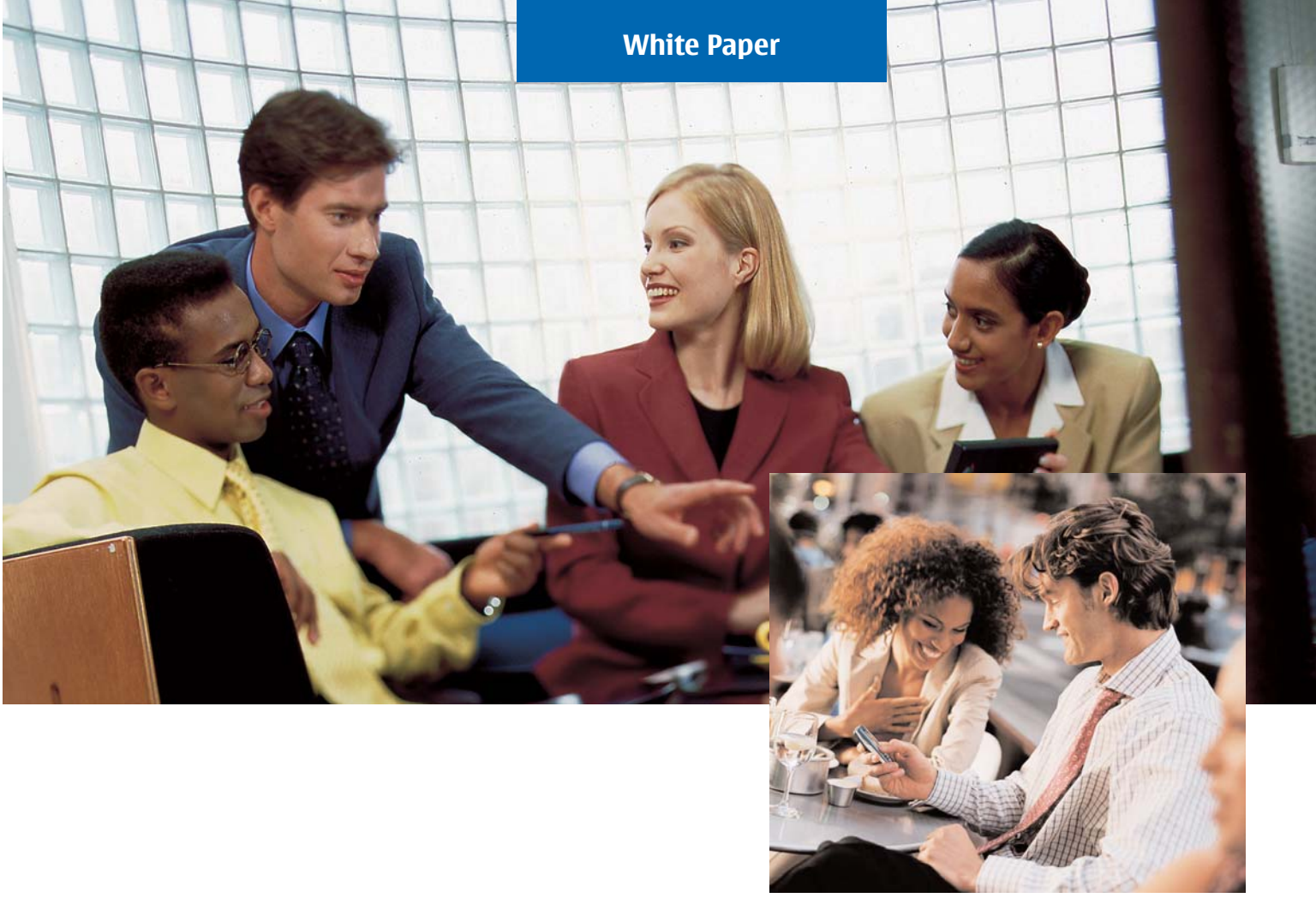
White Paper



CDMA Evolution: cdma2000 1xEV-DV

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Contents

Introduction

To meet the coming need for mobile wireless packet data services, 3G standardization bodies and others interested in the advancement of CDMA technologies have sought to refine and commercialize specifications capable of delivering higher data throughputs.

The cdma2000® specification has recently undergone an important evolutionary step designed to achieve this objective. With the emergence of cdma2000 1x Evolution Data and Voice (1xEV-DV), network operators can enjoy measurably higher data throughput while simultaneously delivering coexisting voice services within the same radio frequency carrier.

This Nokia White Paper evaluates the development, technical features and performance advantages of 1xEV-DV.

Executive Summary

While the primary objective of 2G networks was to provide mobile circuit switched voice and low rate data services, a key goal of the evolution to 3G networks was the introduction of connectivity to packet data networks via cellular systems while at the same time increasing voice capacity.

Early definitions of 3G systems sought to boost the gross bit rates over radio, and to introduce support for QoS classes to improve packet-switched bearer services. As demand for both greater capacity and more packet data services has grown, the industry has sought to improve 3G data throughput while at the same time enhancing voice performance over the same RF carrier. 1xEV-DV technology was developed to meet these requirements and is first included in IS-2000 Revision C (also known as 1xEV-DV).

1xEV-DV is an enhancement to cdma2000's data carrying capability that is designed to deliver rates that are significantly higher than the current cdma2000 Revision 0 system. Revision C of the standard specifies higher data rates on the Forward link, while revision D (standard completion targeted for Sept. 2003) addresses increased rates on the Reverse link.

The 1xEV-DV system is designed to deliver greater spectrum usage efficiencies, backwards compatibility for legacy handsets and all previous versions of IS-95 and cdma2000 (including existing channels and signaling structure) and support for the broadest possible range of applications. 1xEV-DV enhancements occur at the

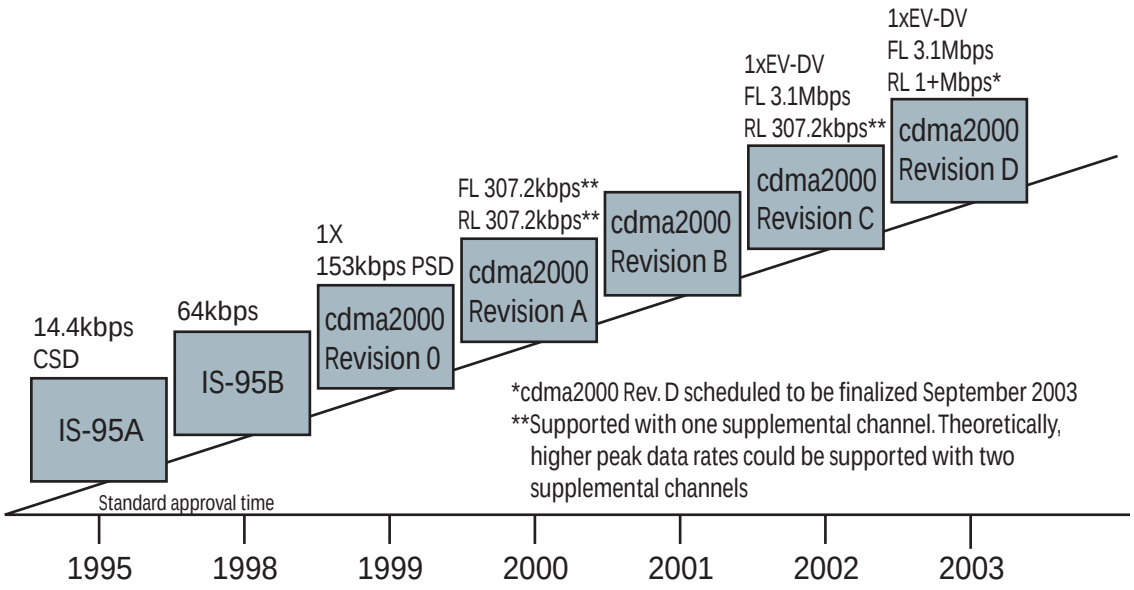
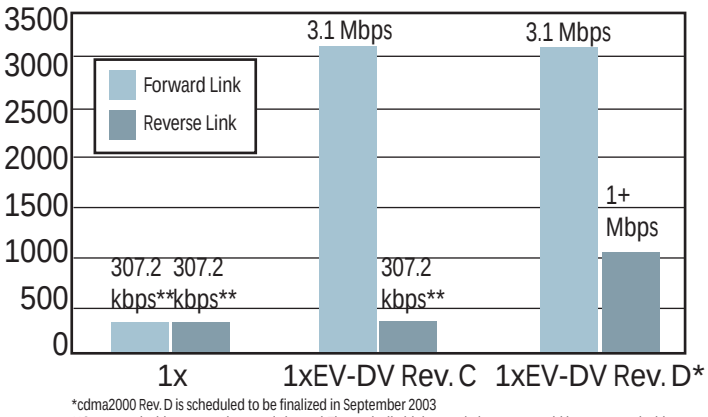


Table 1: cdma2000 Evolution Path



*cdma2000 Rev. D is scheduled to be finalized in September 2003
**Supported with one supplemental channel. Theoretically, higher peak data rates could be supported with two supplemental channels

Table 2: Peak Data Rate Comparison

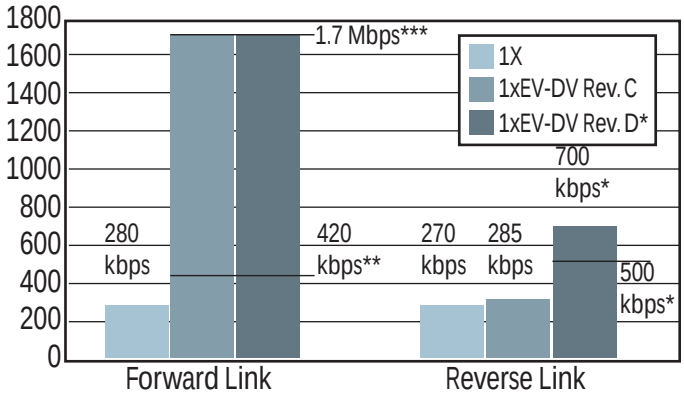
physical layer, MAC, RLP and L3.

1xEV-DV is designed to deliver real-time circuit switched voice services and high data rate packet data services in the same RF carrier. The standard was supported in its development by Nokia and others, and opens a logical and cost-efficient migratory pathway for cdma2000 1x carriers evolving towards 3G networks.

Approved in May 2002 by the Telecommunications Industry Association (TIA) and the International Telecommunications Union (ITU) as an official 3G standard, cdma2000 1xEV-DV (data and voice) delivers peak data rate of 3.09 Mbps and a typical sector throughput of 1Mbps in a 1.25 MHz frequency channel. 1xEV-DV delivers system-wide packet call user throughput that ranges from 420 Kbps to 1.7 Mbps, depending on traffic and channel models, and up to 451.2 Kbps peak reverse link data rate.

Because it supports concurrent voice and data services, 1xEV-DV does not require new spectrum or spectrum dedicated for data-only use, a feature that presents CDMA operators with a more attractive cost structure than other evolutionary options.

The 1xEV-DV evolutionary model provides operators with exceptional flexibility in meeting daily fluctuations in capacity demand. When deployed for voice, data or in a combined voice/data environment, 1xEV-DV delivers needed voice



*cdma2000 Rev. D is scheduled to be finalized and reverse link aggregate throughput (likely between 500-700 kbps) determined in September 2003
**420 kbps: For mixed traffic/channel model, 43 users and c/I limit of 13db
***1.7 Mbps: For full buffer traffic model, 10 users each at 3kph, and c/I limit of 13db

Table 3: Aggregate Throughput

resources during peak-usage commuting hours, while at the same time providing carriers with the resources that will be needed to meet growing demands for data capacity during data busy hours.

1xEV-DV is not an overlay system, but is in fact a true upgrade from 1x, and provides backward compatibility for IS-95 and cdma2000 Revision 0 mobile devices. cdma2000 1xEV-DV also reuses existing cell sites, and thus maintains current coverage in cdma2000 networks.

For these and other reasons to be outlined in the following pages, industry observers now view 1xEV-DV as the next logical step for incumbent CDMA operators who seek to upgrade their existing cdma2000 1x (IS-2000 Revision 0) networks.

New 1xEV-DV Features

Forward Link Capacity
1xEV-DV leverages a number of improvements – including Adaptive Modulation and Coding schemes, the use of both Time Division Multiplexing and Code Division Multiplexing, a Forward Packet Data Channel, and Hybrid Automatic Repeat reQuest at the Physical Layer – to deliver forward link data rates of up to 3.09 Mbps and average sector throughputs of 1 Mbps.

Backward Compatibility
Because it incorporates a number of relevant cdma2000 standards – such as the reuse of 1x reverse link channels, IOS interoperability, cdma2000 MAC and signaling layer procedures, and radio channel handoffs – 1xEV-DV provides seamless support for voice and legacy services. This backward compatibility means consumers can use an operator's entire network with a single terminal. For operators, this strength extends the useful life of existing infrastructure, while opening a smooth evolutionary path from the current 1x infrastructure.

Concurrent Voice and Data
1xEV-DV supports voice and data services in the forward and reverse links. For example, a 1xEV-DV network can support 1x voice users and 1xEV-DV data users on the same channel at the same time, or 1xEV-DV users can have a 1x voice and DV data session active at the same time. This capability gives operators improved spectrum flexibility, the ability to share voice and data spectrum, and the freedom to provide concurrent voice and data.

Multiple Traffic Types
The specification supports multiplexing of signal and user data over the Forward Packet Data Channel and multiple concurrent data sessions. This capability means users can use more than one application – such as voice and data – at the same time. For operators, this capability translates into the ability to generate revenue from multiple simultaneous applications, without the need to dedicate a separate channel for each application.

New Channels
The 1xEV-DV specifications incorporate three new control channels and one new traffic channel. In the forward link, there are two new channels added: a new control channel, Forward Packet Data Control Channel (F-PDCCH) and a new traffic channel, Forward Packet Data Channel (F-PDCH). Two new control channels are provided in the reverse link: the Reverse Channel Quality Indicator Channel (R-CQICH) and the Reverse Acknowledgement Channel (R-ACKCH). Operators can benefit from the fact that 1xEV-DV channels are integrated with current cdma2000 channels to cover areas that need a higher data rate.

TDM/CDM Multiplexing
1xEV-DV is the only standard in the cdma2000 development path that

enables both TDM and CDM scheduling, favoring TDM where that technology works best and supporting CDM for WAP, VoIP, streaming video and other data services. Because data is sent in bursts rather than on a continuous basis, TDM/CDM statistical multiplexing enables the system to maximize throughput gain. Operators can leverage this feature to enjoy optimum flexibility in a demanding marketplace.

Hybrid ARQ

By migrating Automatic Repeat reQuest (ARQ) from the upper layer to the physical layer, 1xEV-DV maintains high bandwidth through the very rapid retransmission of frames received in error. Rather than discarding failed transmission attempts, this Hybrid ARQ technique combines those failed attempts with the current attempt. This supports a higher tolerance to selection errors for faster adaptive modulation and coding (AMC), and creates a more potent code. Two basic forms of combining technique incorporated with Hybrid ARQ are Chase combining and incremental redundancy (IR),

Adaptive Modulation and Coding

To provide real time adaptation in a changing RF environment, 1xEV-DV uses forward link Modulation and Coding variation to adaptively assign users the best modulation and coding rate under current channel conditions, a capability known as “channel sensitive” or “opportunistic” scheduling to maximize the multi-user diversity gain. By varying the number of bits per RF frame and the coding algorithm, and by providing continuous feedback to continually maximize link throughput, this approach delivers higher data rate performance and supports services that could not be provided using previous-generation CDMA technologies.

Cell Selection

Cell selection takes advantage of macro diversity by allowing the handset to select the best serving sector.

Subscriber Benefits

By delivering improved overall data rates, and by allowing users to perform simultaneous voice and data tasks on the same device – for example holding a voice conversation while at the same time downloading e-mail messages – this new standard takes consumers an important step towards the promise of the 3G future.

End users will also benefit from the low latency response time of the 1xEV-DV system. So for even small amounts of data transferred, end-users will see a much quicker response by the network. This quick response time makes today's applications, such as web browsers, much more usable with 1xEV-DV than with today's 1x networks.

The efficiencies supported by 1xEV-DV will allow operators to deliver data-intense services more quickly, more effectively and at a lower cost. Those capabilities translate directly into better services and lower prices for subscribers. The standardization and compatibility advantages of 1xEV-DV will foster the creativity of the development community, driving the introduction of popular new features and applications.

Operator Benefits

The main reason CDMA operators moved from IS-95 to cdma2000 was to boost network voice capacity while moving towards more competitive packet data services. Operators moving along the evolutionary pathway towards cdma2000 must evaluate the relative merits of Revision A and Revision 0. The gains associated with Revision A are insignificant, considering that the signaling and control mechanisms of Revision A are in fact still (relatively slow) Revision 0 mechanisms. As 1xEV-DV nears completion, most CDMA operators now realize a full Revision A deployment is not justified by either technology or network economics.

Carriers can deploy cdma2000 1xEV-DV to support voice and data users in the same radio frequency carrier, thus more closely aligning their 3G network investments with the true data demands of their marketplace. This emerging standard delivers full support for legacy IS-95 and cdma2000 1x devices, and supports services such as a streaming video by providing a real-time packet data connection.

The native flexibility of the 1xEV-DV option means that operators can deploy this technology based directly on market need.

Because 1xEV-DV supports concurrent voice and data sessions, many industry observers expect it to encourage the development of an exciting new generation of videoconferencing, interactive online gaming, remote presentations and other rich multimedia applications. Those are precisely the data-heavy applications consumers the world over now expect and demand.

By enabling dynamic allocation of bandwidth on demand, cdma2000 1xEV-DV allows operators to balance their voice and data traffic. This capability supports what some have called “dynamic load balancing throughout the business day”. Operators can leverage 1xEV-DV’s capabilities to support data traffic with unused voice capacity.

By maximizing spectrum and existing infrastructure, operators can get the most out of their current deployments and increase data capacity through a network upgrade (i.e. new channel card), rather than by adding new cell sites. As a standards-based voice/data solution, 1xEV-DV also promotes increasing economies of scale that are expected to reduce future network investment requirements.

1xEV-DV in the Marketplace

Real Time Gaming

1xEV-DV is fundamentally well suited to satisfy the particular demands of the growing real time gaming applications marketplace.

Real time gaming applications typically generate a relatively small volume of delay-sensitive traffic, which arrive at a fairly regular rate as updates to the game engine state. Counter Strike, to use the example of today's most popular online game, requires about 16kbps on each of the forward and reverse links. While the packets are not as continuous as voice, they do arrive in a reasonably regular fashion at a rate of roughly one packet per 40ms.

To maintain the playability of the game, the application's round trip delay must be less than 160ms, and for this reason the traffic must obtain immediate radio resources. While 1xEV-DO systems do not readily meet this requirement in an efficient way– due to the DO's reported data rate and single-user limitations – 1xEV-DV is ideally positioned to exploit the booming popularity of online gaming. 1xEV-DV game-oriented benefits include:

- 1xEV-DV leverages cdma2000 Rev. 0, A and B mechanisms, and was built with QoS in mind.

- 1xEV-DV supports concurrent voice and data, a key element of the multi-player gaming experience.

- 1xEV-DV's 127-combination radio resource allocation is well suited to handle variable packet sizes and data rates as well as packet retransmissions.

- On the forward link, with slot sizes of 1.25ms, 2.5ms and 5ms, and CDM/TDM capability, DV serves more users-per-cell.

- On the reverse link, DV's frame size is 20ms for Revision C and 10ms or less for Revision D[1], which will meet real time gaming delay requirements.

As a key supporter of the 1xEV-DV initiative, Nokia is a pioneering leader in both mobile telephone and mobile entertainment and media innovations. With the vision of interactive online gaming as an important 3G revenue generating service, Nokia recently introduced a "gaming model" for use in air interface technology evaluation by the 3GPP2 standards organization. This model is significant because it provides a means for validating the ability of new standards, such as 1xEV-DV, to support the low-latency requirements for online gaming and other services.

Voice over IP

The 1xEV-DV evolutionary pathway also provides significant support for Voice over IP (VoIP). IP connectivity is expected to dominate the terrestrial transmission network for cellular systems, with end users expecting seamless connectivity to

services delivered exclusively via IP networks. The All-IP future will enable transcoder-free operation and the use of wideband speech coding, and All-IP voice efficiency is supported by the IP-optimized voice codec.

1xEV-DV requires a lower end-to-end infrastructure investment (compared to 1xEV-DO), and enables simultaneous voice and data services in either a voice capacity enhancement or All-IP deployment.

Due to its native mixed-traffic capabilities (supporting voice, video, gaming, WAP, HTTP and FTP) 1xEV-DV also delivers the superior QoS performance needed to ensure a reliable VoIP revenue stream. When deployed in voice, data or dual voice/data environments, 1xEV-DV provides an assured level of voice resources during high-volume commuting hours, as well as greater data resources when those applications take off.

The 1xEV-DV Business Case

Although each operator must consider their own unique situation – evaluating factors such as spectrum allocation, coverage strategies, equipment architecture and service/revenue models – we can make several broad observations regarding the business case for 1xEV-DV.

When compared to the 1xEV-DO pathway, the 1xEV-DV model does offer several realistic cost/revenue advantages. While the 1xEV-DO approach would indicate the need for dual voice/data networks, 1xEV-DV 's combined voice and data capabilities suggest lower long-term network operation and maintenance costs. Because 1xEV-DO requires a dedicated CDMA channel for data, that commitment represents a potential loss of voice revenue that might otherwise be generated from that resource. Extra spectrum will be needed to deploy 1xEV-DO, and operators may actually need to acquire new spectrum if spare spectrum is not available.

By contrast, 1xEV-DV can be deployed for data-only services to deliver performance at least on par or better when compared to 1xEV-DO, and when implemented in a Voice/Data environment, 1xEV-DV enables a class of services that 1xEV-DO cannot support. Because voice remains the "killer app", a 1xEV-DV deployment will not depend on data "take off" to deliver ROI, but will in fact begin paying for itself immediately.

Based on these findings, it is reasonable to project that 1xEV-DV offers both long-term savings and greater revenue potential than the Data Only alternative.

[1] Expected to be approved in September 2003.

Benefits of 1xEV-DV

- Peak data rates of 3.1 Mbps per sector

- Support for real-time and non-real-time data services

- Reuse of 1x network components, thereby extending the useful life and value of existing cdma2000 1x investments and reducing CAPEX

- Support for voice and data in the same carrier – no need to buy spectrum

- Seamless backwards compatibility with IS-95A/B and cdma2000 1x network equipment and handsets

- The extension of cdma2000 1x capabilities to enable new voice, data and multimedia services

- Support for current IS-95A/B and 1x services, including simultaneous voice and data

- A graceful, standardized migratory pathway for CDMA technology

- Delivers unique new features for CDMA operators

- Dynamic balancing of spectrum between voice & data to maximize network efficiency

- Deployment flexibility – Add spectrum based on demand - new spectrum not needed to deploy

Conclusion

Leveraging the features and improvements described here, 1xEV-DV will enable CDMA operators to improve their competitive positions, launch new value-added services, and enhance their overall ROI.

By enhancing cdma2000 1x capabilities, 1xEV-DV will allow operators to support the new voice, data and multimedia services subscribers expect and demand.

1xEV-DV meets the economic requirements of operators by delivering seamless backwards compatibility with many cdma2000 1x network components and subscriber handsets. The 1xEV-DV technology also provides continuity for current IS-95A/B and 1x services such as simultaneous voice and data. As such, 1xEV-DV (cdma2000 1x Revision C) is now seen as a natural extension of cdma2000 1x Revisions A and B, and is further enhanced in Revision D.

Thus, 1xEV-DV meets the two critical requirements of CDMA operators evolving towards 3G capabilities: the ability to more fully support the emerging generation of data-intense services and applications, and a measurable reduction in new CAPEX requirement through the preservation of current CDMA network investments.

Nokia and 1xEV-DV

As a leader in the global CDMA marketplace, Nokia has taken a pioneering role in the development and deployment of 1xEV-DV technology. Nokia established a CDMA headquarters in San Diego in 1991 and an additional R&D center focused on media and entertainment product initiatives was established in Vancouver, Canada in 1999.

To support the evolution of CDMA technologies, Nokia joined a number of other leading technology companies in advancing the 1xEV-DV standard.

Nokia expects that some operators will conduct field trials of DV network in late 2003, and that the first commercial DV networks to go online during the second half of 2004. Already well established as a leading worldwide manufacturer of IS-95 and cdma-2000 1x handsets built around Nokia chipsets, Nokia expects to develop and market terminals based on Nokia-designed cdma2000 1xEV-DV chipsets.

In January of this year, Nokia confirmed that the evolution of its cdma2000 mobile station chipset supporting Revision C was on schedule for field trials with CDMA operators during the second half of 2003. In addition to Nokia chipsets, chipsets supporting 1xEV-DV will be available from multiple sources, allowing manufacturers various choices for handset development. cdma2000 test equipment to validate 1xEV-DV chipsets is also now under development and will be available to ensure timely delivery of handset products.

Glossary

1x	The first phase of cdma2000, colloquially also known as 1xRTT ("radio transmission technology"). 1x is a cdma2000 technology using one 1.25MHz radio frequency carrier, as opposed to 3X using three 1.25MHz radio frequency carriers.
1xEV	1x Evolution
1xEV-DO	1x Evolution, Data Only
1xEV-DV	1x Evolution, Data and Voice
3G	3rd generation of mobile communications. A new standard that promises to offer increased capacity and high-speed data applications up to 2 megabits. It also will integrate pico-, micro- and macrocellular technology and allow global roaming.
3GPP	3rd Generation Partnership Project. Develops GSM/WCDMA standards
3GPP2	3rd Generation Partnership Project 2. Develops cdma2000-based standards
CDMA	Code Divisible Multiple Access
cdma2000	The name used by the TIA standards body to refer to Third Generation CDMA. The TIA specification for 3G CDMA is called IS-2000 and the technology itself is called cdma2000.
FTP	File Transfer Protocol
HTTP	HyperText Transfer Protocol
IS-95	The standard written by the TIA for second-generation version of CDMA based on the established cdmaOne technology. CdmaOne system uses a 1.25MHz-wide carrier and is forward compatible with cdma2000 system.
IS-2000	The standard written by the TIA for 3G CDMA based on cdma2000 technology.
QoS	Quality of Service
TIA	Telecommunications Industry Association. A US-based standards body that is also a member of 3GPP2.
VoIP	Voice Over IP
WAP	Wireless Application Protocol - a protocol that enables Internet services to be delivered to small-screen mobile devices. WAP is the first step towards true Mobile Internet.

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