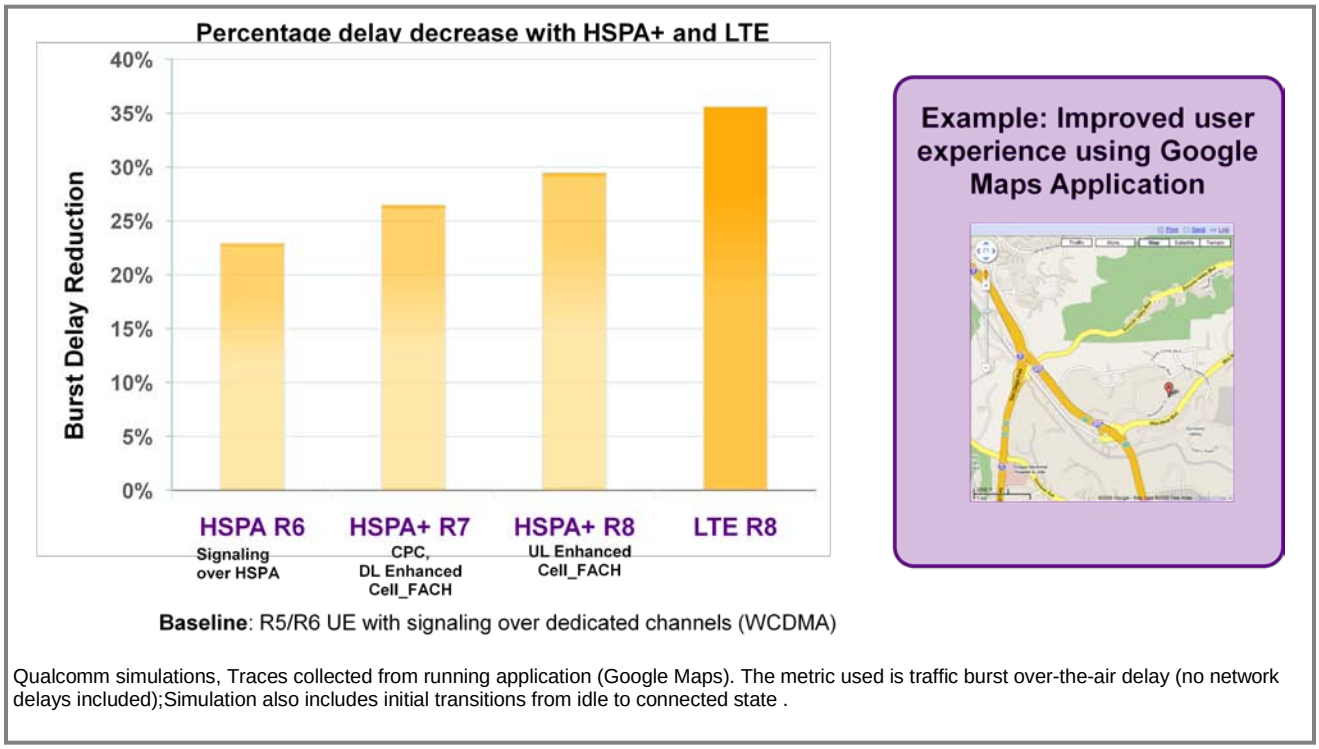


Figure 8: HSPA+ improves the user experience

3.6 HSPA+ is the Natural Evolution of HSPA at a Lower Cost

HSPA+ provides an excellent technology evolution path for operators to maximize return on their existing investments. HSPA+ is designed to be compatible with existing R99, Rel. 5/Rel. 6 devices and networks, and uses the same spectrum and network resources to deliver enhanced performance. The existing radio and core network can be upgraded to HSPA+ without the need for adding any new network elements. WCDMA and HSPA+ devices can roam seamlessly between WCDMA, HSPA and HSPA+ networks. Backward compatibility will enable operators to roll out HSPA+ features in phases, without concern about device/network incompatibility, and provides a time-to-market advantage when

compared with other competing technologies. Many of HSPA+'s features are software upgrades to the existing base stations.

[4] LTE is an Optimized OFDMA System for Wider Bandwidth Spectrum

LTE is designed from the ground up for mobility and high capacity, following the footsteps of successful 3G development. It leverages 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 includes seamless handoffs and interoperability with 3G from day one, demonstrating its superiority over other OFDMA solutions.

LTE incorporates advanced antenna techniques such as MIMO and 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 offer even higher data rates using wider bandwidths and higher order MIMO. For e.g. LTE with 4x4 MIMO, can provide 150 Mbps in 10 MHz and 300 Mbps in 20 MHz of spectrum.

Many major operators have already announced plans to trial and commercially deploy LTE to augment data capacity of their existing 3G networks. The initial multimode LTE commercial launches are expected in the second half of 2010.

4.1 Boosts Capacity in Dense Urban 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 *Fig.9.*

Figure 9: LTE overlay on a 3G network

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.

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. The industry's initial commercial focus has been to offer LTE as a robust data solution through data centric devices such as USB dongles, PC Cards and embedded modules. Full support for voice through VoIP is expected in the future. Meanwhile, the first LTE handsets will rely on 3G for voice services.

4.2 Leverages New Wider Bandwidth Spectrum

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

For the existing, refarmed spectrum, HSPA+ is the most cost-effective upgrade path for HSPA operators. While it provides similar capacity to LTE, with the same bandwidth and same number of antennas, HSPA+ also capitalizes on the investments that operators have already made.

As depicted in *Fig. 10*, 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.

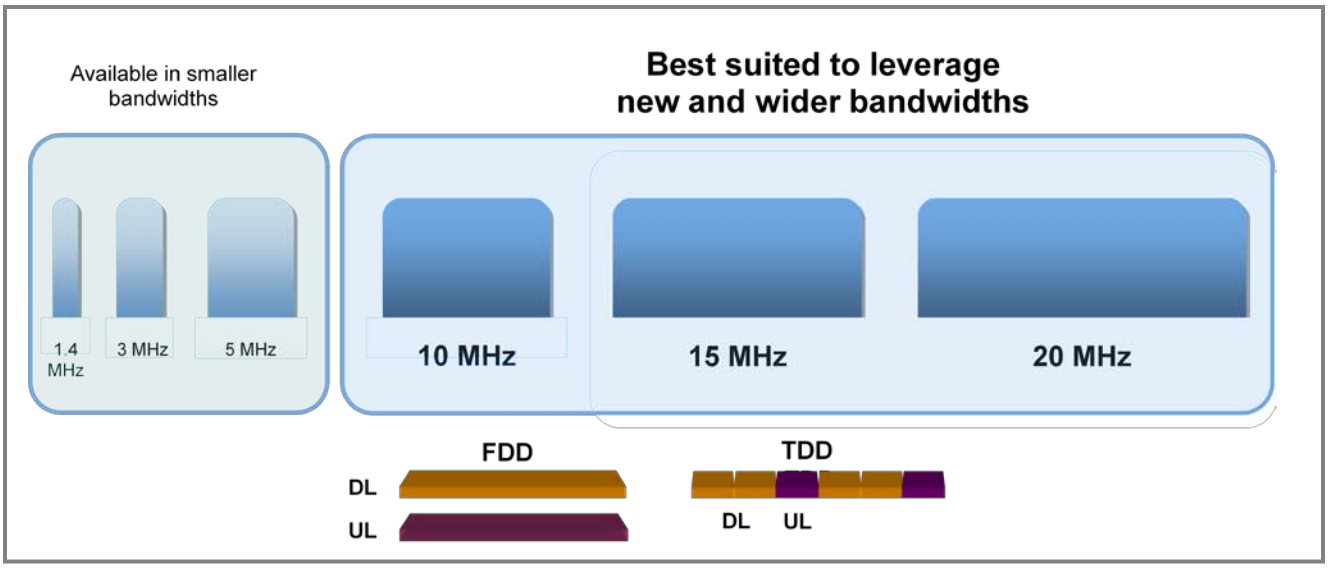


Figure 10: LTE leverages new wider bandwidths

TD-LTE is the optimal solution for the global unpaired TDD spectrum. TD-LTE can be effectively used to increases capacity in hot spots, augmenting 3G and FDD-LTE networks. TDD will have lower coverage than FDD for the same spectrum because of its discontinuous uplink. Also, much of the TDD spectrum is available at higher frequencies, further reducing its coverage. Historically, TDD spectrum has been cheaper than FDD, making TDD-LTE an optimal candidate as a hotspot capacity solution complementing both 3G and TDD-LTE networks.

TD-LTE will leverage the large FDD-LTE/3G ecosystem making it more cost-effective than other alternative TDD solutions in the market.

4.3 LTE is Evolving in Parallel to HSPA+

As explained in the previous chapters, HSPA and HSPA+ Rel. 7 already provide excellent mobile broadband today. With their low latency and efficient QoS features, they 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 HSPA+ are evolving in parallel, as illustrated in *Fig.11.* HSPA+ is the natural evolution path for HSPA networks, as it improves performance through incremental cost-effective upgrades that leverage existing assets. 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.

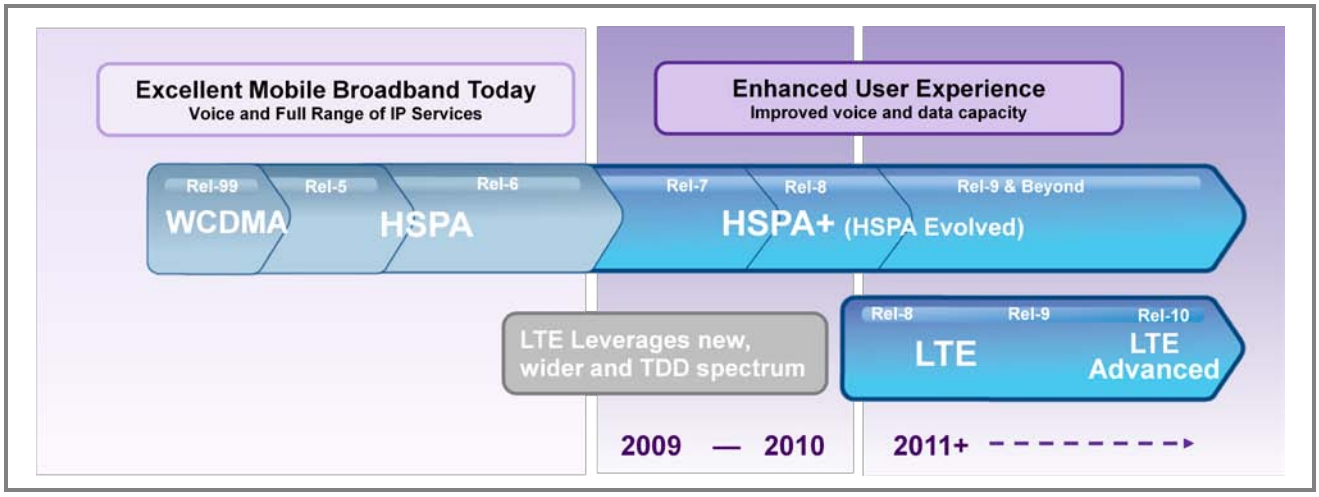


Figure 11: LTE is evolving in parallel to HSPA+

[5] Similar HSPA+ and LTE Performance

Both LTE and HSPA+ leverage the same enhancements to improve performance—shared data channel with adaptive modulation and coding, advanced antenna techniques, wider bandwidth, and higher order modulation. Using the latest generation of receivers available, HSPA+ can provide performance very similar to that of LTE. As shown in *Fig. 12*, both offer similar capacity (spectral efficiency) and data rates as well as latency while using the same amount of spectrum and antenna configuration. Moreover, both HSPA+ and LTE offer similar user perceived latency as well.

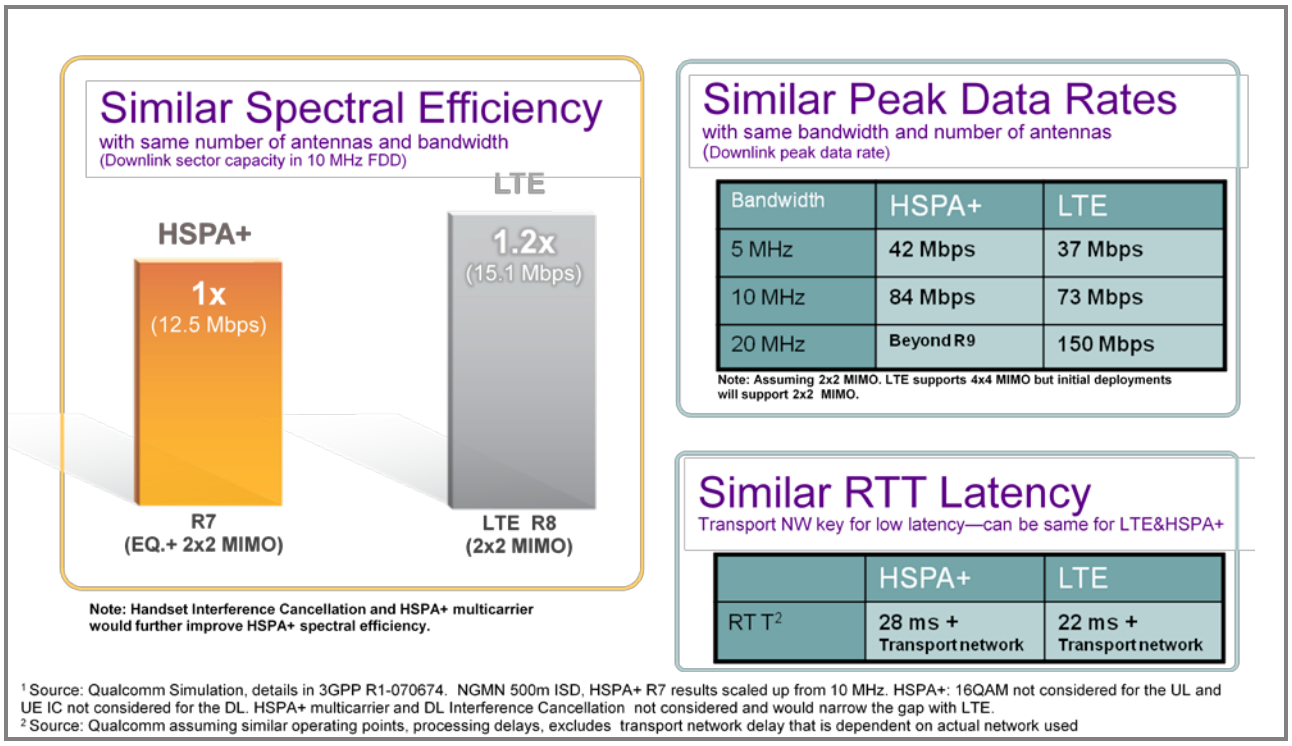


Figure 12: Similar HSPA+ and LTE performance

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

Qualcomm is at the forefront of HSPA+ and LTE commercialization with its industry-leading chipsets—its HSPA+ chipsets are already being used by many of the vendors that have launched Rel. 7 and Rel. 8 devices for commercial networks. Qualcomm was also the first to announce LTE/3G multimode chipsets, supporting both major flavors of 3G—HSPA+ and EV-DO Rev. B—as well as their predecessors. *Fig. 13* highlights some of the main HSPA+ and LTE chipset solutions.

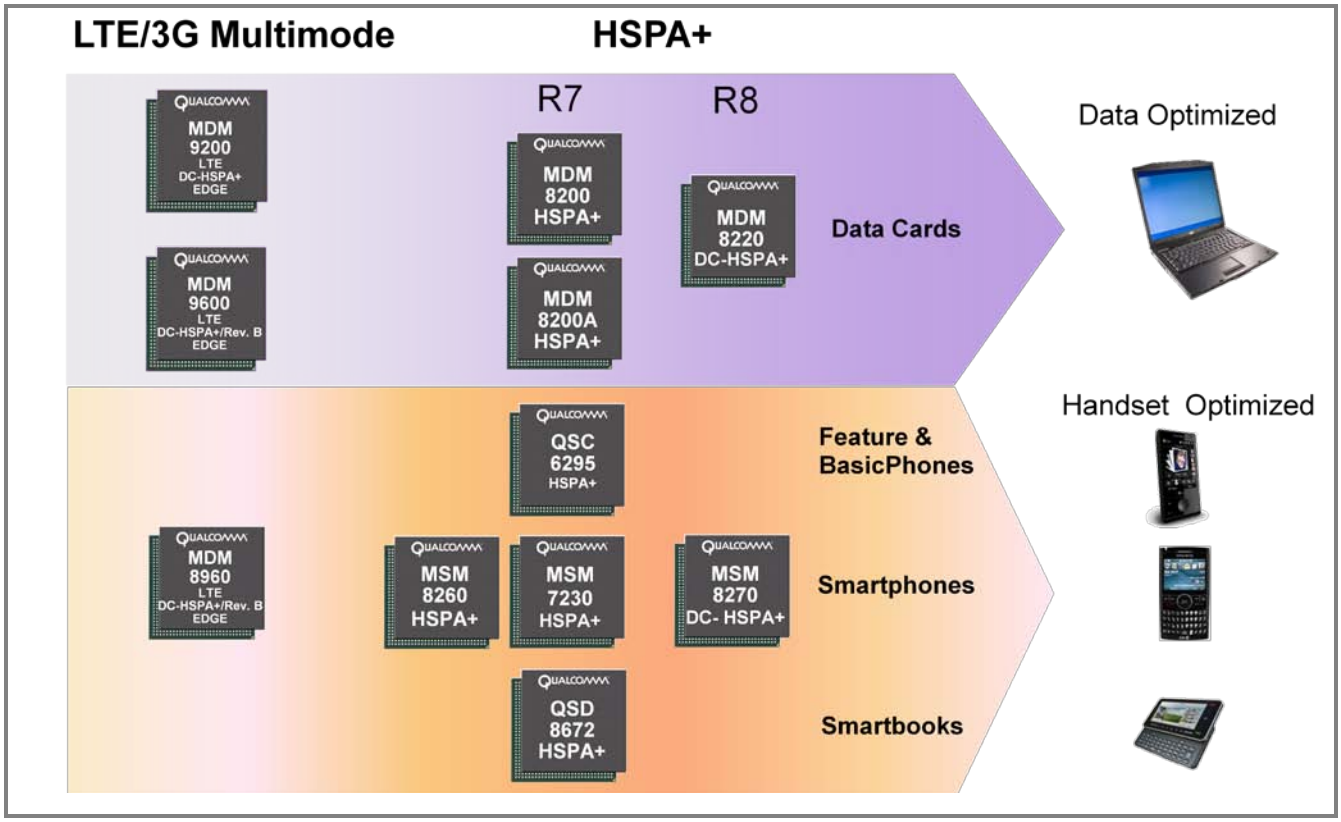


Figure 13: Qualcomm's industry-first HSPA+ and LTE/3G chipset solutions

Qualcomm's HSPA+ and LTE/3G multimode chipset solutions support all device form factors including data connectivity devices such as USB dongles and PC cards, as well as feature phones, smart phones and smartbooks.

[7] Topology Provides Gains beyond Technology

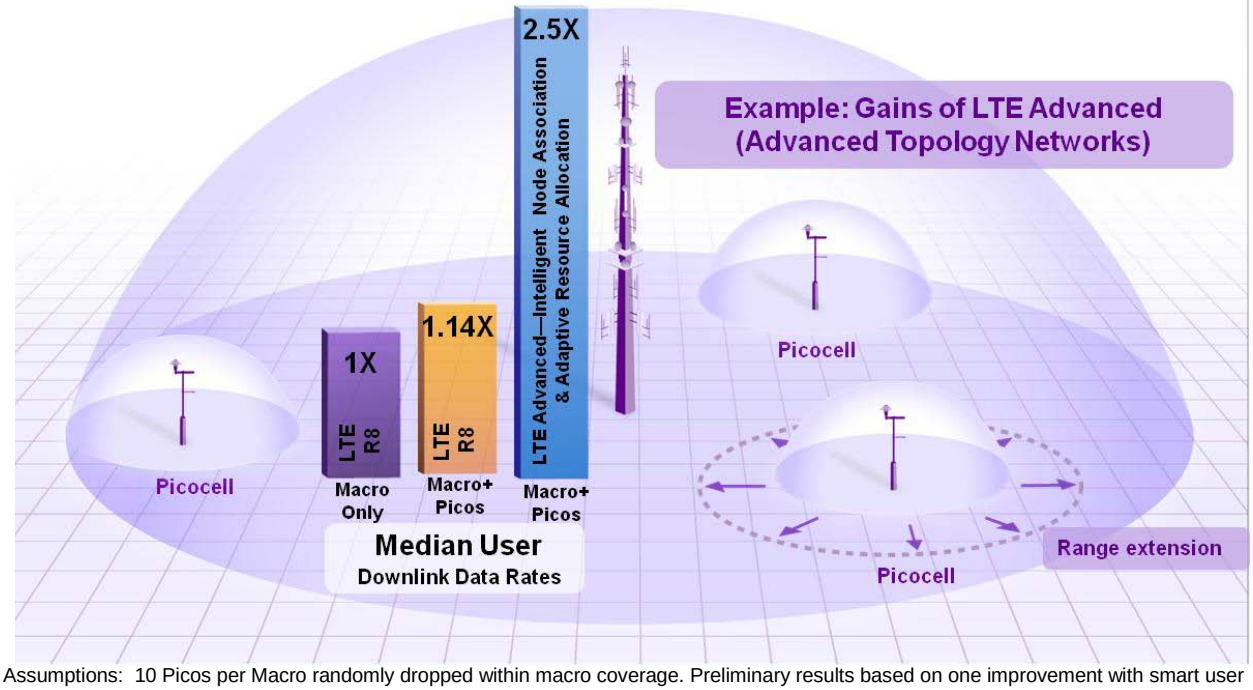
With the enhancements of LTE and the evolution of 3G, air links are approaching the theoretical limit of capacity. Increasing the number of antennas and thereby air links beyond 2x2 MIMO will give incremental improvement. But the next significant leap in performance improvement (10x or more) will likely come from topology enhancements—such as introducing femtocells—and not from technology. The additional nodes such as femto, micro and picocells bring the network closer to the user, significantly increasing data rates and capacity.

These additional nodes provide an excellent user experience through near-peak data rates and help operators by cost-effectively off-loading traffic from the macro networks. Operators can leverage femtocells in many ways including new services that make use of user location

information and consistently good coverage (high data rates), as well as offer attractive home-zone pricing plans and bundles.

Femtocells are already being introduced in HSPA networks. Initial market traction appears to be from the residential side, but with the advent of enterprise femtos, they may be a strong alternative for the traditional micro and picocells. For large scale, high concentration femto deployments, additional optimizations such as interference management and user assignment techniques are required. These features are supported by advanced topology networks.

Advanced topology networks optimize pico, micro and femtocell deployments to further improve performance. For example, they can assign users more effectively—assigning users to more optimal cells rather than the strongest cells—which can further double the data rates and improve overall capacity of the network, as shown in *Fig.14*. Such enhancements are one of the areas that technologies such as LTE Advanced are focusing on.



Assumptions: 10 Picos per Macro randomly dropped within macro coverage. Preliminary results based on one improvement with smart user assignment, additional benefit from other advanced interference management techniques. Based on proposed LTE-A evaluation methodology in R1-08402610 MHz FDD, 2x2 MIMO and 25 users

Figure 14: An example of LTE Advanced (and advance topology networks) further improving network performance by assigning users to more optimal cells, not always to strongest cells (advanced interference management)

HSPA+ Rel. 8 already brings standardized support for femtocells and some aspects of advanced topology networks. The next evolutions are expected to further improve these techniques.

[8] Conclusion

HSPA+ is the natural and most economical evolution for HSPA, allowing operators to make the most efficient use of their existing assets and investments in network, spectrum and devices at a lower cost. HSPA+ is backward compatible, allowing for a gradual introduction of devices and a smooth, cost-efficient and simple network upgrade to existing HSPA nodes. Thanks to increased capacity, HSPA+ enables operators to offer mobile broadband and voice services at an even lower cost. HSPA+ further enhances the end user experience through increasingly higher data rates, lower latency, extended talk time and an improved "always-on" experience.

HSPA+ has a strong evolution path, with Rel. 8, Rel. 9 and Rel.10, and continues to be the optimal solution for singe or aggregated 5 MHz carriers. Rel. 8 doubles the data rate for all users in cell through multicarrier and will be commercial in 2010. Rel. 9 expands multicarrier across spectrum bands and introduces multicarrier in the uplink. Rel. 9 specifications are expected to be frozen in early 2010. Rel. 10 supports 20 MHz deployment through 4x multicarrier in the downlink and offers an impressive 168 Mbps peak data rate. Rel. 10 standardization is currently underway. 41 operators have already launched HSPA+ Rel. 7 networks and about 40 more have shown strong commitment.

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. Designed for seamless interoperability with 3G networks and their evolutions, LTE allows operators to capitalize on existing HSPA and future HSPA+ investments. LTE/3G multimode devices play a pivotal role in LTE deployments .The multimode LTE networks has expected to be commercial 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.

HSPA+ and LTE are on parallel evolution paths providing similar performance as they both leverage the same enhancements. Qualcomm, with its industry-first HSPA+ and LTE/3G multimode chipset solutions, is in a unique position to support both evolution paths.

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.