

Overcoming Challenges for Real-time Voice Applications in CDMA 2000 EV-DO Release 0 Networks

KODIAK NETWORKS WHITE PAPER

1.0 Introduction

CDMA2000 1xEV-DO (Evolution – Data Optimized) is a commercial 3G wireless technology which is expected to enable adoption of new mobile data applications worldwide. These bandwidth-intensive applications include web browsing, media content downloading, multimedia messaging, and interactive gaming. EV-DO Release 0 is the current implementation of this technology, which includes device chipsets predominantly from Qualcomm and network infrastructure from major suppliers such as Lucent Technologies and Nortel Networks. As designed, EV-DO Release 0 supports data speeds up to 2.4Mbps, with average data rates of 300 – 600kbps.¹ For operators choosing the CDMA2000 technology upgrade path, EV-DO Release 0 provides a competitive response to wireless broadband technologies such as GSM/EDGE/UMTS, WiMAX, and DSL, and cable modem solutions offered by other wireless carriers, Local Exchange Carriers (LECs), and cable providers. Robust growth for this technology is expected over the next several years, as over 250 million EV-DO subscribers are forecasted by 2009.²

2.0 Market Overview

As of the third quarter 2005, there are over 12.9 million EV-DO subscribers worldwide, supported by 16 commercial networks. This includes major operators such as Verizon Wireless, Sprint PCS (now Sprint/Nextel), SK Telecom Korea, and KDDI Japan.³ EV-DO technology is being launched by CDMA2000 operators largely to support broadband wireless applications, including web browsing, electronic mail, streaming audio/video clips, interactive gaming, and other entertainment applications. Operators in North America who have launched EV-DO have positioned the offering (e.g. Verizon Wireless offering Vcast) mostly as a data-centric service enabled with EV-DO laptop cards. This is due to limited EV-DO handset availability (Verizon currently had 3 devices available as of September 2005) and coverage only in major metropolitan areas.

Amp'd Mobile, a Mobile Virtual Network Operator (MVNO) using Verizon's EV-DO network, recently announced the launch of these broadband data services combined with low-latency voice applications such as Push to Talk (PTT). Amp'd represents an departure from previous EV-DO operator positioning, by emphasizing entertainment-focused broadband applications tightly integrated with PTT as a complementary package for the youth market. Combining these offerings on present EV-DO technology, operators can create technical and performance trade-offs which have a direct impact on the quality of the user experience.

3.0 The Kodiak RTX System

EV-DO is part of the Qualcomm family of CDMA2000 technologies, and is the successor to CDMA2000 1x technology. While CDMA2000 1x technology can support 307kbps downlink/153kbps uplink speeds, EV-DO can support up to 3.1 Mbps downlink/1.8Mbps uplink speeds.⁴ Typical downlink data rates, however, range between 400kbps and 700kbps, while uplink data rates are highly sensitive to the number serving subscribers and distance to the cell site.⁵ EV-DO operates within a 1.25MHz slice of spectrum and uses a combination of techniques of data transmission (both CDMA and time division multiplexing) on the downlink and uplink. EV-DO Release 0 is the technology version most broadly released by CDMA operators today. Follow-on versions of EV-DO are not expected to be commercially deployed on a broad basis until 2008 at the earliest.^{6,7}

4.0 CDMA 1xEV-DO Release 0 Issues and Implications to the User Experience

While EV-DO is fulfilling what it was designed to do – supporting broadband data applications - there are technical challenges which directly impact the anticipated EV-DO Release 0 user experience for voice applications.

¹ Growth and Evolution of CDMA2000 1xEV-DO – Airvana, February 2004

² Qualcomm Presentation Lehman Brothers Technology Conference, June 2005

³ Qualcomm Presentation Lehman Brothers Technology Conference, June 2005

⁴ Qualcomm Website overview on EV-DO, August 2005

⁵ Verizon press release on EV-DO coverage and prices, August 2005

⁶ Sprint PCS CTO comments at recent analyst meeting, July 2005

⁷ JP Morgan Equity Research Report, December 2004

These performance issues include:

- **Longer Call Set-up Delays** – Is EV-DO designed to support real-time voice applications with its long paging cycle?
- **Lack of Quality of Service (QoS)** – Can a network technology built to optimize overall throughput of the radio channel while downloading large amounts of data, web browsing, and content access, still support real-time, high QoS voice applications including PTT?
- **Link Limitations, Asymmetries, and Inefficiencies** – How do inherent EV-DO link limitations such as lack of multi-user slotting and an asymmetric data channel, adversely impact PTT capacity and the typical user experience?
- **Poor Multi-Network Interaction** – How do EV-DO handsets process calls as they enter into CDMA2000 1x coverage areas and how does it impact the typical user experience?
- **Coverage Inadequacies** – How does the overlay of EV-DO and CDMA2000 1x networks negatively impact consistent, seamless coverage needed for PTT?

The following sections will discuss each set of performance issues.

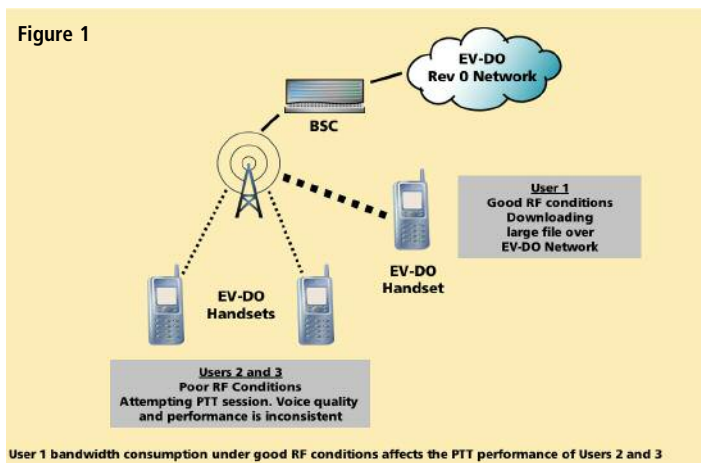
4.1 Longer Call Set-up Delays

EV-DO has built-in limitations which adversely affect performance of real-time voice applications such as PTT, especially call set-up time. EVDO terminal devices only "wake up" every 5.12 seconds to look for incoming data sessions (idle state Slot Cycle Index of 2). Therefore the average "wake-up" cycle for the terminating mobile to recognize an incoming session is 2.5 - 3 seconds, with a maximum time of over 5 seconds. This "wake-up" time causes the call set-up time (time from pushing the PTT button until the voice is delivered to the receiving user) to be significantly longer than CDMA2000 1x. Lowering the Slot Cycle Index setting to change these characteristics is not supported under EV-DO Release 0. This design limitation results in longer call set-up delay for PTT subscribers than other solutions available today.

4.2 Lack of Quality of Service (QoS)

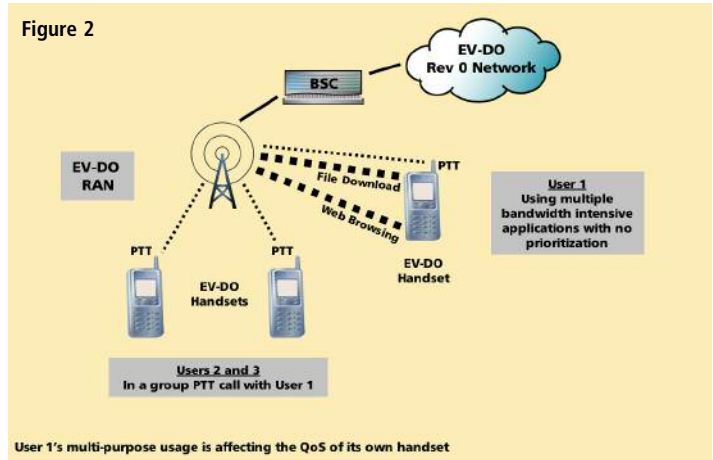
The inherent design attributes of CDMA2000 networks do not distinguish between traffic priority, applications, or bandwidth usage. In order to maximize throughput per sector, EV-DO assigns the highest data rates to users in the best RF conditions, regardless of what application they are running. Therefore, within a specific coverage area, the traffic being serviced at any given cell site will be handled by a scheduler that does not differentiate between the relatively "priority" of sessions. This situation creates QoS problems with multiple manifestations, including prolonged intra-call latencies, poor voice quality, and an inconsistent user experience. The lack of any end-to-end QoS in EV-DO release 0 further impacts the user experience and requires the operator to overprovision the core network. The lack of QoS is termed either "inter-user" QoS (between multiple users on the EV-DO network) or "intra-user" (impacting a specific device on the network). The follow paragraphs describe this distinction.

Figure 1 depicts the lack of support for "Inter-User" QoS. While User 1 is downloading a large file or other bandwidth-intensive content (music track, video/audio clips) to its device, User 2 and User 3 are attempting a PTT voice session. The cell site is maximizing overall throughput of the cell by sending more data to User 1 in favorable RF conditions while waiting until RF conditions improve for User 2 and User 3. In this case, performance and QoS deteriorates for User 2 and User 3. Latency-sensitive applications such as PTT will suffer in this scenario as EV-DO maximizes data throughput, at the expense of QoS. Moreover, any QoS measures implemented in the core network itself, such as Diffserv or Multi-protocol



Label Switching (MPLS), will not improve the situation because there is no linkage between core network QoS and EVDO radio networks. Figure 2 illustrates the "Intra-user" QoS scenario with different adverse effects. There is no differentiation of service priority on an individual handset which places the quality of the individual EV-DO PTT session at risk. Concurrent PTT, file download, and web sessions compete for network resources available to the EV-DO. As EV-DO does not distinguish between the high priority PTT application and lower priority file transfer or web browsing session, the quality of the PTT session is negatively impacted.

Figure 2

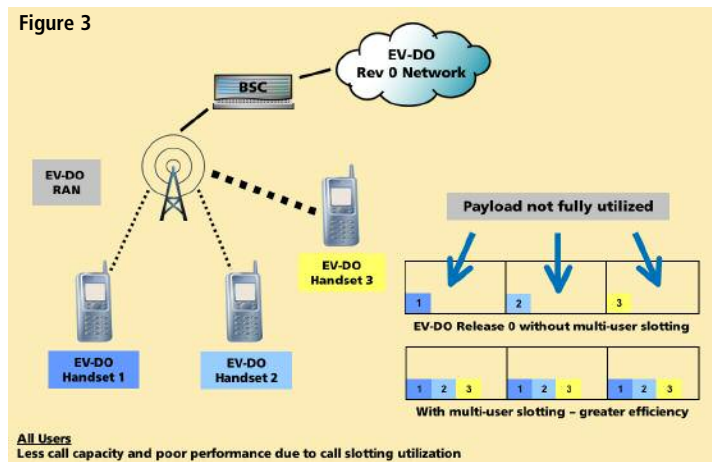


4.3 Link Limitations, Asymmetry and Inefficiencies

EV-DO Release 0 has limitations as a result of inefficient uplinks and downlinks. Figure 3 depicts a situation where each EV-DO device is connected to a specific cell site. Time "slots" are appropriately assigned to each device, but the content being downloaded (voice or data) is being delivered to the handset in an inefficient manner as time-sequenced EV-DO release 0 payloads are not fully utilized. As shown in the graphic inside the figure, this lack of multi-user packets and limited frame encapsulation options on the downlink in EV-DO can dramatically decrease the quantity of users supported on the specific cell site. This scenario can manifest itself to the any of these users through lower channel availability per cell site and poorer performance in higher loading situations.

The EV-DO radio interface is asymmetrically designed to provide maximum bandwidth for large files and applications such as the file download and Web sessions described previously. The uplink is bandwidth-limited by design and presents a challenge to maintaining consistent performance for real-time applications including PTT. PTT performance is highly sensitive to the available uplink throughput, and demands a more symmetrical design such as the existing voice network (which is symmetrical and has QoS). EV-DO is also impacted by variables such as the number of users serviced in the particular area; the applications currently being accessed; and distance to the cell site. EV-DO was not designed, nor is it being deployed with highly symmetrical applications like PTT in mind.

Figure 3



4.4 Poor Multi-Network Interaction

All EV-DO operators expect to retain a broad CDMA2000 1x footprint in addition to their EV-DO network. As evidenced by the pattern of coverage by the major U.S. EV-DO carriers⁹, further EV-DO deployments are expected to be centered around major metropolitan areas, while CDMA2000 1x service is expected to support more suburban and rural areas. EV-DO deployment requires a network overlay of the 1x network using another RF carrier. In the situation where there are adjacent or "overlaid" EV-DO and CDMA2000 1x networks, there are some fundamental limitations of handoff during a call session, if the subscriber is transitioning from one coverage area to another.

Figure 4 shows the User 1 subscriber on an EV-DO PTT session with User 2. User 1 is mobile and moves from EV-DO coverage, into CDMA2000 1x-only coverage. This is a reasonable use case while the subscriber is driving, on a train, etc.

⁹As of August 2005, SprintNextel EV-DO coverage is in 60 major markets, and Verizon Wireless EV-DO is available in 62 major market

As User 1 enters the CDMA2000 1x coverage area, the EV-DO signal will gradually decrease and the call will be dropped. While the Packet Data Serving Node (PDSN) is a common element for handling traffic between the two networks, it cannot support a continuous data session during a handoff of the User 1 device to the 1x network. This lack of handoff creates another inferior user experience as the call session must be re-started when entering the new coverage area.

4.5 Poor Multi-network Coverage

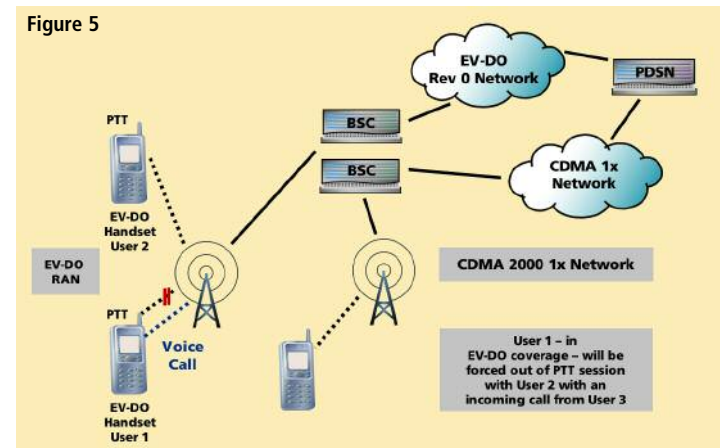
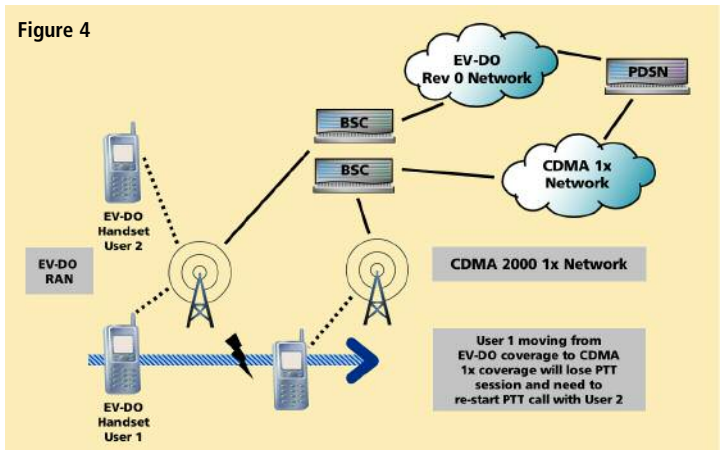
In addition to the network and feature interaction limitations while transiting from EV-DO to CDMA2000 1x coverage areas, there are other implications when communicating in "mixed" coverage areas. The CDMA device will always default to EV-DO over CDMA2000 1x, so that PTT over CDMA 1x data is not possible in an EV-DO environment. Figure 5 depicts this situation which occurs when conducting an EV-DO PTT session while co-located with CDMA2000 1x coverage.

Additionally, EV-DO handsets always give priority to voice calls over data calls. Therefore, an EV-DO PTT handset will be forced out of the PTT session if presented with an incoming voice call from another handset. EV-DO Release 0 cannot support a user-friendly interface to support a PTT session on EV-DO and a voice call on CDMA2000 1x. The device will always give priority to voice calls, with negative consequences for the EV-DO PTT user experience.

5.0 Kodiak Networks Approach to EV-DO Release 0 Implementations

Kodiak Networks is uniquely positioned to supply EV-DO Release 0 operators a PTT offering which avoids these major limitations. The Kodiak solution utilizes the existing voice channel resources on the EV-DO network – the only transport alternative with built-in QoS. Amp'd Mobile has selected the Kodiak Real-Time Exchange™ (RTX) System to deploy their PTT service offering. The Kodiak solution was selected based on superior QoS, maximum voice coverage, and seamless network interaction between their EV-DO and CDMA 2000 1x networks. For example, the Kodiak RTX System on EV-DO (unlike the situation previously presented) uniquely enables the call waiting feature – while in a PTT call, a full-duplex call can be answered and PTT call put on hold (or vice versa). The Kodiak RTX System also allows upgrading from a half-duplex PTT session to full-duplex voice calling – in either one-to-one or group situations. The Kodiak RTX System provides an ideal complement to the extensive EV-DO content being offered by amp'd Mobile.

As further evidence of Kodiak technology leadership and those of its partners, the Kyocera Jet handset (Figure 6, right) – powered by the Kodiak PTT client – will be the first EV-DO PTT handset to be commercially deployed, worldwide. The Kodiak RTX System leverages the resources and quality of the host Verizon Wireless voice network (recently cited as the nation's most reliable wireless network⁹)



Kyocera Jet
Figure 6

⁹Verizon Wireless web site, citing a J.D. Power and Associates Survey September 2005

and its growing EV-DO coverage¹⁰ to deliver a superior real-time voice application. In addition to one-to-one and group PTT calling, Kodiak also integrates other competitive features such as real-time presence/availability, call-me alerts, handset-based contact and group management, PTT upgrade to conference, and PTT call waiting.

6.0 Summary

Kodiak Networks can help operators deploy today, an end-to-end QoS, real-time PTT system on EV-DO networks with its unique approach to leveraging the superior characteristics of the voice network. The Kodiak approach is the first of its kind on any EV-DO network, delivering unique functionality not available on any competing PTT systems.

7.0 List of Acronyms

Acronym	Description
AVS	Advanced Voice Services
EV-DO	Evolution - Data Optimized
kbps	Kilobits per second
LEC	Local Exchange Carrier
Mbps	Megabits per second
MHz	Megahertz
MPLS	Multi-Protocol Label Switching
MVNO	Mobile Virtual Network Operator
PDSN	Packet Data Serving Node
PTT	Push to Talk
QoS	Quality of Service
RNC	Radio Network Controller
WiMax	Wide-area Fixed Wireless Broadband

¹⁰Verizon Wireless press release, EV-DO market expansion and price changes, August 29, 2005