WHITE PAPER

4G Network Migration cdma2000® to LTE Evolution

Today's wireless users may use their mobile devices in thousands of different ways, but they have one thing in common – a seemingly insatiable hunger for more. By the end of the decade, satisfying the demand for advanced services will not be possible on 3G legacy networks. That's why many traditional cdma2000 service providers are investigating technology alternatives in order to maintain and grow profitability. Motorola can offer a direct, well planned transition path that evolves service providers from cdma2000 to LTE and makes use of the existing CDMA network coverage with seamless hand-over between CDMA and LTE.

cdma2000® Leading the Industry with Innovation

CDMA has continuously led the industry in innovation since the late 1980s. Today, cdma2000 is an accepted standard for 3G networks. However there was a time when the concept of basing an air interface on code-division, rather than traditional time-division technology, was revolutionary.

The first analog cellular systems were deployed in the early 1980s, and were the beginning of this new wireless era. By the late 80s, carriers realized that analog technology could not provide the capacity they would need as wireless technology continued to be readily adopted. It was also apparent that the IS-54 standard (U.S. TDMA), would not satisfy the projected capacity needs.

A digital satellite technology showed promise for more efficient use of spectrum. Instead of GSM and TDMA's time-division-based technology, this code-division-based system encoded multiple voice conversations on an assigned 1.25 MHz carrier. The technology was being used for fleet-tracking by a then little-known San Diego, U.S. company called QUALCOMM Inc. As CDMA began entering the marketplace it was vital to convince service providers of the realities of CDMA's efficiency, cost-effectiveness, and ease of implementation. It was critical to ensure that service providers understood CDMA's ability to increase system capacity and that the future was designed so that upgrades would be inexpensive and simple, allowing CDMA service providers to offer advanced features and services very quickly.

The first CDMA standard for mobile networks is referred to as Interim Standard 95A (IS 95A). The IS-95A standard was completed in 1993 and served as a digital wireless technology that could replace analog systems. IS-95B is an upgrade to IS-95A. Both IS-95A and IS-95B are considered to be 2G technologies. 1X is the technology that follows IS-95. The term 1X is an abbreviation of 1xRTT (1x Radio Transmission Technology). 1X is considered to be 2.5G technology. EV-DO Revision 0 is a data centric technology that allows service providers to take advantage of the performance characteristics of the technology to offer advanced data services. The standard, cdma2000 High Rate Packet Data Air Interface, IS-856, was approved in August 2001. EV-DO Revision A (TIA-856-A) is the first in a series of planned upgrades for Release 0. The Revision A standard was approved in March 2004, with commercial services beginning at the end of 2006. EV-DO is considered to be 3G technology.

Figure 1: cdma2000 Technology Evolution

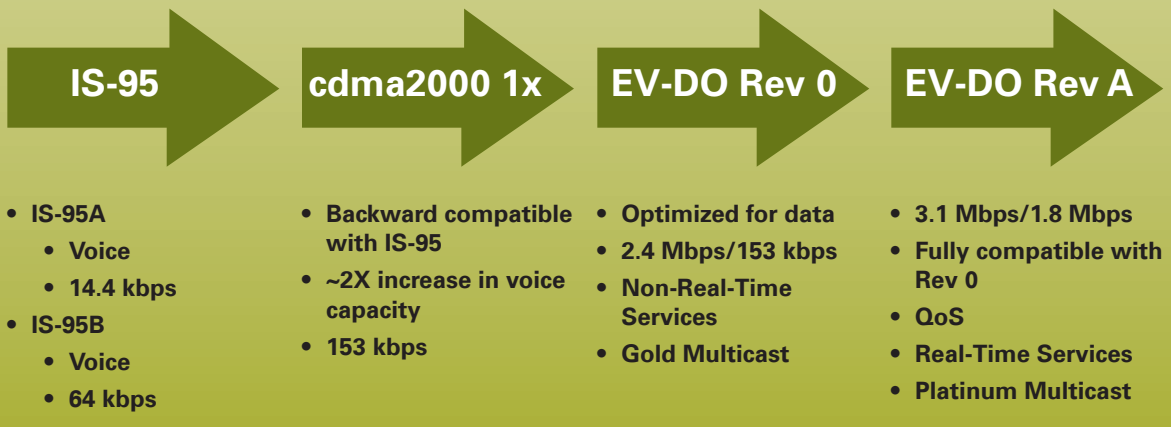
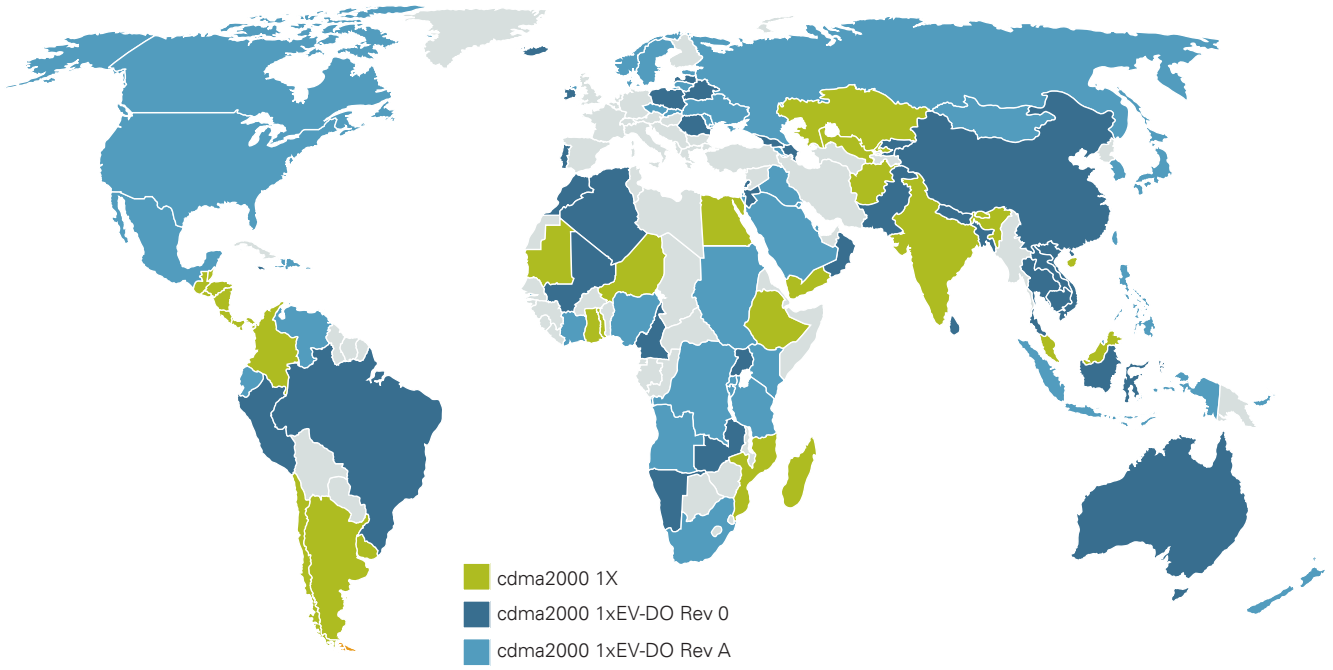


Figure 2: cdma2000 Worldwide Deployments



Today more than 275 service providers worldwide have selected cdma2000, and this number continues to grow. Within the past three years, over 100 service providers have selected cdma2000. cdma2000 services are available in 99 countries in every major market of the world, across all six continents.

The rapid growth of cdma2000 subscribers is due to its ability to satisfy the diverse wireless communication needs of consumers, small businesses, and large enterprises by offering high-quality voice and a broad range of applications. There were more than 400 million cdma2000 subscribers at the end of 3Q 2007. cdma2000 is on an accelerated path to broadband with 83 million 1xEV-DO subscribers worldwide.

Motorola has led the way in cdma2000 innovation, with a deep heritage in developing world-class CDMA systems for our global customers. Motorola CDMA solutions feature a robust, high quality portfolio of applications and services, with a solid roadmap and unique end-to-end capabilities.

1xEV-DO (Rev. 0/Rev. A) – Propelling the Industry into the Next Decade

The greater use of data applications, the increased amount of data being transmitted by these applications, and consumer demand for increased responsiveness to data requests has driven the need for a network infrastructure capable of providing higher data throughput at higher quality levels. Service providers across the world have found that this demand can be effectively and economically filled by cdma2000 1xEV-DO technology. With 1xEV-DO, mobile data subscribers enjoy faster access to Internet, m-commerce and corporate intranets. The higher capacity of the 1xEV-DO system accommodates a larger number of users and had increased the revenue potential for service providers. The higher capacity also allows service providers to reduce their per-subscriber cost of operating their wireless data network. 1xEV-DO has been deployed in mobile telecommunications networks around the world since 2002.

1xEV-DO Revision A was approved by the 3GPP2 Technical Specification Group (TSG-C) in April 2004. 1xEV-DO Revision A is an enhanced version of 1xEV-DO Revision 0, which delivers up to 2.4 Mbps data speeds. 1xEV-DO Revision A supports peak data rates of 3.1 Mbps on the forward link and up to 1.8 Mbps on the reverse link. The high data rates on the reverse link and low data latency has enabled service providers to greatly enhanced the wireless user experience for not only business users, but also for consumers, who have enjoyed broadband Internet access, email, audio and video streaming, music downloads, and location-based services. The OFDM waveform has been introduced into cdma2000 1xEV-DO Revision A to offer high capacity multicast capabilities that will allow service providers to offer lower cost multicast services while maintaining a robust high speed mobile network.

Motorola is a worldwide leader in 1xEV-DO technologies (Rev. 0/Rev. A), providing integrated solutions that enable new services while leveraging service providers' existing CDMA 1X networks to help protect existing investments. Motorola 1xEV-DO solutions have successfully been deployed globally since 2004.

LTE as the Next Evolutionary Step

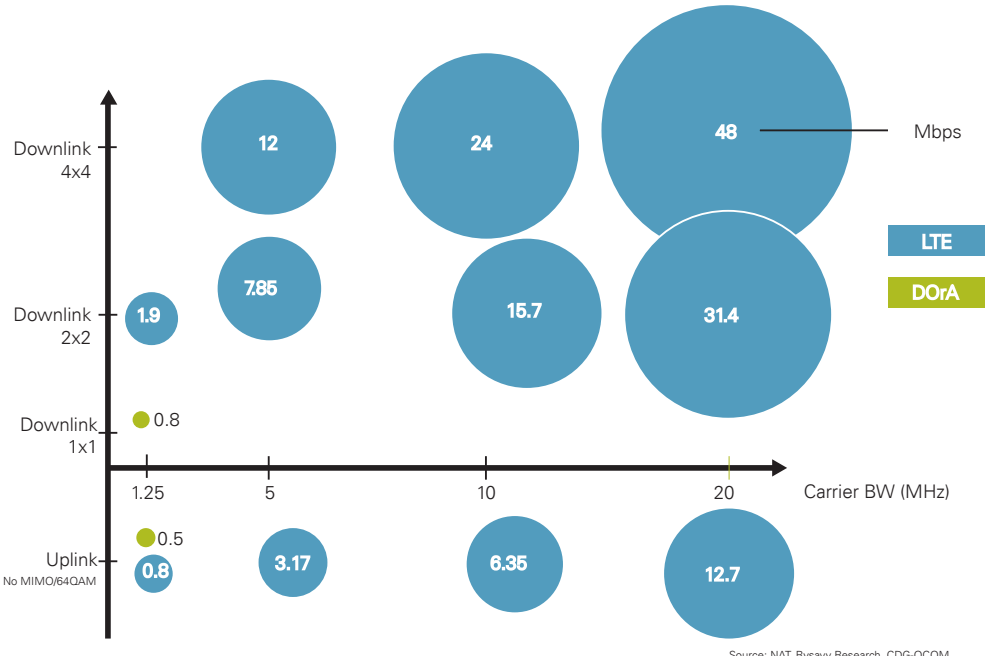
Recent industry analyst figures show significant growth in the number of mobile data service subscribers and in data consumption; these factors combined will result in exponential growth of the amount of data that will soon be flowing through mobile networks. The migration to 4G networks will be influenced by a number of subscriber driven factors including their evolving appetite for more information, entertainment, and functionality, combined with the expectation for easy access, high speed, and media mobility.

Over the course of the next decade, it will become difficult to fulfill this rapidly growing demand on cdma2000 legacy networks. As a direct result, cdma2000 service providers are inspired to investigate technology alternatives in order to maintain and grow profitability. LTE is the latest technology from the 3GGP standards group that brought the world GSM and UMTS which now account for over 85% of all worldwide mobile subscribers. LTE RAN (also referred to as Evolved UMTS Terrestrial Radio Access Network (E-UTRAN), is expected to substantially improve end-user throughputs, sector capacity and reduce user plane latency, bringing a significantly improved user experience with full mobility. With the emergence of Internet Protocol (IP) as the protocol of choice for carrying all types of traffic, LTE will provide support for IP-based traffic with end-to-end Quality of Service (QoS). Voice traffic will be supported mainly as Voice over IP (VoIP), enabling better integration with other multimedia services. Initial deployments of LTE are expected by 2010 with commercial availability on a larger scale expected 1-2 years later.

While there are several wider bandwidth OFDM solutions to be evaluated, it is expected that many traditional cdma2000 service providers will want to take advantage of the benefits of LTE and choose to migrate along the 3GPP standards path. Many service providers will find no significant technological advantages among the other 4G options and the decision to depart from the 3GPP2 standards will be based on pure economics: a desire to get on the same 4G standard and become part of the global wireless community. It should be noted that, although possible, it is neither necessary nor advisable for cdma2000 Operators to first migrate to GSM or UMTS in order to deploy LTE. Motorola can offer a direct, well planned, transition path that evolves service providers from cdma2000 to LTE and makes use of the existing CDMA network coverage with seamless hand-over between CDMA and LTE.

Into the next decade service providers' focus will continue to be on providing a more diverse service mix, including entertainment content, business

Figure 3: DOrA vs LTE Performance - Average Throughput per Sector



applications and access to corporate networks. LTE will revolutionize the way in which existing services are consumed, as well as enable the delivery of a whole new range of high-value services and applications, thereby addressing the trend of declining ARPU common to many mobile markets.

Traditional cdma2000 service providers will benefit from the global connectivity afforded by LTE. The 3GPP family of technologies (i.e. GSM and UMTS) has been a tremendously successful and has an unsurpassed installed base of both infrastructure and subscribers. Global roaming enabled solely by expensive dual-mode world phones with GSM and CDMA embedded in them have put many cdma2000 service providers at a competitive disadvantage as the majority of worldwide service providers have been able to leverage GSM/UMTS as a world standard.

Significant economies of scale are achievable through the adoption of a common access platform with true global scale. Compatibility with existing technologies will increase the competitive dynamics of the infrastructure market place thus driving down overall CAPEX for Mobile Operators who will, in turn, be able to deliver advanced LTE services profitable.

Spectrum

The availability of adequate spectrum resources will remain a major challenge to the deployment of LTE for cdma2000 service providers. LTE suits several FDD spectrum allocations, particularly AWS and the impending 700 MHz auctions in the United States.

Advanced Wireless Services (AWS)

In September 2006 the U.S. FCC completed an auction of AWS licenses ("Auction No. 66") in which the winning bidders won a total of 1,087 licenses. In the spirit of the U.S. government's free-market policies, the FCC does not usually mandate that specific technologies be used in specific bands. Therefore, owners of AWS spectrum are free to use it for just about any 2G, 3G or 4G technology.

This spectrum uses 1.710-1.755 GHz for the uplink and 2.110-2.155 GHz for the downlink. 90 MHz of spectrum is divided into six frequency blocks A through F. Blocks A, B, and F are 20 megahertz each and blocks C, D, and E are 10 megahertz each.

The FCC wanted to harmonized its "new" AWS spectrum as closely as possible with Europe's UMTS 2100 band. However, the lower half of Europe's UMTS 2100 band almost completely overlaps with the U.S. PCS band, so complete harmonization wasn't an option. Given the constraint the FCC harmonized AWS as much as possible with the rest of the world. The upper AWS band lines up with Europe's UMTS 2100 base transmit band, and the lower AWS band aligns with Europe's GSM 1800 mobile transmit band.

700 MHz

In the U.S., this commercial spectrum was auctioned in January-March/ 2008. This includes 62 MHz of spectrum broken into 4 blocks; Lower A (12 MHz), Lower B (12 MHz), Lower E (6 MHz unpaired), Upper C (22 MHz), Upper D (10 MHz). These bands are highly prized chunks of spectrum and a tremendous resource: the low frequency is efficient and will allow for a network that doesn't require a dense buildout and provides better in-building penetration than higher frequency bands.

The upper D block will come along with a Public/ Private Partnership obligation. As part of the 700 MHz FCC decision, the winner of the commercial license will combine this asset with an additional 10 MHz of adjacent spectrum licensed to a national Public Safety Broadband Licensee (PSBL), creating a public-private partnership. In exchange for constructing and operating the shared network to Public Safety specifications, the D Block commercial licensee will gain access to spectrum, on a secondary basis, held by the PSBL to provide it with additional capacity to furnish non-priority communications services to commercial subscribers.

Band	Uplink (MHz)	Downlink (MHz)	Carrier Bandwidth (MHz)	Comments
700 MHz	776-793	746-763	1.25 5 10 15 20	Digital dividend: U.S. commercial spectrum auctioned in January/ February 2008. Potential future alignment with Europe
AWS	1710-1755	2110-2155	1.25 5 10 15 20	U.S. auctions completed September 2006

Other Candidate Bands

Cellular 800: Refarm this spectrum in the U.S. after new 700 MHz and AWS spectrum is consumed. In Japan, reallocation of this spectrum is likely.

GSM 900: Refarm this spectrum as subscriber migration from GSM to UMTS takes place.

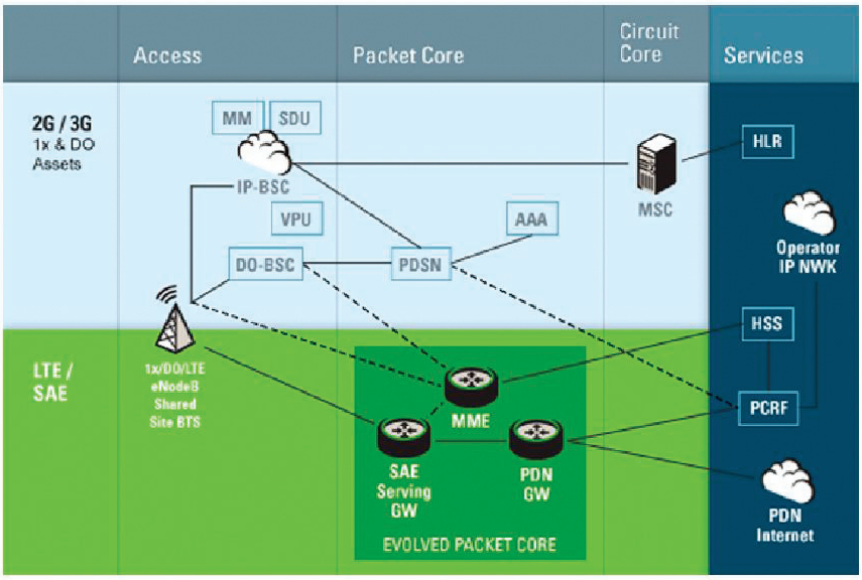
GSM 1800: Interest from Americas, Asia Pac and some countries in EMEA, especially for the refarming of existing GSM spectrum. UMTS Core Band 2.1 GHz: This is the core 3-3.5G band for EMEA and AsiaPac with deployments of networks in over 150 countries. Most service providers were awarded 2, 3 and in some limited instances 4 x 5 MHz carriers in this spectrum band. Most service providers are so far only used one band but with mobile data growth and subscriber migration to UMTS/HSPA, it is yet unclear if and how many carriers will be available in that band for LTE services in 2009-2010.

PCS 1900: Alternative to core band, which is not available in EMEA. Service providers may refarm this spectrum in the U.S. after new 700 MHz and AWS spectrum is consumed.

cdma2000/LTE Architecture

Migration/evolution of 3GPP2 service providers to EUTRAN/EPC involves the overlay of the EPC elements (MME, SGW, and PDN-GW) and the potential to use the EV-DO BTS frame to deploy the EUTRAN components (both the baseband and the radio head).

Figure 5: cdma2000/LTE Architecture



Functional Elements

A brief description of the functional elements that make up the EUTRAN/EPC is provided below:

- **eNodeB (eNB)** encompasses the bottom layers of the radio link between the user equipment (UE) and the network. It performs many functions including radio resource management, admission control, scheduling, enforcement of negotiated UL QoS, cell information broadcast, ciphering/deciphering of user and control plane data, and compression/decompression of DL/UL user plane packet headers.
- **Serving Gateway (SGW)** routes and forwards user data packets, while also acting as the mobility anchor for the user plane during inter-eNB handovers and as the anchor for mobility between LTE and other 3GPP technologies. It also performs replication of the user traffic in case of lawful interception.
- **Mobility Management Entity (MME)** is the key control-node for the LTE access-network. It is responsible for idle mode UE tracking and paging procedure including retransmissions. It terminates Non-Access Stratum (NAS) signaling used for bearer activation/deactivation process, user authenticating the user (by interacting with the HSS), and generation and allocation of temporary identities to UEs. Lawful interception of signaling is also supported by the MME.
- **Packet Data Network Gateway (PDN GW)** provides connectivity between the UE and external packet data networks (PDN) by being the point of exit and entry of traffic for the UE. A UE may have simultaneous connectivity with more than one PDN GW for accessing multiple PDNs. The PDN GW performs policy enforcement, packet filtering for each user, charging support, lawful Interception and packet screening. Another key role of the PDN GW is to act as the anchor for mobility between 3GPP and non-3GPP technologies such as WiMAX and 3GPP2 (CDMA 1X and EV-DO).

Motorola has been very active in the development of LTE standards and has been pushing for an architecture in which all the radio-specific functions are at the eNB; cellular specific control functionality is contained in control-plane nodes, and CN user plane nodes can be based on generic IP routers. Such architecture will result in lower capital (CAPEX) and operational (OPEX) expenditure for service providers. The topics on which Motorola has made significant contributions include:

- Flat RAN architecture
- Termination of RLC and PDCP protocol layers in the eNB

- Distributed radio resource management using direct eNB to eNB interaction
- Control-plane and user-plane separation resulting in the split between MME and Serving Gateway
- Enabling Serving Gateway sharing between service providers
- Use of IETF mobility protocols, specifically (proxy) Mobile IP, for mobility on the different interfaces
- Mobility solutions in active mode, including context transfer at RLC/PDCP layers, location of packet reordering function etc. Motorola's position on the LTE architecture has been motivated by maximizing reuse of components and network elements across different technologies. Our position has been driven by the desire to reuse generic routers and IETF-based mobility protocols and network elements, such as Home Agent (HA) and Foreign Agent (FA), as much as possible. Such re-use is expected to significantly reduce the CAPEX for service providers. Motorola has also been actively supporting mobility between 3GPP and non-3GPP networks, such as WiMAX, to enable seamless mobility of dual-mode devices across these technologies.

cdma2000/LTE Network Interaction

Migration/evolution of 3GPP2 service providers to EUTRAN/EPC involves updates to the 1x/DO-A network deployed today for seamless interworking of services between the two technologies.

These upgrades allow service providers to realize one of the key LTE capabilities: providing a common service environment for their subscribers while supporting different access technologies.

Upgrades to the DO-A network allow subscribers to use a common mobility anchor point between LTE and DO-A networks (PDN GW) thereby enabling HRPD-LTE handovers. This enables seamless support for services while supporting mobility between LTE and DO-A, a key requirement during the initial stages of LTE deployment. These DO-A upgrades impact the IP-BSC-DO and the PDSN. The IP-BSC-DO is upgraded to support a signaling interface to the LTE MME.

The PDSN is also upgraded to support a data forwarding interface to the LTE Serving Gateway There are also new changes to support the LTE mobility protocols to the PDN GW. This enhanced PDSN is also known as the HRPD Serving Gateway (HSGW). Multi-mode terminals will be necessary to support the access technologies.

Interworking cdma2000 voice calls using 1xRTT with LTE VoIP is also possible using the Virtual Call Continuity (VCC) service. This service, originally developed for 1xRTT/DO-A handovers, is being extended for LTE and plans are underway to standardize this solution in 3GPP. An Interworking Function between the 1x BSC and the LTE MME will be required to interwork the signaling between the two access networks. Once this Interworking Function is deployed, service providers will have the capability of LTE VoIP call to 1xRTT call handover, providing seamless voice service.

Figure 6: 1xEV-DO/LTE Network Interaction

Network Element	1X EV-DO (Rel 0/A)	EUTRAN/EPC (LTE)
PDSN	• Upgraded to support a data forwarding interface to the LTE Serving Gateway (S103) • Changed to support the LTE mobility protocols • Enhanced PDSN is also known as the HRPD Serving Gateway (HSGW) • Integrated QoS management with LTE	N/A
IP-BSC-DO	• Upgraded to support a signaling interface (New - S101) to the LTE MME for DO-LTE mobility	N/A
AAA	• Shared	• Shared
PDN Gateway	N/A	• New – common mobility anchor point that enables DO-LTE mobility
Serving Gateway (SGW)	N/A	• New – routes and forwards user data packets for DO-LTE mobility
Mobility Management Entity (MME)	N/A	• New – control-node and signaling interface for DO-LTE mobility

Conclusion

Motorola has led the way in cdma2000 innovation, with a deep heritage in developing world-class CDMA systems for our global customers. By the end of the decade it will not be possible to fulfill the surging demand for advanced services on cdma2000 legacy networks. It is expected that many traditional cdma2000 service providers may want to take advantage of the benefits of LTE and choose to migrate along the 3GPP standards path. It is not necessary for cdma2000 service providers to first migrate to GSM or UMTS in order to deploy LTE. Motorola can offer a direct, well planned, transition path that evolves Service providers from cdma2000 to LTE.

Motorola's LTE solution presents a straight-forward evolution to the world of mobile broadband for the 3GPP2 service provider. With the envisaged throughput and latency targets complimented by and emphasis on simplicity, spectrum flexibility, added capacity and lower cost per bit, LTE is destined to provide a greatly improved user experience, and delivery new revenue generating mobile services that will excite users.

To realize these goals Motorola is leveraging its extensive expertise in mobile broadband innovation, including OFDM technologies (wi4 WiMAX), cellular networking (EVDOrA, HSxPA), IMS ecosystem, collapsed IP architecture, standards development and comprehensive services to deliver best-in-class LTE solutions. Leveraging the benefits of Motorola's mobile broadband experience and proven expertise in OFDM network deployments, Motorola's LTE end-to-end solution will provide a seamless and flexible path to LTE with a high degree of future proofing for the service provider. Following this path, Motorola's 3GPP2 customers will be well positioned to provide the world's most compelling mobile broadband services and applications.

For more information on Motorola LTE and CDMA to LTE migration, please talk to your Motorola representative.

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