

1X-Advanced: Overview and Advantages

Evolution to CDMA2000 1X

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Introduction

Since the first commercial introduction in September 1995 in Hong Kong, CDMA systems have proliferated rapidly, becoming the most reliable and efficient vehicle to deliver wireless mobile voice and data on all five continents. CDMA has experienced spectacular subscriber growth- it has been adopted by over 300 operators around the globe, and more than 560 million people in 120 countries are currently using CDMA for mobile communications. Through new enhancements with a continuous evolution of standards, CDMA technology has transformed the wireless industry and is providing operators with increased quality, capacity and coverage for delivering toll-quality voice and high-speed data services reliably and economically.

1X-Advanced Evolution

1X-Advanced, yet another step in the evolution of CDMA2000, is designed to fulfill the need for better use of expensive radio spectral resources. As the CDMA2000 technologies roadmap shown in Figure 1 demonstrates, both 1X and EV-DO technologies are on a strong evolution track. 1X-Advanced, a technology solution in 1.25 MHz frequency bandwidth maximizes return on investments in existing 1X deployments by significantly improving the economics, capacity and user experience with cost effective upgrades.

Planned to be commercially available in 2011, 1X-Advanced is designed to provide a voice capacity enhancement up to four times greater than existing CDMA2000 1X systems while significantly outperforming existing wireless wide area technology offerings. It further promises additional enhancements to data capacity, system coverage and voice quality with minimal changes to the infrastructure and terminals:

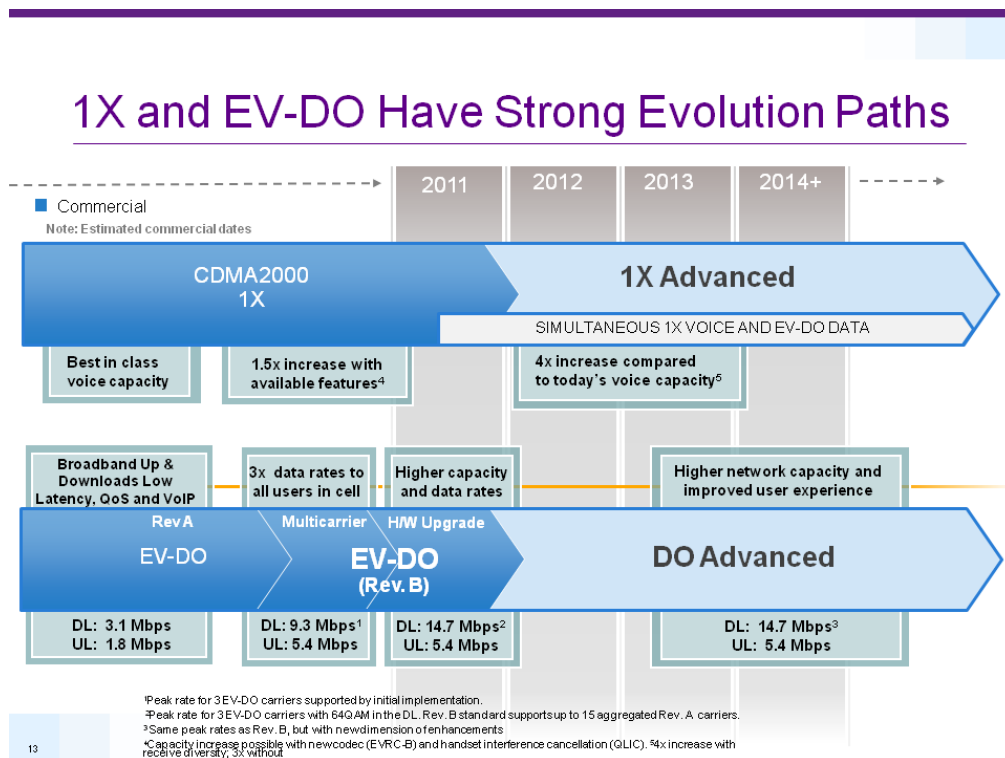
- 1X-Advanced offers opportunities for enhanced mixed voice and data capacity tradeoffs. For instance, networks can offer two times the maximum data throughput of 1X in addition to one and a half times the maximum voice capacity of 1X¹.
- 1X-Advanced offers valuable tradeoffs in enhanced voice capacity and system coverage. For example, 1X-Advanced can extend the coverage of a 1X network by 65 percent at the existing maximum voice capacity; and at existing coverage, 1X-Advanced networks can provide four times the voice capacity of current 1X systems.

¹ Note: All capacity benefits mentioned in the paper can be realized only with a 100% market penetration of the devices supporting corresponding enhancements. Partial gains can be achieved with less than 100% penetration of new devices.

- 1X-Advanced offers an opportunity to enhance voice quality such as high definition voice with a wideband vocoder while increasing voice capacity of existing 1X voice capacity by three times.

One of the key value propositions of 1X-Advanced is that by efficiently delivering increased voice capacity in each carrier, it enables operators to free up existing spectrum used for voice for expanding data services using EV-DO with DO Rev. A or Rev. B technologies.

Figure 1: 1X-Advanced provides a strong evolution for CDMA2000 1X technology



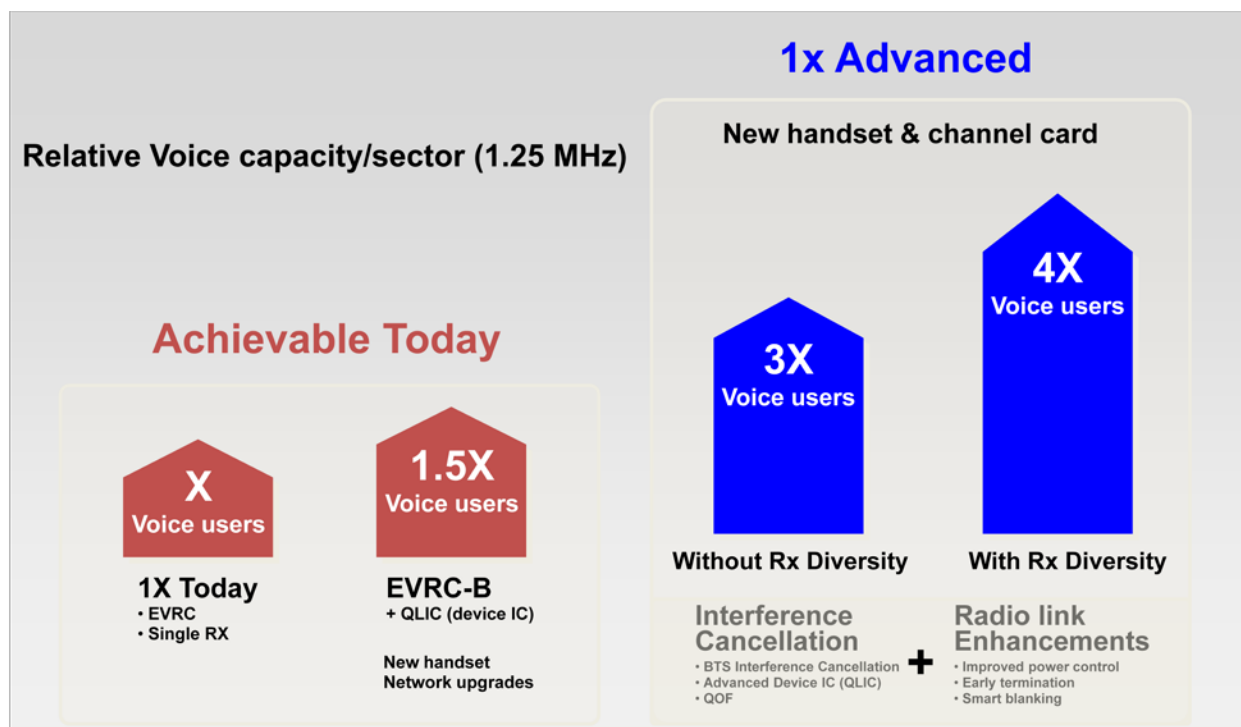
1X-Advanced Provides Four Times the Voice Capacity

For operators who have already deployed 1X, the transition to 1X-Advanced can be effected incrementally and gradually as shown in Figure 2. Some key enhancements, however, are already available to the operators today.

With existing infrastructure, and using new handsets supporting the new vocoder EVRC-B and radio link improvements using QLIC feature on the forward link, operators can increase voice capacity by 50 percent. At the network end, the Base Station Controller (BSC) requires a software upgrade to support the new vocoder EVRC-B. Some operators have already deployed these new enhancements and have commercially introduced new handsets that support new vocoder EVRC-B and QLIC.

With the addition of a new channel card that supports interference cancellation on the reverse link and the new Radio Configuration (RC) features, and new terminals that support Interference Cancellation on the forward link, 1X-Advanced can provide a 300 percent increase in voice capacity with mobile receive diversity, and a 200 percent increase without receive diversity.

Figure 2 Voice Capacity Enhancements in the Transition to 1X-Advanced



It is important to note that operators can adopt cost effective transition procedures by first addressing high-demand regions such as the dense metropolitan areas and upgrade other areas as necessary. This allows operators to free up spectrum which can be used to launch higher ARPU data services via EV-DO Rev. A, thereby improving return on their investments.

Opportunities for Enhanced Mixed Voice and Data

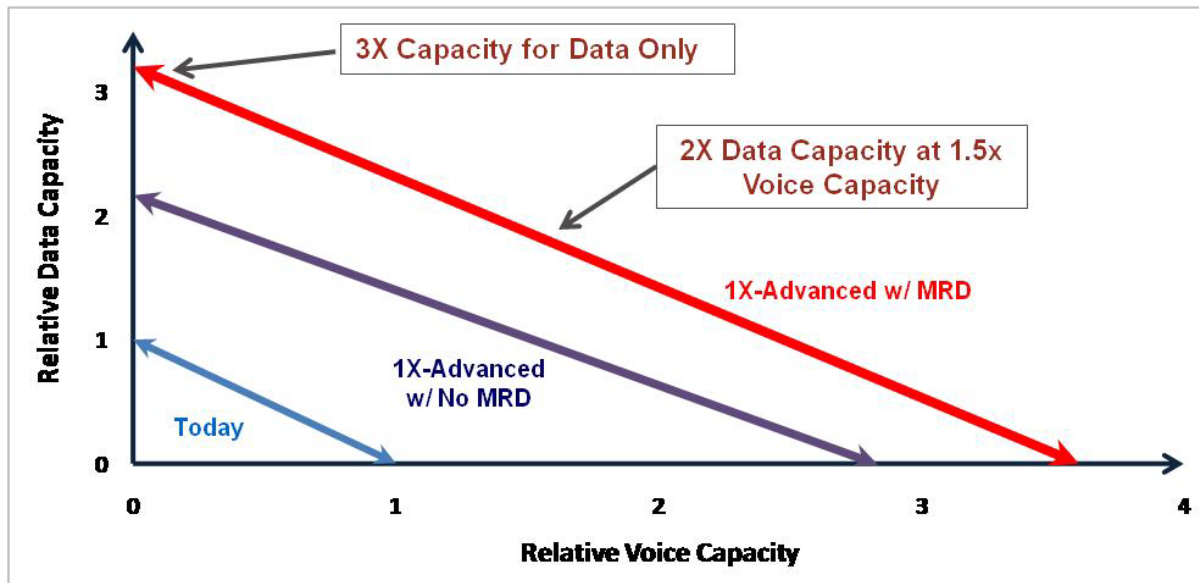
With receive diversity, interference cancellation techniques and the new radio configuration, 1X-Advanced also enhances data capacity substantially. Simulations demonstrate that the data capacity is expected to increase by a factor of approximately 200 percent for terminals with receive diversity compared to the existing maximum data performance of 1X. For terminals without receive diversity, data throughput gains are over 100 percent compared to 1X.

For operators intending to provide a mix of voice and data services, especially in rural areas, 1X-Advanced can provide a host of options. Figure 3 charts the simulation results showing the

tradeoff opportunities available for operators in providing different mixes of voice capacities and average sector data throughputs.

In markets and regions where there are demands for good voice capacity and rising data requirements, 1X-Advanced provides a compelling choice to the operator to serve both needs in a cost-effective manner. As the demand for data grows over time, operators can accommodate this by supplementing existing 1X-Advanced carriers with additional DO carriers at an appropriate time.

Figure 3: Enhanced Mixed Data and Voice Capacity Tradeoffs with 1X-Advanced



New Features and Enhancements

1X-Advanced includes several new features and enhancements targeted at improving airlink efficiencies. Among them are a combination of innovations in forward and reverse links centered in interference cancellation techniques and higher-order receive diversity and radio link enhancements that provides a four-fold increase in voice capacity relative to existing 1X voice systems while delivering the same voice quality. Some of the key new features and their benefits are described in the following paragraphs.

EVRC-B: This is an enhanced vocoder that replaces the existing EVRC vocoder. It is designed to provide similar voice quality while reducing the effective codec rate by about 30 percent. This results in lower power consumption and increased voice capacity for both forward and reverse links.

Quasi-Linear Interference Cancellation (QLIC): This is a feature added to handset modems that effectively cancels forward link interference from the different multipath signals from all

sectors. This feature essentially removes intra- and inter-sector interference within the active set. As a result mobiles require less energy-per-bit from the base stations which leads to improved voice capacity on the forward link.

QOF: The increased voice capacity requires additional code space to the existing orthogonal 128-Walsh code structure. When the forward link is limited by Walsh codes, 1X-Advanced makes use of the Quasi-orthogonal functions (QOF) introduced in CDMA2000. However, utilizing QOF creates additional interference among users.

eFLIC: Enhanced Forward Link Interference Cancellation (eFLIC) is a mechanism that is incorporated into 1X-Advanced chipset design that cancels the additional interference from QOF and also improves the forward link performance by canceling interference from base stations in the neighbor set.

RLIC: In addition to interference cancellation techniques for forward link voice capacity enhancements, 1X-Advanced also incorporates Interference Cancellation for the Reverse Link (RLIC). The RLIC feature reduces interference and the rise-over-thermal caused by the additional users in the system enabled by the improved forward link. The RLIC techniques are applicable to both legacy and new users and, therefore, provide an immediate RL capacity benefit.

New Radio Configuration: 1X-Advanced introduces a new Radio Link Configuration (RC-11 for forward link and RC-8 for reverse link) resulting in significant power savings that allow for higher capacity. The new radio configuration allows selectively blanking of $1/8^{\text{th}}$ rate frames (smart blanking) which reduces the power used on both forward and reverse links.

The power control mechanism is optimized by using a lower frequency (400Hz or 200Hz) leading to a significant reduction in power control overhead on the forward link without affecting the performance of the system.

The RL capacity is increased despite slower RL power control due to frame early decode or termination and interference cancellation. The new radio configuration introduces frame early termination which is a low-complexity mechanism to achieve gains similar to that observed in other 3G systems with H-ARQ but without adding airlink latency.

The new radio configuration also allows for new service option S073 which provides a choice between either EVRC-B (narrowband vocoder) providing high capacity with existing voice quality or a wideband vocoder with exceptionally high voice quality. Details of the wideband vocoder and corresponding voice capacity are discussed in a later section.

Mobile Receive Diversity (MRD): Mobile receive diversity is a well understood antenna technique that improves the signal-to-noise ratio of the received signal. The greatest benefit of

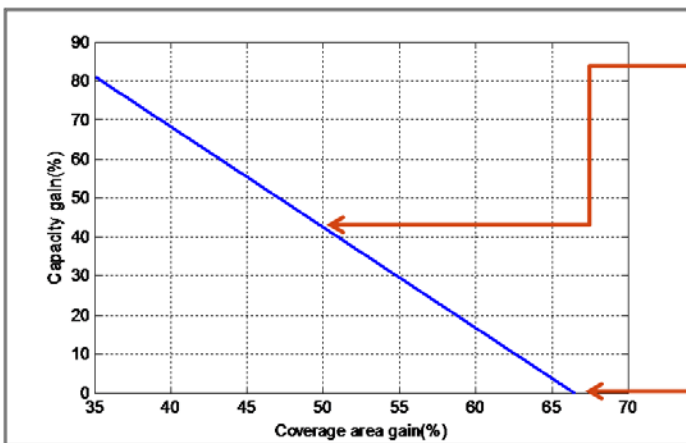
the MRD feature is that it provides significant enhancements to voice capacity without impacting infrastructure or requiring new standards. Qualcomm currently provides several commercial Mobile Station Modems (MSMs) that support receive diversity.

Coverage Enhancements

The introduction of interference cancellation methods now enables 1X-Advanced to offer significant new benefits in enhanced coverage for the current 1X systems. The RLIC technique that effectively cancels the interference enables the system to operate at a higher interference rise over thermal (ROT). This enables 1X-Advanced significant tradeoffs between either improving the capacity or the link budget of the reverse link. At the current voice capacity levels offered by existing 1X, 1X-Advanced provides a reverse link budget advantage leading to 65% larger coverage. From the simulation results shown in Figure 4, it can be seen that 1X-Advanced provides a tradeoff in higher voice capacity for slightly lower increase in coverage compared to current 1X systems.

Figure 4: 1X-Advanced provides Enhanced Coverage and Voice Capacity Tradeoffs

1X-Advanced Relative Capacity and Coverage compared to 1X



Provides 50% larger coverage at 40% higher voice capacity

1X-Adv provides 65% larger coverage for existing voice 1X voice requirements

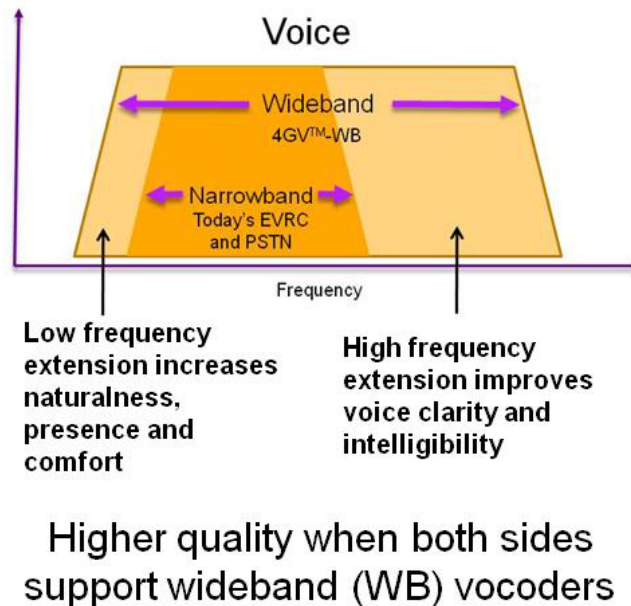
Note: Coverage is defined to be the maximum area in which less than 1% of users are in outage

High Definition Voice with a Wide Band Vocoder

Traditionally, given the bandwidth processing limitations, wireless systems have employed narrowband codecs limiting voice coding to a sound spectrum much narrower than the range of the human voice. 1X and other wireless technologies have adopted narrowband codecs such as EVRC-B or AMR 12.2 to optimize voice capacity while making appropriate tradeoffs on the audio experience.

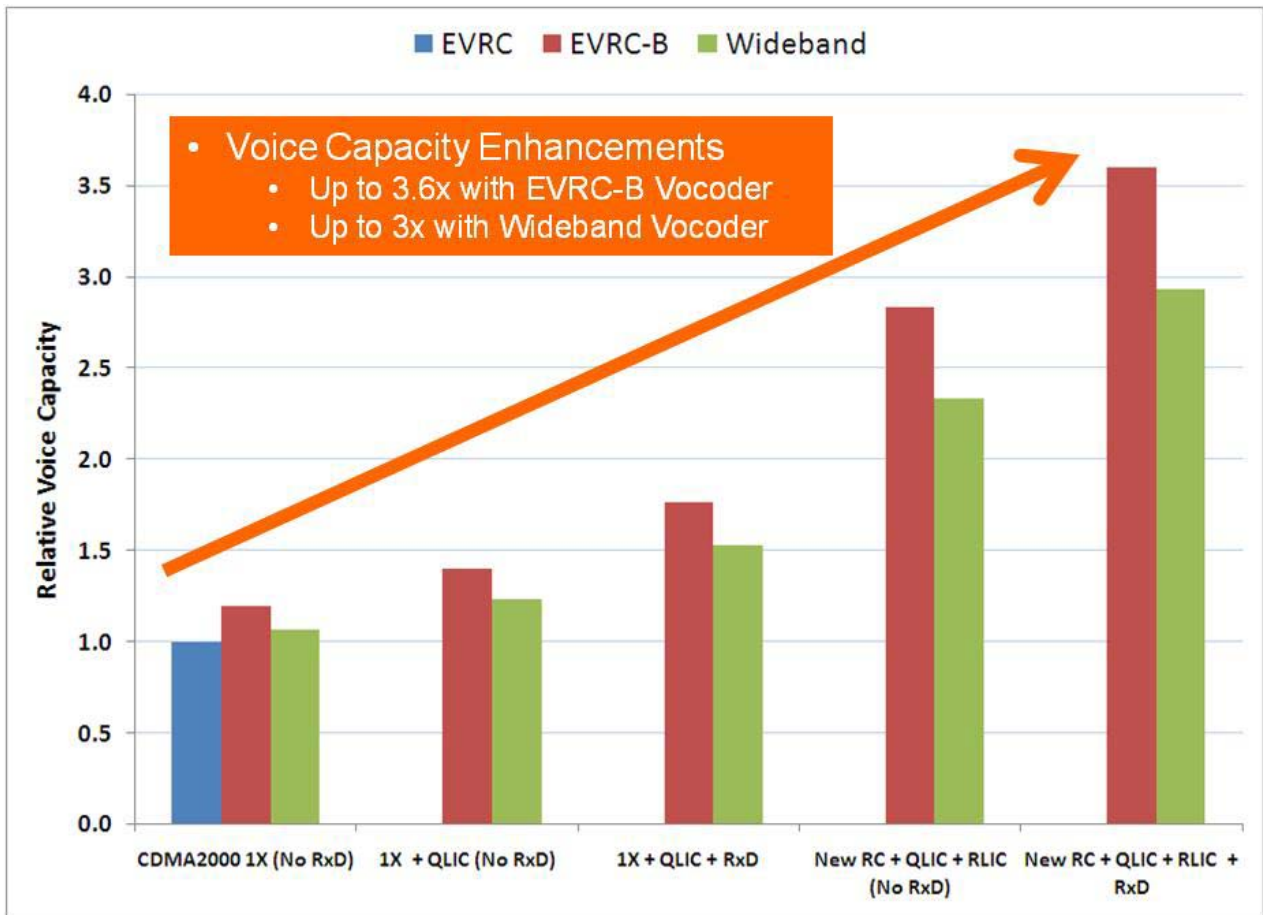
As shown in figure 5, wideband vocoder extends both higher and lower frequency ranges of the sound spectrum and thereby provides a richer audio experience. Wideband voice captures and transmits very high quality sound at twice the frequencies of narrowband voice. Wideband voice is encoded at about 16,000 samples per second, which is double the rate of narrowband voice.

Figure 5: 1X-Advanced provides an option for high definition voice with a wideband vocoder



Offering significantly high spectral efficiency, 1X-Advanced provides an opportunity to incorporate the wideband vocoder option and yet provide high voice capacity which was previously unthinkable. Based on simulations, Figure 6 shows a range of voice capacities available for different vocoder options with various combinations of new enhancements that are included in the evolution of 1X technology. From Figure 6, it can be noted that 1X-Advanced with a wideband vocoder can offer three times more voice capacity compared to current 1X systems using an EVRC vocoder.

Figure 6: 1X-Advanced with Wideband Vocoder offers 3X voice capacity compared to 1X with EVRC Vocoder



Spectrum Savings for DO Data

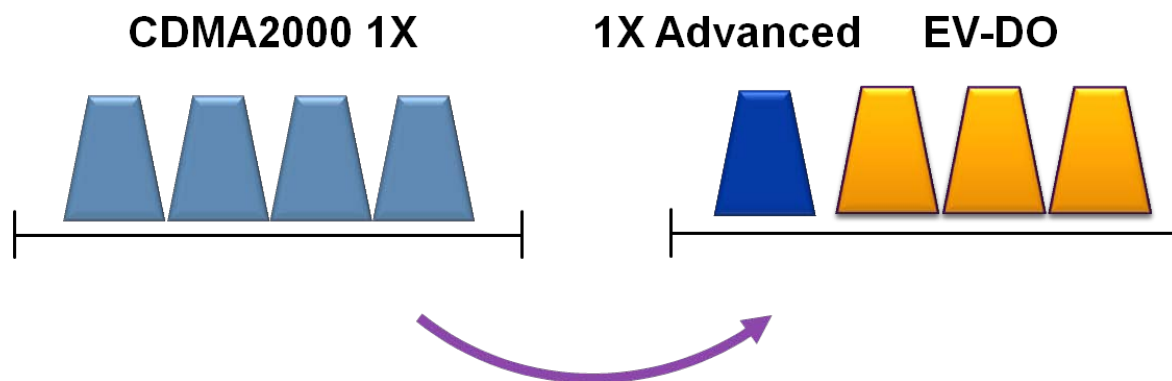
For operators who have deployed 1X systems and are looking to expand on data services using DO technologies, 1X-Advanced provides significant savings on the current spectrum allocated for voice using 1X. As 1X-Advanced provides four times the voice capacity as current 1X systems, only a quarter of the current spectrum can support the same amount of voice traffic

as 1X today by replacing 1X with 1X-Advanced. This frees spectrum to be used efficiently to offer high revenue-earning, EV-DO-based broadband data services, as illustrated in *Figure 6*

1X-Advanced capabilities in high voice capacity can be well-leveraged in different markets in different ways. Voice traffic continues to be a major driver in emerging markets and 1X-Advanced allows operators to support the growing voice traffic without the need for additional spectrum. In developed markets, 1X-Advanced provides operators much needed economic means to offer the unlimited voice plans that have recently increased in popularity.

In markets where voice traffic is leveling off and where broadband data traffic is substantially ramping up, 1X-Advanced helps operators dedicate more spectrum to EV-DO for broadband data services while sustaining the same amount of voice traffic. In many scenarios where operators have limited spectrum for data use with DO Rev. A technology today, 1X-Advanced can free up one or multiple carriers. 1X-Advanced provides operators an opportunity to combine multiple carriers and offer more efficient data services using DO Rev. B technology.

Figure 6: 1X-Advanced helps to free up precious spectrum resources for data by efficiently offering high voice capacity in less spectrum



Conclusions

1X-Advanced ensures operators who have deployed CDMA2000 networks with a formidable evolutionary roadmap. As an evolution to 1X, 1X-Advanced provides significant benefits offering three- to four-fold voice capacity enhancements.

1X operators can gain a capacity boost of 50 percent right away in existing networks with a simple software upgrade to the BSC with the new, improved vocoder EVRC-B and with new handsets that support the new vocoder and forward link interference cancellation enhancements (QLIC).

1X-Advanced with a channel card upgrade and new handsets that support new radio configuration and mobile receive diversity provides voice capacity enhancements four times of existing 1X networks. The tremendous increase in voice capacity using 1X-Advanced allows operators to meet increased voice demand or free up spectrum resources for expanded data services using DO Rev. A or Rev. B technologies

1X-Advanced also provides enhancements to 1X data that are much needed by operators in emerging countries, especially in the rural areas. 1X-Advanced provides improvements three times of existing 1X data offerings. For rural areas, 1X-Advanced also provides coverage enhancements as a tradeoff to increased voice capacity over current 1X-systems. In areas where voice capacity is not an important requirement, say in rural areas, 1X-Advanced can provide a coverage enhancement of 65 percent over existing 1X networks thus offering significant capEx savings for rural deployments.

1X-Advanced is fully backward compatible and leverages existing assets such as the Radio Access Networks, reuse of the deployed RF equipment, core network, and network planning and provides major financial savings to operators.