QUALCOMM®

What's Next for CDMA

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1   Executive Summary

Mobile services have experienced a phenomenal expansion in recent years. Both voice and broadband data services have registered record growth in developed and emerging markets. CDMA2000, a leading 3G technology, is at the center of this global proliferation, with more than **280** operators worldwide embracing it to offer cost-effective voice and broadband data services. The CDMA Development Group (CDG) announced in September 2009 that the CDMA subscriber base crossed 500 millions, reaching a remarkable milestone. That subscriber base is forecasted to grow to more than 630 millions by 2013, primarily driven by growth in China, India, and other emerging markets.

CDMA2000 already offers excellent voice and mobile broadband solutions through CDMA2000 1X and EV-DO, respectively. Keeping up with the ever increasing demand, CDMA2000 continues to evolve and further increase the capacity and user experience through cost-efficient, incremental, and in many cases, software-only upgrades.

Multicarrier, the first phase of EV-DO Rev. B, is the natural next step for today's vastly successful EV-DO Rev. A networks. Multicarrier is a simple software-only upgrade, expected to be commercial in the latter part of 2009. Multicarrier triples data rates for all the users in the cell and can double the capacity for bursty applications such as Web browsing. The second phase of Rev. B, which involves a simple channel card upgrade, further increases data rates and capacity through the introduction of higher order modulation 64 QAM and BTS Interference cancellation (also known as Reverse Link IC). DO Advanced, another software upgrade, introduces a new dimension of improvement, and substantially improves network capacity and data rates by exploiting inherent uneven loading in the networks. The benefits of DO Advanced can be realized immediately after the upgrade as it improves network performance with the existing device base.

The voice-centric CDMA2000 1X is evolving to 1X Advanced, which quadruples the capacity of today's 1X networks. This unprecedented capacity increase afforded by 1X Advanced can also be used to free up spectrum for high revenue-earning EV-DO data services or to achieve up to 70 percent increase in coverage. 1X Advanced is expected to be commercial in the latter part of 2010.

Simultaneous 1X Voice and EV-DO Data (SVDO) is a complementary device enhancement that will significantly improve the user experience without impacting standards or infrastructure. SVDO allows devices to access EV-DO data services while in an active 1X voice call.

Some mobile operators who have access to new wider bandwidth spectrum are planning to augment their CDMA networks with LTE. LTE is an optimized OFDMA solution that complements EV-DO and 1X evolutions. It augments the data capacity of EV-DO networks in dense urban areas and leverages new, wider bandwidth spectrum to provide very high data rates. LTE will be overlaid on the EV-DO/1X network and seamless interoperability will be supported from day one. Hence, LTE/3G multimode devices will play a pivotal role in the commercialization of LTE.

Qualcomm with its strong lineup of industry leading infrastructure and device chipsets is in a unique position to support operators in the evolution of their CDMA2000 networks as well as the data capacity augmentation that will be possible with LTE.

2 CDMA2000 1X and EV-DO Provide Excellent Voice and Mobile Broadband Solutions Today

CDMA2000 1X was the world's first 3G technology and is the most widely deployed as of September 2009, based on number of subscribers. It incorporates efficient vocoders, robust power control and soft handoff mechanisms to offer excellent voice quality with best-in-class capacity.

Complementing CDMA2000 1X is EV-DO, offering excellent mobile broadband today and serving more than 130 million subscribers as of Jun 2009. It provides high data rates and capacity in a variety of deployments (fixed/mobile) and frequency bands. It supports all device and market segments as well as the entire range of applications and services demanded by consumers and enterprises.

2.1 CDMA2000 has a Large Ecosystem

CDMA2000 is supported by a large ecosystem of operators and manufacturers, as shown in *Fig. 1,* ensuring a full range of devices with varying feature sets and price points.
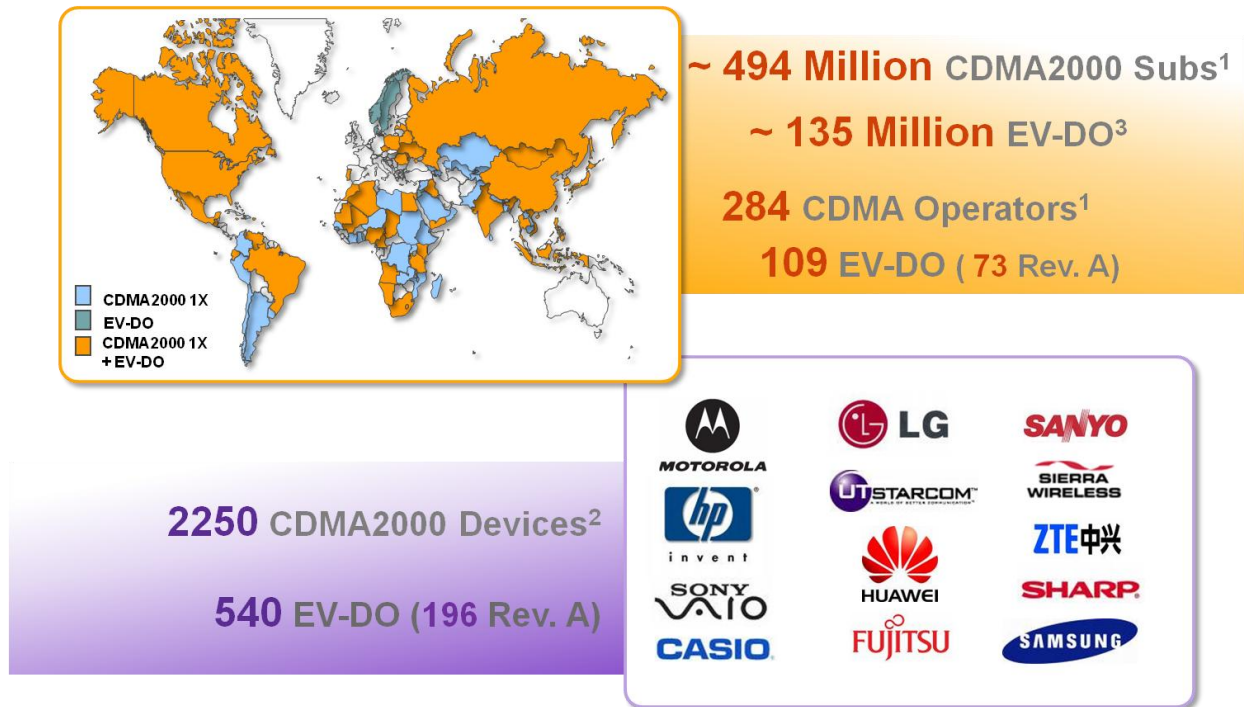
Figure 1: CDMA2000 has a large ecosystem

CDMA2000's low total cost of ownership has made it a popular choice among developed and emerging markets.

2.2   CDMA2000's Strong Growth Continues

CDMA2000 has experienced strong growth in the recent years, as illustrated in *Fig.2,* and this growth is expected to continue. The recent introduction of EV-DO Rev. A to India in 2008 and to China in 2009 is fueling continued growth in the world's two largest mobile markets. Various operators, including China Telecom and KDDI, have already committed to Multicarrier, ensuring CDMA2000's successful evolution.

Note: F – Forecasted; Source: Wireless Intelligence (August 24th, 2009)

Figure 2: EV-DO's strong growth continues

3   Strong CDMA2000 1X and EV-DO Evolution Paths

Since its commercialization in 1995, CDMA technology has been at the forefront of wireless innovation; and it continues to set new standards in voice and data efficiency. Its 3G version, CDMA2000, is enabling operators to economically address the ever-increasing demand for voice and data services through 1X and EV-DO, respectively.

As shown in *Fig. 3*, both 1X and EV-DO have strong and well established evolution paths. Both of these evolution paths provide simple, cost-effective upgrades that are future-proof and fully backward compatible.
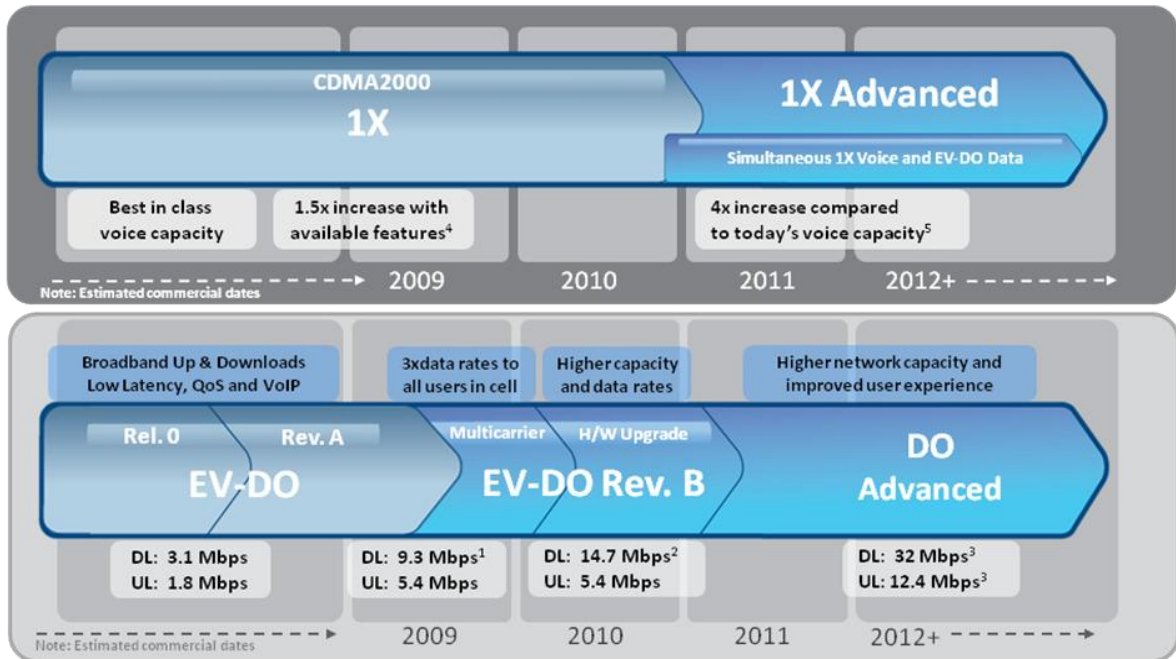
Figure 3: Both CDMA2000 1X and EV-DO have strong evolution paths

4 EV-DO Rev. B's Multicarrier is a Cost-effective Software Upgrade from Rev. A.

The phenomenal growth in the popularity of mobile broadband has resulted in the significant increase in data traffic worldwide. EV-DO operators around the globe are continuing to deploy multiple Rev. A carriers to address this increased traffic. In the evolution of these networks, Multicarrier, the first phase of EV-DO Rev. B is the natural next step. Multicarrier aggregates multiple Rev. A carriers through a cost-effective software upgrade, allowing operators to leverage their existing network assets. Thanks to seamless handoffs between Multicarrier and Rev. A base stations, further economies can be realized by introducing Multicarrier in phases, beginning with high-demand areas and urban hotspots, followed by a wider deployments that gradually reach suburban and rural clusters. Multicarrier is expected to be commercial in late 2009. Some operators like Wana in Morocco have already completed trials and many more are being planned during 2009.

4.1 Multicarrier Enhances Broadband Experience and Increases Capacity

Rev. B's Multicarrier allows the aggregation of up to three carriers which correspondingly triples the data rates for all the users in the cell. It also reduces latency, providing users with an enhanced broadband experience. *Fig. 4* shows the peak, median and cell-edge date rates that can be experienced with Multicarrier.

Source: Peak rates are as defined in standards. The median and cell edge rates are based on Qualcomm simulations, using mixed channel model with Rev. B Phase-II devices supporting 64 QAM
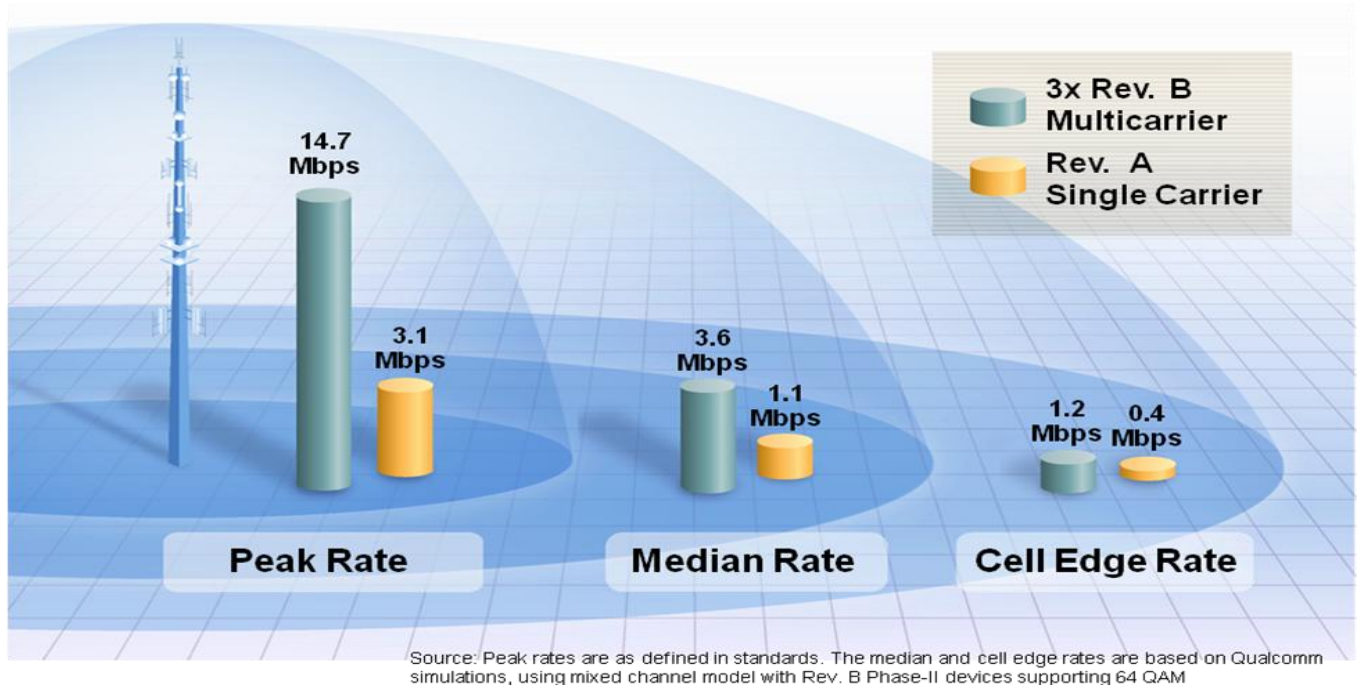
Figure 4: Rev. B's Multicarrier triples data rates for all users in the cell

For bursty applications such as Web browsing (under typical network loading conditions), Multicarrier can double the total capacity of three single Rev. A carriers while still offering users the same user experience. The increase in capacity can also be traded to reduce latency, and thereby increase the *perceived* data rates by the users. *Fig. 5* highlights this trade-off between capacity and user experience.
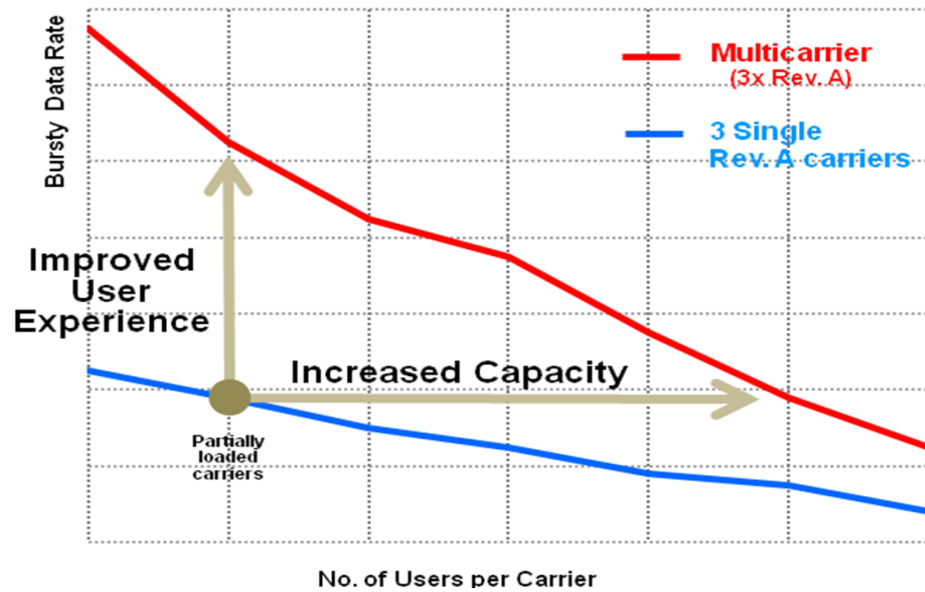
Note: Based on lab measurements using realistic traffic models from the web. The average burst download time (over the air) is reduced ~ 66%. The capacity gain depends on the sector load which in this case is typical for a EV-DO Rev. A system.

Figure 5: Rev. B's Multicarrier can double capacity of bursty applications

In Multicarrier deployments, the carrier allocation to each user is dynamically controlled by the network based on the type of application being used, the amount of data to be transferred, and the capabilities of the specific user device. For example, a user sending or receiving a simple text-based email may only be connected to a single carrier, but the act of downloading a large file or attachment may automatically trigger the allocation of additional carriers.

4.2   EV-DO Rev. B Channel Card Upgrade Offers Even Higher Data Rates and Capacity

The second phase of Rev. B involves a simple channel card upgrade based on Qualcomm's CSM6850 chipset. CSM6850 introduces Higher Order Modulation 64 QAM, offering a high downlink peak data rate of 14.7 Mbps. It is also the first commercial chipset to support BTS IC, which allows cancelling of both overhead and traffic signals of other users, which can yield an impressive ~65 percent increase in the uplink data capacity.

CSM6850 benefits not only multicarrier networks, but also single carrier networks, providing a peak rate of 4.9 Mbps per every 1.25 MHz CDMA carrier. CSM6850's ability to support up to four carriers on a single channel card enables better integration of BTS, thereby reducing upgrade

costs as well as network opex. Also, CSM6850 based solution can support up to 20 MHz of spectrum (15 EV-DO carriers) with only two channel cards, The commercial launch of the CSM6850 chipset is expected in late 2009.

4.3   EV-DO Rev. B is Gaining Momentum

The interest in EV-DO Rev. B is steadily growing worldwide, especially in markets where operators have deployed multiple Rev. A carriers to cater to the growing demand for data services.

KDDI, a leading Japanese operator, was the first to commit to Multicarrier, followed by Wana Telecom of Morocco, which successfully completed trials with infrastructure vendor ZTE. China Telecom has indicated that it will upgrade the network to Multicarrier in late 2009.

All the major CDMA2000 infrastructure vendors including Alcatel-Lucent, Airvana, Huawei, and ZTE have already announced products supporting EV-DO Rev. B. On the device side, Qualcomm has lined up a strong portfolio of chipsets supporting all device and market segments, ranging from connectivity devices like PC Cards and USB dongles, to low-cost single chip-based entry level feature phones, to high-end Snapdragon™-based smartbooks*. *Section 7* of this report details Qualcomm's extensive chipset support activities. PC cards and USB dongles are expected to be the first commercially available EV-DO Rev. B devices.

5   DO Advanced Maximizes the Performance of EV-DO Networks

DO Advanced adopts existing network resources to respond to uneven loading in networks to significantly increase network capacity and quality of user experiences where needed, through Smart Network techniques. Along with these new Smart Network techniques, DO Advanced also introduces Enhanced Connection Management to better manage bursty applications such as push/pull mobile email, as well as device enhancements that improve performance without impacting infrastructure or standards. DO Advanced is a simple software upgrade that benefits the existing as well as new devices. It improves the performance of all deployment scenarios including advanced topology networks that make us of macro-, pico and microcells, remote radio heads to bring the transmitter closer to the user.

To fully understand the benefits of DO Advanced, it is helpful to examine how EV-DO networks are typically deployed and used. A closer look reveals a notable pattern:

- In any mobile network, loading is inherently uneven. The loading is continuously changing with respect to time and location. For example, commercial areas will have more traffic during business hours, while residential areas peak during the evening hours.

- Usually, fully loaded sectors are surrounded by lightly loaded neighboring sectors.

- The network configuration is typically non-uniform. In EV-DO networks, the urban and high-traffic areas typically have a higher number of Rev. A carriers and suburban and rural areas have fewer carriers. Even within these areas there will be clusters with varying carriers, creating "hot-spot" scenarios.

DO Advanced is designed to exploit such inherent unevenness in network configuration and loading to significantly improve performance where and when needed.

5.1   New Dimension of Enhancements

DO Advanced introduces a new dimension of enhancements using Smart Network techniques designed to increase *Network Capacity* where and when needed. *Network Capacity* is defined as the total capacity of a cluster of sites (or per unit area) while meeting the desired user experience. This is different from *Spectral Efficiency*, the conventional term used to measure capacity. The difference is that *Spectral Efficiency* considers a fully loaded network, whereas *Network Capacity* considers an uneven loading, which is more typical of actual network conditions.

There are three Smart Network techniques that are a core part of DO Advanced:

- **Network Load Balancing** – This feature offloads the users on the edge of fully loaded sectors to lightly loaded neighboring sectors. The redistribution happens only if the user experience can either be maintained or improved. The offloading eases traffic congestion, alleviates any backhaul loading, increases overall network capacity in the cluster and improves user experience.

- **Demand Matched Configuration** – This feature dynamically changes the transmit power of the sectors of secondary carriers (second and third carriers on each sector) based on the amount of load they carry. In uneven loading scenarios, the transmit power of the second and third carriers of lightly loaded sectors is reduced to minimize interference, and in turn increase the capacity of highly loaded neighboring sectors.

- **Distributed Network Scheduler** – This feature increases data rates for users, especially at the edge of the cell in "hot-spot" deployment situations, by assigning the most suitable carriers to them, without sacrificing the gains achieved through Multicarrier. In such scenarios, the secondary carriers will most likely be the appropriate carriers to assign as they will have larger coverage area because of lower interference.

Smart Networks techniques enhance the performance of all network configurations. For example, single carrier networks benefit from Network Load Balancing, multicarrier networks benefit from both Network Load Balancing and Demand Matched Configuration, and mixed networks that have both single and multicarrier configurations benefit from all the Smart networks techniques.

Enhanced Connection Management (ECM) is another key feature of DO Advanced that manages connections based on the type of application being used by the device. This feature is particularly useful for applications such as "Push" email using smartphones and Mobile Instant Massaging. These applications generate huge volumes of short and bursty traffic, creating lots of overhead and congestion. ECM optimizes the process of allocation and de-allocation of resources to such applications and improves the usage of access and paging channels, resulting in support for a large number of simultaneous connected devices.

5.2   Significantly Increasing Network Capacity and User Experience

As discussed here, the gains of DO Advanced Smart Networks vary based on loading and unevenness factors across the network. In the typical network and distribution models, studies have shown an increase of twofold or more in *Network Capacity* as well as cell-edge data rates, thereby improving the overall user experience. *Fig. 6* shows an example of network capacity gains that can be achieved through DO Advanced.
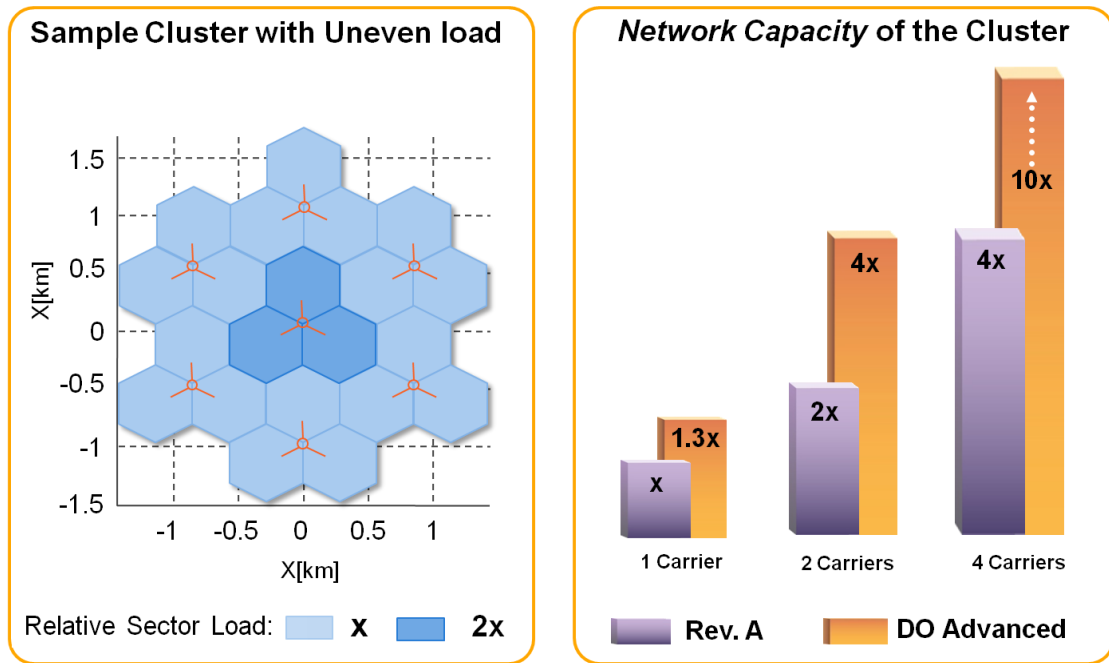
Figure 6: Example of DO Advanced Network Capacity gains of

The DO Advanced ECM significantly increases connection-capacity of the network and reduces congestion. It also improves battery life, decreases connection set-up time and enhances the "always-on" experience.

5.3 Cost-Effective Software Upgrade that Benefits Existing Devices

DO Advanced is a simple, software upgrade that leverages operators' existing infrastructure assets and device base. As shown in *Fig. 7*, the impressive improvements of DO Advanced can be achieved in all types of deployments:

1) Networks with single or multiple Rev. A carriers;

2) Rev. B Multicarrier networks;

3) Networks with only macrocells;

4) Advanced topology networks with macrocells as well as microcells, picocells, etc.
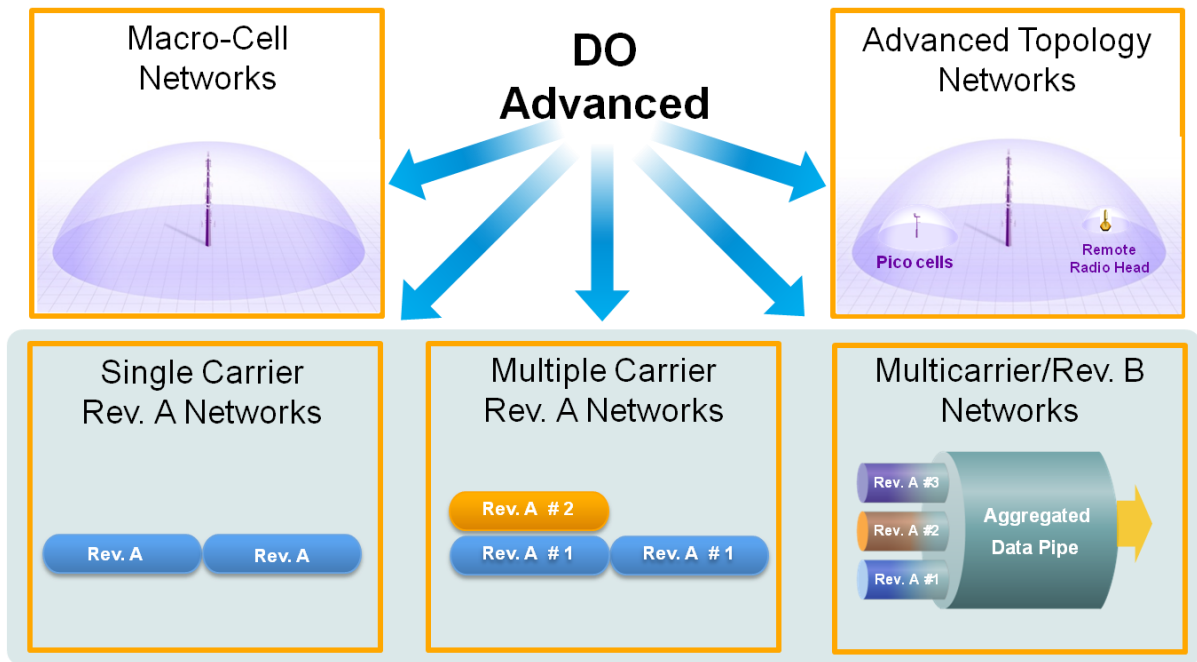
Figure 7: DO Advanced improves performance of all deployment scenarios

DO Advanced also supports both CSM6800- and CSM6850-based channel cards. It provides the existing devices an immediate performance improvement based on the infrastructure upgrade.

5.4 Devices Enhancements Can Significantly Improve Performance without Infrastructure Impact

Devices with Enhanced Equalizer and Mobile Transmit Diversity further increase the overall performance of DO Advanced networks, without requiring any changes in the infrastructure.

The Enhanced Equalizer exploits uneven and bursty traffic conditions to increase cell-edge data rates and downlink sector capacity. The increase in cell-edge rates can be as high as 45 percent, under typical network load, in dense urban areas where site-to-site distances are as short as 0.5km, and up to 25 percent for distances of 1.5km. The downlink sector capacity improvement largely depends on the relative load of the neighboring sectors. The increase can be as high as 25 percent for low-load scenarios, up to 20 percent under typical loads, and up to 10 percent for full load situations.

Mobile Transmit Diversity (MTD) utilizes dual transmit antennas to increase the uplink capacity by as much as 30 percent and almost double

the uplink data rates for cell-edge users. Another important observation is that any improvement in the uplink data rates significantly improves latency of applications like Web browsing on the downlink, especially for users at the cell-edge. Hence, with MTD, the user experience of bursty applications is greatly enhanced.

These device enhancements will be commercialized in phases and many of the features are expected to be available around the same time that DO Advanced launches commercially.

6   1X Advanced is the Natural Migration for CDMA2000 1X

In the era of "unlimited voice" offerings and the emergence of voice-centric developing markets, operators are in search of efficient voice solutions. At the same time, the growing popularity of broadband data is compelling operators to dedicate increasingly larger quantities of spectrum to data services. The evolution of CDMA2000 1X, of which 1X Advanced is a cornerstone, is designed to fulfill operators' needs.

Given the fact that it provides a significant capacity increase over today's 1X networks and that it is simple to implement via a channel card upgrade, 1X Advanced is a natural next step for CDMA2000 1X network operators.

6.1   Four-fold Increase in Voice Capacity

1X Advanced builds on the proven CDMA2000 1X technology platform and leverages interference cancellation, radio link enhancements and mobile receive diversity to provide an unprecedented four-fold increase in capacity over the majority of today's 1X networks. The transition to 1X Advanced has the advantage of being an incremental and economical upgrade, as shown in *Fig. 8*.
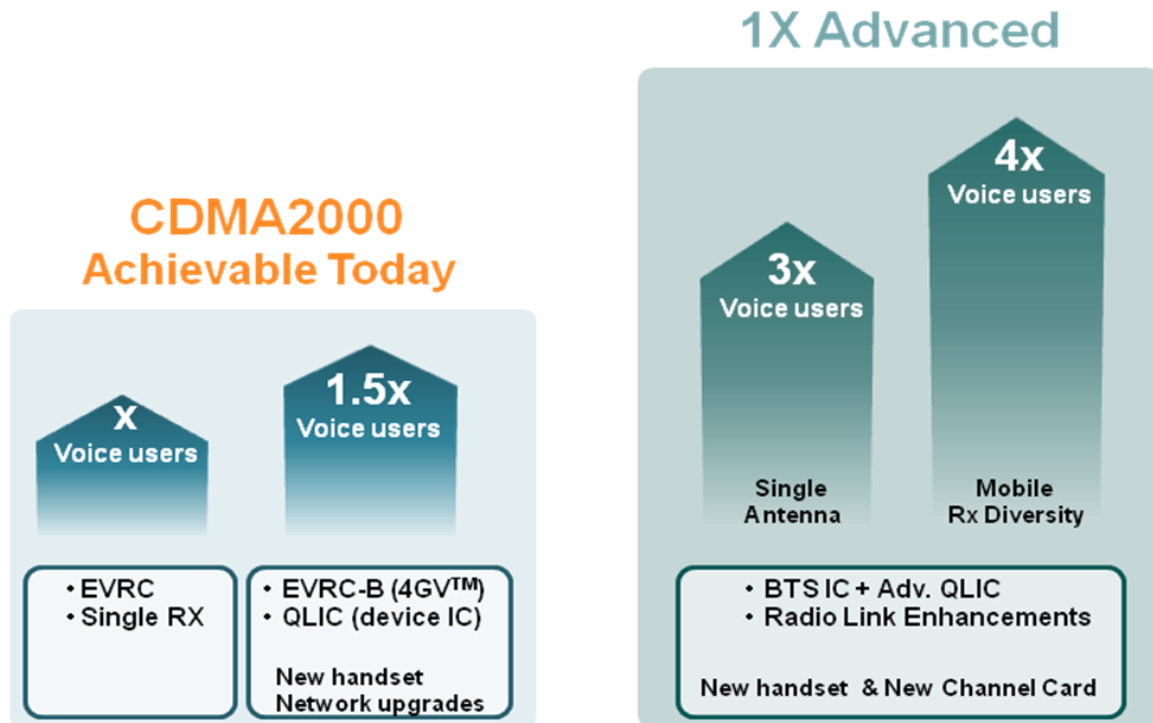
Figure 8: 1X Advanced offers up to 4x increase over today's 1X capacity

The capacity of today's 1X networks can easily be increased up to 50% by employing devices with enhanced features such as improved vocoder EVRC-B and handset interference cancellation QLIC. Devices supporting EVRC-B (4GV[TM]-WB) and QLIC are already available on the market today.

The next logical step is to move to 1X Advanced, which is a simple channel card upgrade supporting BTS Interference Cancellation, as well as radio link enhancements such as efficient power control, early termination and smart blanking, etc.

New 1X Advanced-capable devices will be required in order to realize the full benefits of the upgrade (a potential four-fold increase in capacity). However, since 1X Advanced is fully backward and forward compatible, new 1X Advanced devices will work with existing 1X infrastructure and the new 1X Advanced infrastructure will support existing 1X devices.

6.2   Early Time-to-Market by Leveraging Available MSMs with Mobile Receive Diversity

BTS interference cancellation (BTS IC) and Mobile Receive Diversity (MRD) features contribute substantially to the gains achieved with 1X

Advanced. Qualcomm's many commercially available MSMs support MRD today, allowing operators to pre-seed the market with devices supporting MRD, in addition to EVRC-B (4GV^{TM}-WB) and QLIC. This not only improves the capacity of existing networks, but also sets the stage for an immediate capacity boost when the network is upgraded with new channel cards supporting BTS IC.

As illustrated in *Fig. 9*, pre-seeding can yield capacity increases of up to 2.3x immediately after the new channel card upgrade. In addition, the new channel card will support BTS IC in the first release, followed by support for other enhancements coming in later commercial releases.
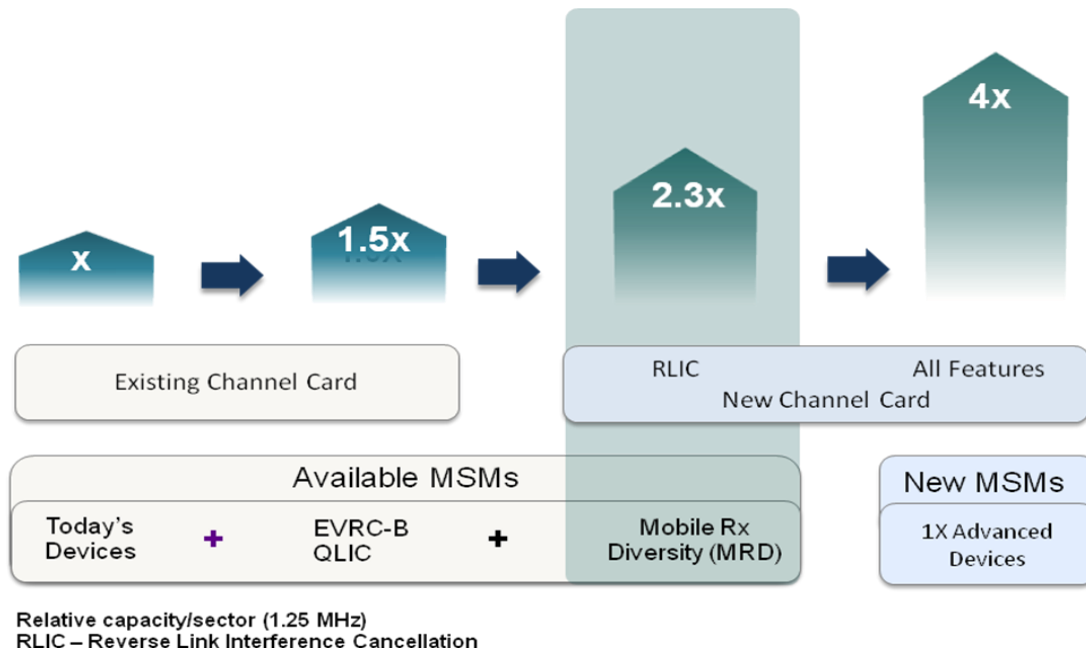

Relative capacity/sector (1.25 MHz)
RLIC – Reverse Link Interference Cancellation

Figure 9: Immediate capacity increase up to 2.3x by leveraging available MSMs supporting MRD

6.3   1X Advanced Frees Up Spectrum for EV-DO Data

1X Advanced uses only a quarter of the amount of spectrum that 1X uses to support the same amount of voice. As illustrated in *Fig. 10,* this frees up precious spectrum resources to offer high revenue-earning EV-DO broadband data services.
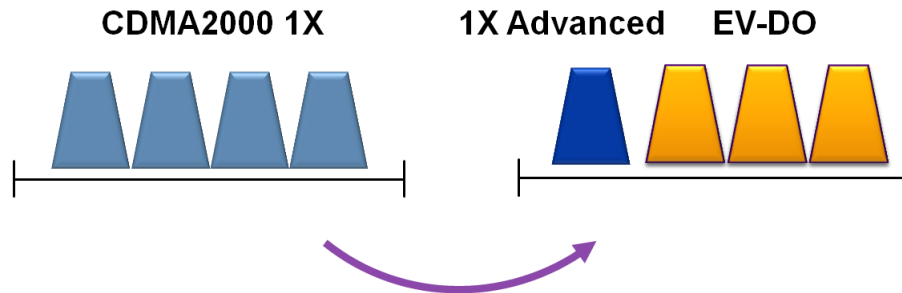
CDMA2000 1X **1X Advanced EV-DO**

Figure 10: 1X Advanced frees up spectrum for EV-DO data

In many developed markets, voice traffic is leveling off while broadband data traffic is substantially ramping up. In such a scenario, 1X Advanced helps operators dedicate more spectrum to EV-DO for broadband data services while sustaining the same amount of voice traffic.

6.4   Up to 70% Increase in Coverage

The impressive increase in capacity of 1X Advanced can be traded off to achieve up to a 70 percent increase in coverage. 1X Advanced represents an attractive solution for economically providing coverage in low population density areas as well as for improving indoor coverage in dense urban areas. Operators can flexibly design their networks to provide either a four-fold increase in capacity (with the same coverage as their current 1X network) or a 70 percent increase in coverage (with the same capacity as their current 1X network) or somewhere in between.

7   Simultaneous 1X Voice and EV-DO Data Improves the User Experience

Simultaneous 1X voice and EV-DO data, sometimes referred to as SVDO, is a new standard-independent device feature that significantly enhances the user experience without impacting the infrastructure side.

In today's networks, a device can be paged to receive 1X voice calls while in an EV-DO data session. However, no data connectivity is possible while in a voice call. SVDO establishes independent voice and data sessions using separate transmit and receive chains in the device, as shown in *Fig. 11*.

The SVDO feature can be effectively utilized by many applications. For example, users will be able to send emails or access the Web while on voice calls; phones with GPS can update maps or download real-time traffic information while on voice calls, etc.
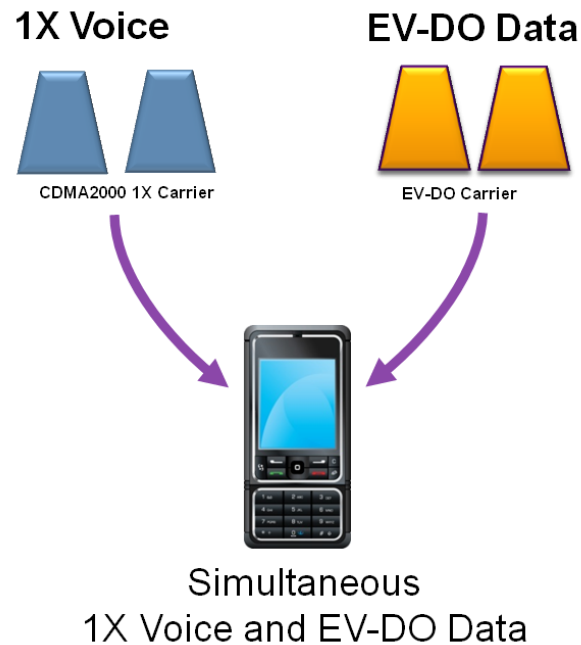
1X Voice   **EV-DO Data**

Figure 11: SVDO establishes independent 1X voice and EV-DO data sessions

The SVDO feature will be supported in new devices, and will work with 1X or 1X Advanced with EV-DO Rev. A or Rev. B. Qualcomm is planning to support the SVDO feature in all of its new EV-DO MSM chipsets.

8   LTE Complements CDMA2000 Evolution

Operators who have access to new, wider bandwidth spectrum are planning to augment their CDMA networks with LTE, an optimized OFDMA solution. Following the footsteps of successful 3G developments, LTE was designed from the ground up for mobility and high capacity. With its wider bandwidth, LTE is viewed as a practical solution to offer very high data rates and augment data capacity in dense urban areas. LTE's robust mobility features and seamless handoffs, as well as its interoperability with CDMA2000 1X and EV-DO, demonstrate its superiority over other OFDMA solutions.

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

8.1 Capacity Boost in Dense Urban Areas

LTE, with its ability to leverage new and wider bandwidths, can be employed to significantly increase data capacity, effectively augmenting underlying EV-DO networks, as illustrated in *Fig. 10.*
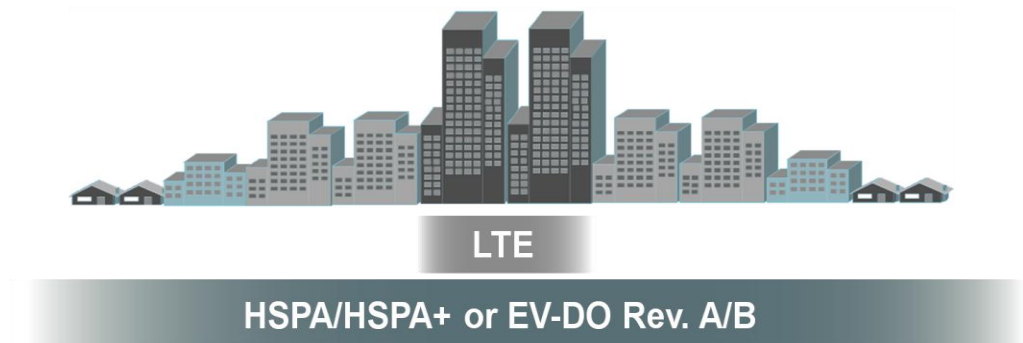

Figure 12: LTE overlay on a 3G network

EV-DO and its evolutions will continue to provide ubiquitous broadband service outside of focused LTE coverage areas, as well as voice services throughout the network.

LTE is designed to support the entire range of IP-based applications and services. The wireless 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. The first LTE handsets will rely on CDMA2000 1X for voice service and full support for voice through VoIP is expected in the future.

8.2 Leverages New Wider Bandwidth Spectrum

LTE's OFDMA technology excels at leveraging wider bandwidths. It is best suited for *new* spectrum with bandwidths of 10 MHz or more. The very high data rates made possible by wider bandwidths will result in an enhanced user experience.

For existing, re-farmed and new non-contiguous spectrum, EV-DO Rev. B and DO Advanced are the most cost-effective upgrade paths. They provide similar capacity as LTE, and also allow operators to extend the value of their current network investments.

As depicted in *Fig. 13*, LTE supports bandwidths of up to 20 MHz and supports both frequency division duplex (FDD) and time division duplex

(TDD) modes, allowing operators to address all available spectrum resources. The initial commercial LTE deployments are expected to support bandwidth of 10 MHz.
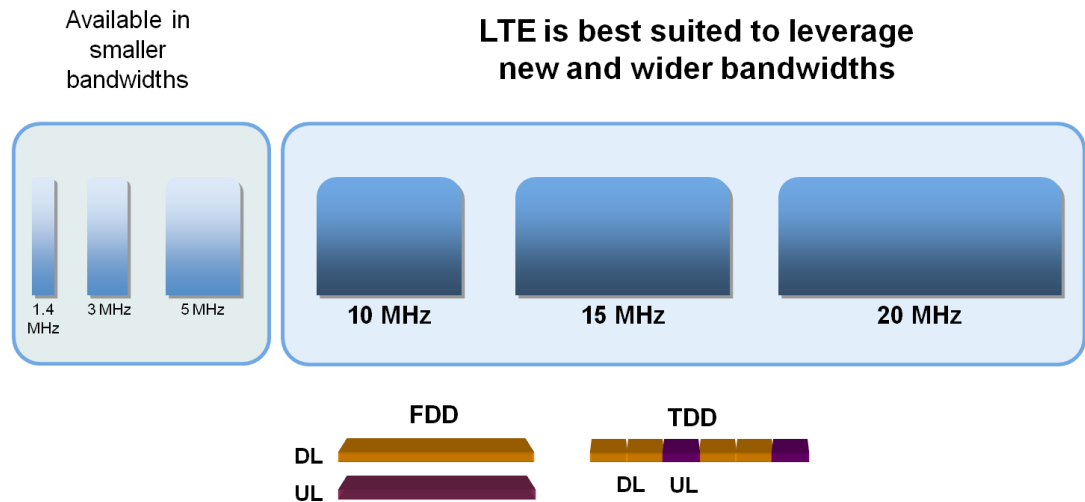

Figure 13: LTE leverages new wider bandwidths

TD-LTE is the optimal solution for the global unpaired TDD spectrum. Since TDD systems covers a smaller area compared to FDD systems for the same frequency, TD-LTE can be utilized to augment capacity in dense urban hotspots, effectively complementing underlying EV-DO and FDD-LTE networks. TD-LTE will leverage the large FDD-LTE/3G ecosystem, and hence will be more cost-effective than alternative TDD solutions in the market.

8.3   LTE is Evolving in Parallel with EV-DO

As previously noted, EV-DO already provides excellent mobile broadband today. With its low latency and efficient QoS features, it can 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 in user experience, both LTE and EV-DO are evolving in parallel (as illustrated in *Fig.14).* Rev. B and DO Advanced are the natural evolution paths for EV-DO networks, as they improve performance through simple, 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 EV-DO networks and their evolution.
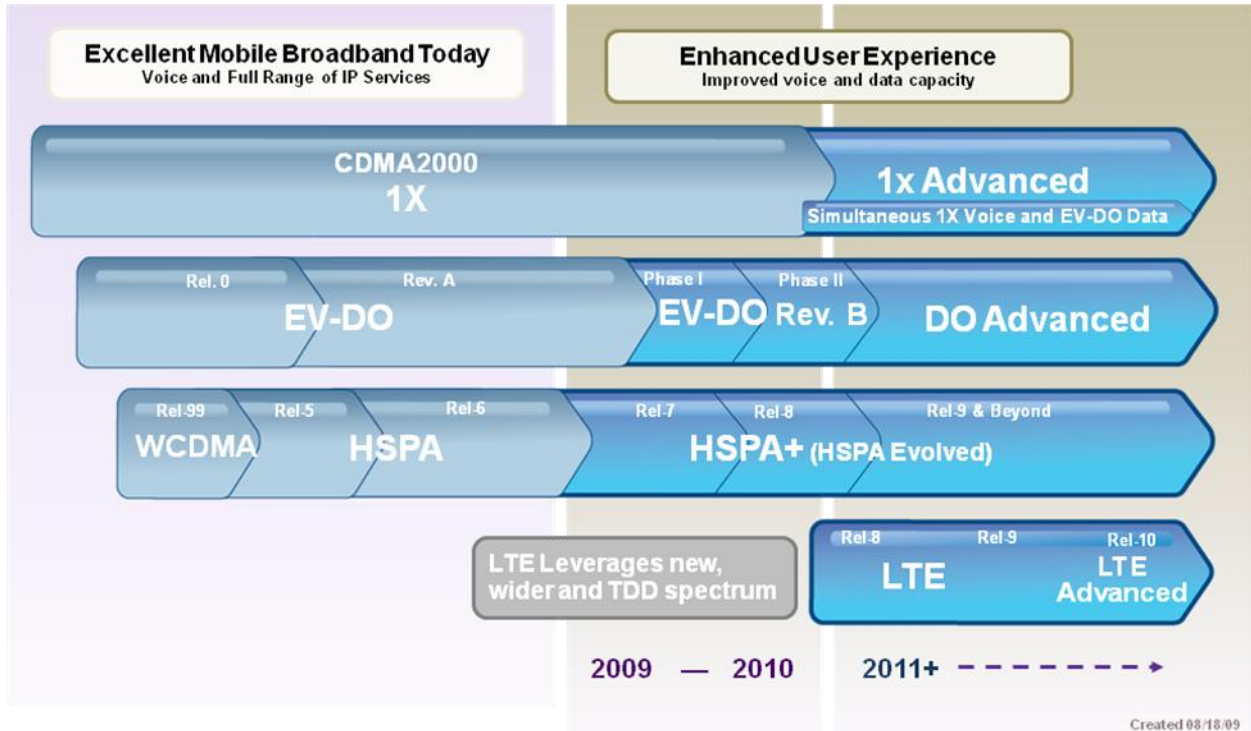

Figure. 14: LTE is evolving in parallel with EV-DO

9 Qualcomm's Strong Chipset support for CDMA2000 Evolution

Qualcomm has announced a strong line up of both infrastructure and device chipsets to support the complete CDMA2000 evolution. Qualcomm's device chipsets support all market segments from basic data connectivity devices like USB dongles and PC cards to feature phones, to smartphones and smartbooks*, including support for low-cost single chip solutions. Qualcomm with the industry's first LTE/3G multimode chipset solutions, is in a unique position to support operators, whenever they decide to augment the data capacity of their EV-DO networks with LTE.

*Legal notice: In the territory of the Federal Republic of Germany, the use of the term "Smartbook" in connection with portable computers is reserved exclusively to Smartbook AG, Germany.

10 Conclusion

CDMA2000 already provides an excellent voice solution with 1X and a mobile broadband solution with EV-DO. CDMA2000 is supported by a large ecosystem of operators; infrastructure and device vendors; and applications and services developers, providing economies of scale. Both 1X and EV-DO have strong evolution paths, successively increasing capacity, data rates and user experience. The evolutions are simple, cost-effective, incremental, and in many cases software-only upgrades, leveraging operators' existing infrastructure assets.

LTE is an optimized OFDMA solution that complements EV-DO and 1X evolutions. It augments the data capacity of EV-DO networks in dense urban areas and leverages new, wider bandwidth spectrum to provide very high data dates and enhanced user experience. LTE will be overlaid on the EV-DO/1X network and will deliver seamless interoperability from day one. LTE/3G multimode devices will play a pivotal role in the commercialization of LTE.

Qualcomm is well positioned to support the evolution of both CDMA2000 and LTE with a strong line up of industry-leading infrastructure and device chipsets.