

EV-DO Rev B

A Technical Whitepaper

CDMA2000 Roadmap

CDMA2000 EV-DO is the most widely deployed commercial wireless broadband technology today with 95 commercial and soon-to-be commercial 1xEV-DO networks worldwide – in Africa, Asia-Pacific, Europe, North America, Latin America, and the Middle East – and projected to grow to nearly 350 million users by 2010¹. This rapid adoption is attributed to the following.

Leading performance. EV-DO's performance and feature set continue to maintain a significant lead over alternative technologies such as UMTS/HSxPA.

Strong support for multimedia content and VoIP. EV-DO Rev A provides QoS capabilities specifically designed to support bursty, high-rate applications such as digital video, and delay-sensitive low-rate applications, such as Voice over IP (VoIP).

Efficient use of spectrum. EV-DO provides very efficient spectrum utilization -- delivering end-user performance superior to that of UMTS/HSxPA using only one quarter the bandwidth.

Clear migration path and backward compatibility. EV-DO continues to evolve on an aggressive technology schedule with minimal capital investment and full backward compatibility for multiple generations of handheld mobile devices.

Increased average revenue per users (ARPU). Operators are reporting rapid growth in ARPU as a result of EV-DO broadband services. KDDI, for example, reported a 14% year-over-year increase in broadband data ARPU² in 2006.

EV-DO Revision B (Rev B) is an evolutionary step on the CDMA2000 roadmap, providing improved support for multimedia content, substantially improved packet data, and VoIP performance with minimal capital investment (see Figure 1). The standard for Rev B was published by the Third Generation Partnership Project 2 (3GPP2) and the Telecommunications Industry Association (TIA) in 2006.

Figure 1 shows alternative, emerging OFDM-based air interface technologies. These alternatives are primarily designed for wideband 10-20 MHz deployments in new spectrum. Rev B is very competitive with these emerging alternatives, and offers backward compatibility, lower deployment cost, and a significant time-to-market advantage, as discussed next.

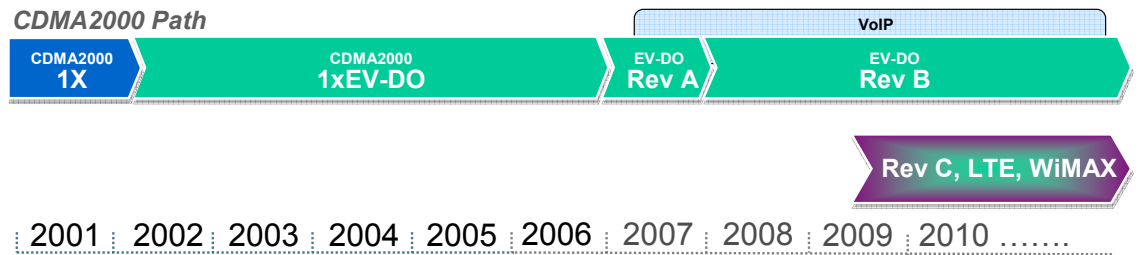


Figure 1: CDMA2000 roadmap

¹ Strategy Analytics, 2006

² KDDI Financials, 2006

EV-DO Rev B Overview

In simplest terms, Rev B extends EV-DO to multi-carrier operation by serving users *simultaneously* over multiple 1.25 MHz carriers. Rev B offers compelling benefits to a wireless operator and its subscribers.

Superior Performance – EV-DO Rev A enables broadband access in cellular networks using only 1.25 MHz of paired spectrum. As a result, operators can grow capacity linearly by enabling Rev A on additional 1.25 MHz carriers. For example, twice the number of subscribers can be served by enabling Rev A on a second carrier. However, growing capacity by enabling Rev A on additional carriers does not fully utilize the available spectrum. Since user traffic continues to flow over a single carrier, an additional carrier increases user capacity, but users still experience the same network performance as with one Rev A carrier.

Rev B, on the other hand, allows user traffic to flow over more than one carrier. This improves user data rates and transaction latencies, on both forward link and reverse link, in proportion to the number of carriers used – when serving the same number of subscribers as Rev A on same number of carriers. This is a dramatic improvement in user experience relative to a Rev A system. A simple way to see this improvement is to compare peak user rates in Rev B vs. Rev A (see Table 1).

Radio Access Network	Required Spectrum	Peak Forward Link Throughput	Peak Reverse Link Throughput
EV-DO Rev A (One carrier)	1.25 MHz	3.1 Mbps	1.8 Mbps
EV-DO Rev B (Two carriers)	2.50 MHz	6.2 Mbps	3.6 Mbps
EV-DO Rev B (Three carriers)	3.75 MHz	9.3 Mbps	5.4 Mbps

Table 1: Comparison of peak data rates

Low-cost Upgrade – EV-DO Rev A base station channel cards can be easily upgraded to Rev B, thereby protecting an operator's Rev A hardware investment. In some cases, the entire upgrade to Rev B can be achieved without adding any new hardware. Existing base station channel cards and Radio Network Controllers (RNCs) can be upgraded in software, and base station radio transceivers in existing radio modules can be activated to support the new carriers. In some cases, a new base station channel card and/or a new radio module may need to be added to support Rev B. RNCs, such as those from Airvana that can be clustered using IP RAN technology, can meet the increased capacity needs of Rev B without introducing new EV-DO subnet boundaries. No changes are required to operators' Packet Data Service Nodes (PDSNs), Home Agents (HAs), or other core network elements (see Table 2). Overall, the cost of a Rev B network upgrade will be a fraction of the cost of new networks based on alternative non-backward compatible technologies such as Rev C, WiMAX and LTE.






Terminal 	Fully backward compatible with Rev 0 and Rev A handsets - new Rev B handsets
BTS 	Same cell sites, link budgets Software upgrade of Rev A channel cards
RNC 	Software upgrade of RNC
PDSN 	Same platform, same software
MMD/IMS 	Same platform

Table 2: Rev B infrastructure software upgrades

Backward compatibility – Rev B’s backward compatibility with both EV-DO Rev 0 and Rev A is of utmost importance. Backward compatibility allows Rev B carriers to continue to support older Rev 0 and Rev A devices. As they benefit from the newly added carriers, such flexibility will lead to improved experience for millions of Rev 0/Rev A users.

Rev B’s backward compatibility also applies to new terminals. A new Rev B handset will continue to receive uninterrupted service from Rev 0 and Rev A networks. This will allow operators to roll out Rev B as needed in critical, high density and high performance markets – geographies consistently supporting subscribers with high data ARPU. Backward compatibility also ensures that when a device crosses Rev 0, Rev A, and Rev B network boundaries, handoffs will be completely seamless.

Backward compatibility is a distinct advantage of Rev B over other non-backward compatible alternatives such as LTE, WiMAX and Rev C.

Full QoS support – EV-DO Rev A was specifically designed to support VoIP and multimedia applications. Rev B builds on that foundation and provides the same QoS capabilities in the RAN. In alternative air interface technologies, such as Rev C, WiMAX and LTE, the same functionality must be developed largely from scratch. As a result, reaching feature parity with EV-DO will take a considerable amount of time.

Flexible Device support – Since Rev B is a multi-carrier air interface technology, a Rev B network has the flexibility to support both single-carrier and multi-carrier devices on the same spectrum. This means the operator can offer lowest-cost single-carrier handsets to its most cost-sensitive subscribers, while providing higher-end multi-carrier handsets, PDAs, and PC cards to serve the needs of its high-performance subscribers. Such flexibility is not supported in other wideband systems, such as UMTS/HSxPA.

In addition, all Rev B devices will be implemented using a single integrated baseband modem ASIC leading to simpler and lower-cost implementations. This will be in sharp contrast with devices for alternative air interface technologies that will initially require expensive multi-ASIC baseband modem implementations for multi-mode operation.

Non-contiguous Spectrum Configurations – Because available spectrum may often be non-contiguous, operators need the flexibility of using non-adjacent channels to improve performance. Rev B allows multiple carriers to be aggregated even if they are in non-adjacent or non-contiguous blocks of spectrum. Such flexibility is not available in alternative wideband air interface technologies such as UMTS/HSxPA. (Certain Rev B handset radio implementations may require the carriers to fit within a 6.25 MHz band.)

Fast time to market – Rev B will be available for trial in mid-2007 and commercial deployments in mid-2008. This schedule will allow CDMA operators to remain performance leaders in broadband wireless for a fraction of the deployment cost – even in the presence of emerging alternative and yet-to-be-proven technologies such as WiMAX. For operators looking to boost data ARPU, Rev B could provide an 18-36 month time-to-market advantage over other emerging Radio Access Network (RAN) technologies, such as WiMAX, Rev C, or LTE.

Superior Performance of Rev B

Peak rates shown in Table 1 are achievable when the user is near the cell site and the sector is lightly loaded. Rev B delivers a dramatically improved user experience as measured by user throughput and latency, not only when the user is near cell site and the sector is lightly loaded, but under all user scenarios.

Significant Trunking Gain

When it comes to the quality of user experience, an EV-DO RAN can be thought of as a queue – a line at the grocery checkout counter or bank teller window. These are first come, first serve queues much like a Rev A or Rev B RAN. In all cases, the faster users are able to move through the queue and complete their transactions, the better their experience tends to be.

In Rev A, operating over N carriers, we have N independent queues, each serving (on average) 1/N'th of the subscribers. In Rev B, operating on the same N carriers, we have a single queue serving these same subscribers. Something remarkable occurs when we move from N independent queues in Rev A to a single queue in Rev B. The customer wait time (or transaction completion time) is reduced by a factor of N.

Imagine N separate queues each handling user transactions. Each Rev A carrier or queue delivers an average wait time of T, the mean time to complete a user transaction (for example, a file or web page download) including the over-the-air signal transmission time. Assuming that the random arrival rate of transactions is the same in each carrier, at λ arrivals per second, and the rate at which each carrier can service the transactions is μ transactions per second, a classic queueing theory formula can be used to describe the average transaction completion time.

$$T = \frac{1}{\mu - \lambda}$$

In the case of Rev B, imagine $N=2$ queues, or two carriers, being combined into one faster queue. The transaction arrival rate λ is doubled and the service rate μ is also doubled (because 2 carriers are together serving the single queue), so the transaction completion time T is cut in half. The resulting user experience – as measured by the average download completion time or download rate – is improved by a factor of N . This is Rev B's remarkable trunking gain.

Frequency Diversity Gain

Using a single queue for N carriers in Rev B, as opposed to N independent queues in Rev A, also helps improve the user experience in the presence of frequency-selective (frequency-dependent) fading. In the bank teller example, fading may be considered analogous to one of the tellers taking a short break. As long as the other tellers can continue to serve customers in a single queue system as in Rev B, the users will experience much less of a fading slow-down than they would in Rev A-like system with multiple independent queues. According to computer simulations, Rev B provides performance gains from frequency diversity in the range of 10-40%.

Rev B Performance

Rev B's improved user experience is both measurable and quantifiable in terms of file download times, quality of video streaming, and voice over IP (VoIP) latency. Simulations show marked improvements in all of these areas. While these simulations are for the forward link (downloads), significant gains are also expected for the reverse link (uploads).

File Transfer

Simulation results comparing the user experience with 200 users on two Rev A carriers and 200 users on two Rev B carriers, an average file size of 2 MB, and a mix of pedestrian and vehicle speeds, show that Rev B file download times are half of the times for Rev A devices, even though the number of users supported and the number of carriers is the same (see Figure 2).

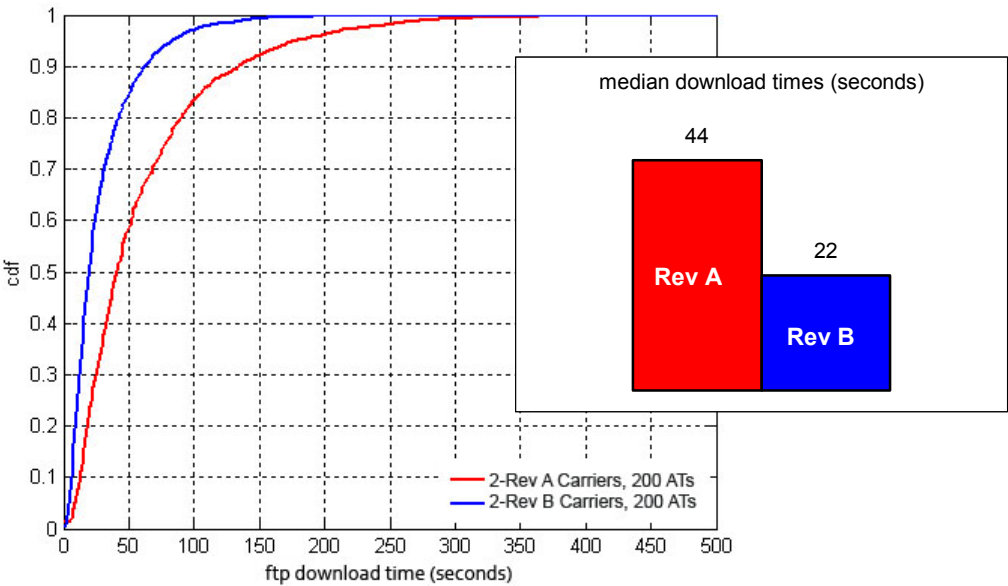


Figure 2: File download times for 2-carrier Rev A vs. 2-carrier Rev B

Correspondingly, Rev B ftp download speeds are twice those of Rev A using the same simulation assumptions (see Figure 3). In Rev A, 50% of users experience download rates of 375 Kbps or better, while in Rev B the same percentage of users experience download rates of 750 Kbps or better. Similar simulations show comparable gains in user rates for web browsing traffic.

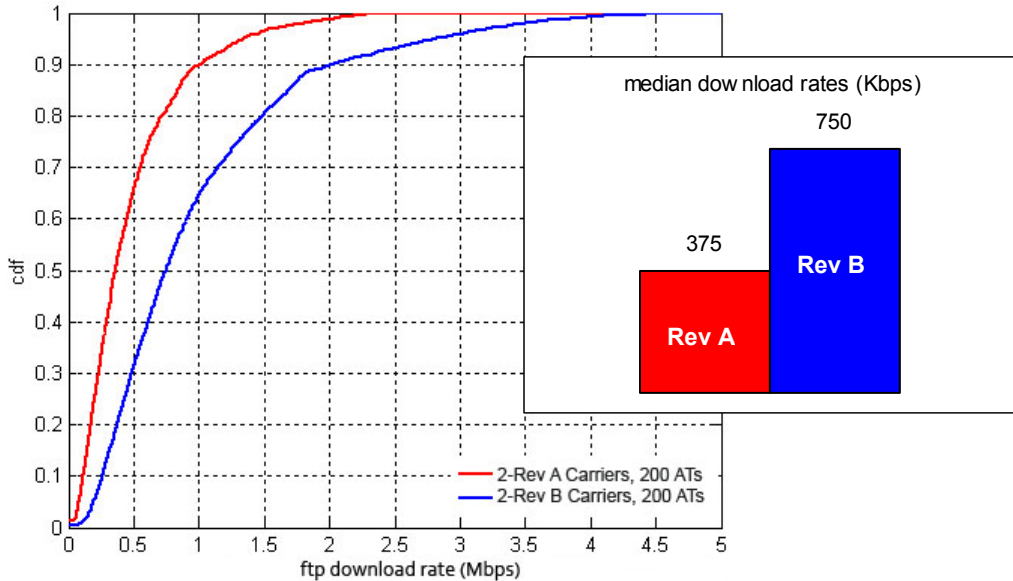


Figure 3: File download throughput for Rev A vs. Rev B

Streaming

Simulation data with 64 Kbps streams of video on 20 Rev B devices on two Rev B carriers were compared with 20 Rev A devices evenly split across two 2 Rev A carriers using the same mix of pedestrian and vehicle speeds. The cutoff for acceptable packet loss rate without impacting video quality was 5% for both. Rev B was able to support 96% of the handsets with acceptable coverage. Rev A supported only 85% with acceptable coverage, almost a factor of 4 decrease in out-of-coverage video subscribers (see Table 3). Overall, Rev B will offer a much superior video experience compared to Rev A.

	Rev A	2xDO Rev B
% users out-of-coverage	15%	4%

Table 3: Video streaming Rev A vs. Rev B

VoIP

Comparable simulations were run for VoIP, with 80 Rev B devices on two Rev B carriers and with 80 Rev A devices evenly split across two Rev A carriers – again using the same mix of pedestrian and vehicle speeds. Each device was modeled with a single VoIP call. Rev B showed a 30 millisecond reduction in latency on the forward link, indicating that Rev B can provide even higher voice quality than Rev A (see Figure 4).

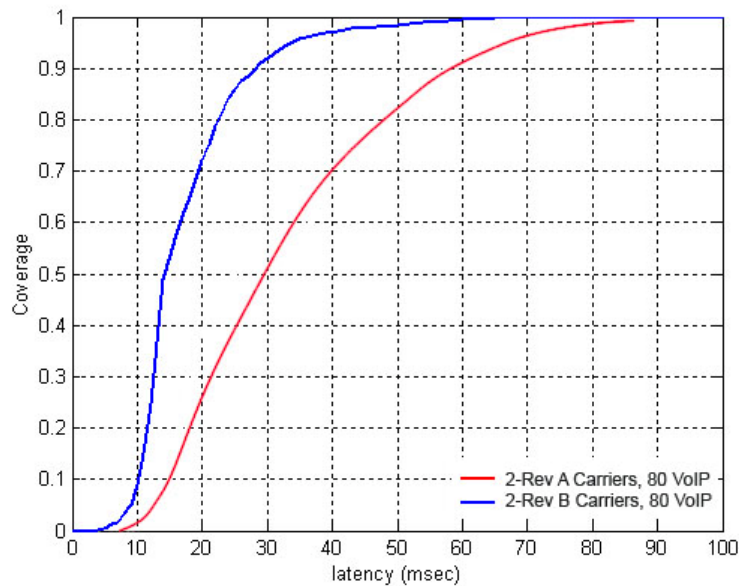


Figure 4: Forward link VoIP latency for Rev A vs. Rev B

Multi-carrier Operation

Rev B derives many of its core capabilities from the aggregation of multiple carriers. Rev B manages the radio resources on multiple carriers in the most dynamic fashion by assigning or allocating carriers based on application need, device type (Rev 0, Rev A, or Rev B) and airlink load. Rev B also improves the user experience (throughput and latency) through multi-carrier adaptive modulation.

Multi-carrier Active Set Management

Rev B manages multiple carriers across multiple cell sites using an extended multi-carrier active set management protocol between the handset and the RAN.

In Rev A, the handset continuously measures the signal-to-interference power ratio based on pilot signals received from individual base stations (more specifically, sectors) and reports this information to the RAN. The RAN uses the information to construct a set of best available sectors for the handset. These sectors all operate on the same carrier. This set, often referred to as the active set, is communicated to the handset using a Traffic Channel Assignment (TCA) message. A Rev A handset with an assigned traffic channel then almost instantaneously selects, using the so-called Data Rate Control (DRC) feedback channel, to receive data at an indicated data rate from the best individual forward link sectors in the active set. On the reverse link, the Rev A handset transmits only on the designated carrier and these transmissions are received by all sectors in the active set and are combined using well-known soft-combining techniques. Rev A handset adjusts its transmission power and its reverse link transmission bit rate based on power and rate control information received from the RAN.

Rev B takes this active management procedure to a new level that involves multiple carriers per sector. The Rev B RAN constructs a multi-carrier active set which consists of one or more sectors as in Rev A, but now may have more than one carrier for each sector – even different set of carriers may be used on different sectors. The active set is again

communicated by the RAN to the Rev B handset using a now expanded multi-carrier Traffic Channel Assignment (TCA) message. The Rev B handset with an assigned traffic channel then selects, using the Data Rate Control (DRC) feedback channel, to receive from one of the individual forward link sectors in the active set at an indicated data rate. This is similar to Rev A, except in Rev B such selection occurs independently for each carrier in the active set. On the reverse link, the Rev B handset may transmit on any one or more of the carriers in the active set. A Rev B handset determines the transmission power and transmission bit rate for each the carriers based on power and rate control information received from the RAN independently on each carrier, thereby optimizing its operation across the various available carriers.

Conclusion

EV-DO Rev B provides operators the means to address the need for increased capacity and an improved multimedia user experience. When EV-DO operators need to deploy additional carriers to meet their capacity needs, Rev B is a much superior option compared to deploying additional Rev A carriers. By introducing devices based on a new Rev B baseband modem ASIC, and deploying Rev B software in the network, operators can deliver significantly enhanced experience to their subscribers. In some situations, Rev B could be justified even before operators run out of capacity on their existing Rev A carrier – allowing EV-DO operators to stay ahead of competitors who are deploying alternative technologies (e.g., HSxPA or WiMAX).

Glossary

For a glossary of technical and marketing terms used in this paper, go to:
http://www.airvana.com/technology/technology_glossary.htm .

About Airvana

Airvana builds mobile broadband infrastructure solutions deploying an innovative IP-Radio Access Network architecture that delivers carrier-class performance and reliability. Networks based on Airvana's technology service millions of consumer and business subscribers; and a wide range of mobile broadband information, communications, and entertainment applications.

Worldwide, Airvana's mobile broadband systems based on advanced CDMA2000 1xEV-DO are deployed on six continents in 16 major networks by industry-leading service providers who demand high standards of carrier-class performance. In North America, Airvana's largest deployments are Alltel (USA), Bell Mobility (Canada), Sprint PCS (USA), Telus (Canada), and Verizon Wireless (USA). The company's products are also deployed in networks including Eurotel (Czech Republic), Pelephone (Israel), and Telefonica (Latin America).

In addition, Airvana builds solutions for other wireless markets including in-flight, air-to-ground communications; and fixed-mobile convergence (FMC) for the integration of cellular and IP-based access technologies. Airvana is headquartered in Chelmsford, MA, USA.

For more information, please visit the company's Web site at <http://www.airvana.com>