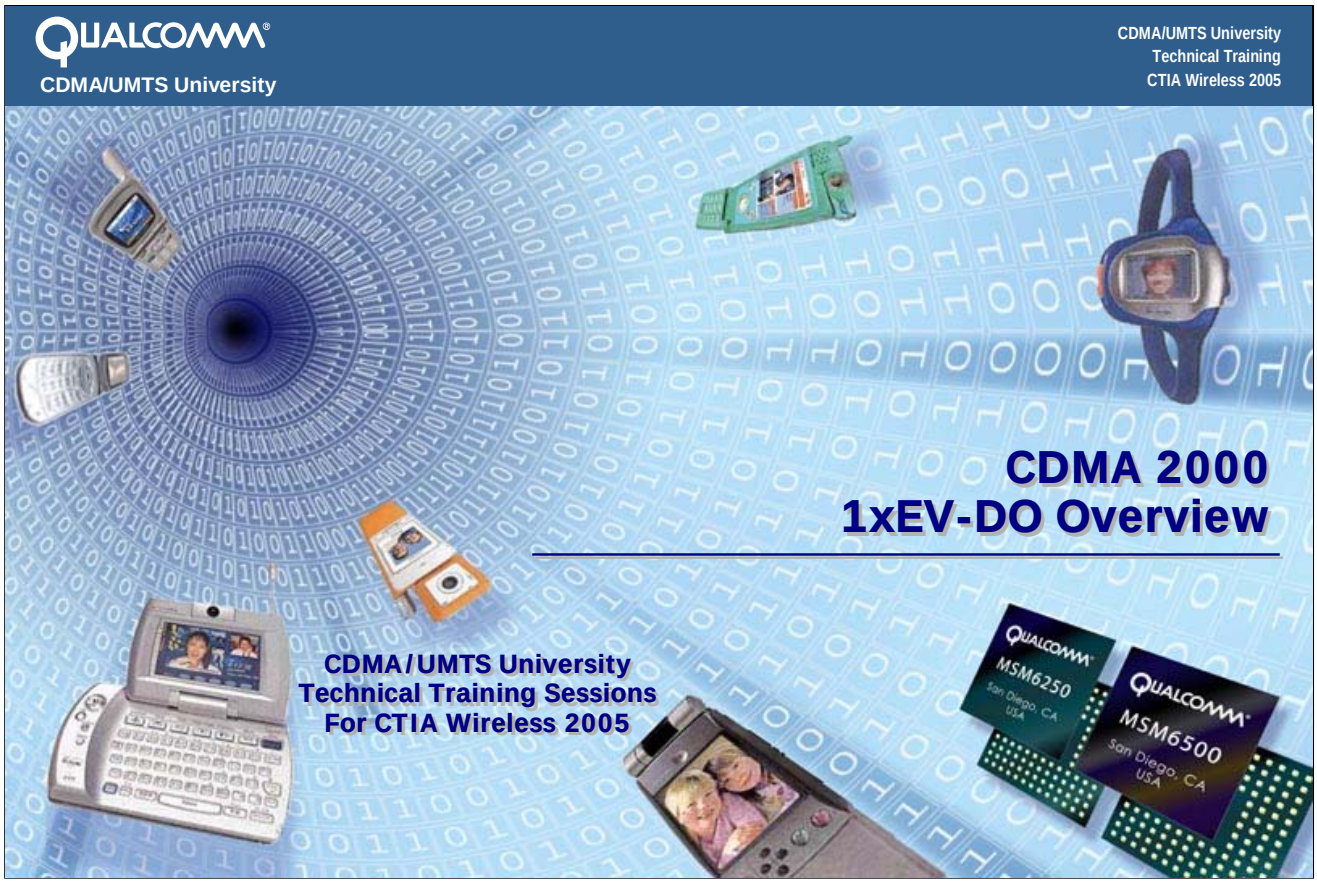

CDMA/UMTS University
Technical Training Sessions
For CTIA Wireless 2005

80-W0327-1 Rev A

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The material in this seminar is a brief sampler excerpted from technical training developed by QUALCOMM's CDMA/UMTS University.

To learn more about this seminar topic, sign up for the following courses:

- ***WCDMA (UMTS) Network Optimization*** (2 days)
- ***WCDMA (UMTS) Network Optimization Workshop*** (3 days)
- ***WCDMA (UMTS) Network Optimization Workshop – PS Data*** (1 day – coming soon!)
- ***WCDMA (UMTS) HSDPA Standards and Performance Overview*** (2 days – coming soon!)

www.cdmauniversity.com/cdma/

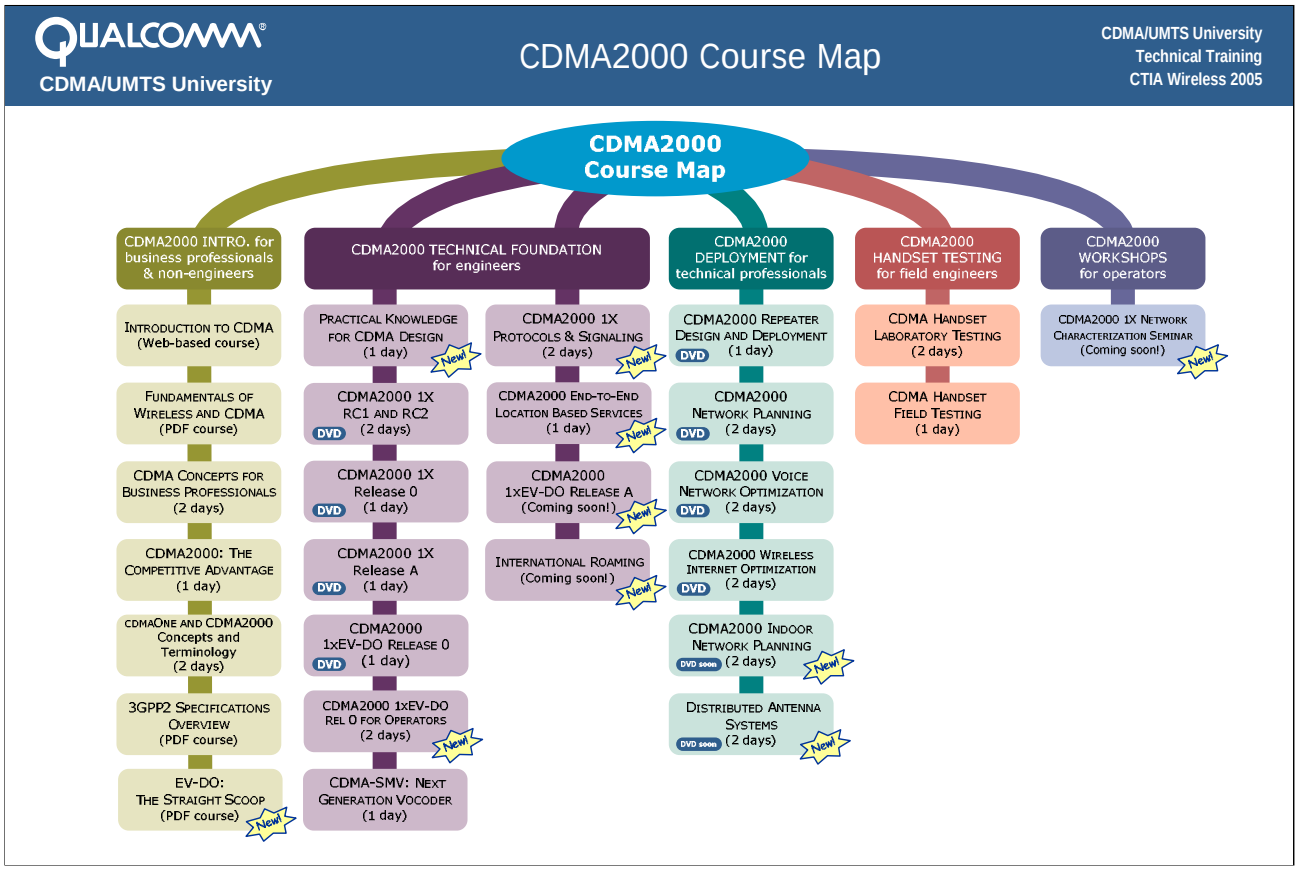
www.cdmauniversity.com/umts/

CDMA/UMTS University

CDMA/UMTS University is the Technical Training division of QUALCOMM Incorporated, the wireless technology leader.

Whether your area of interest is CDMA2000 or WCDMA (UMTS), we have courses to increase your understanding of the technology, its optimum design, and how it operates in real-world networks.

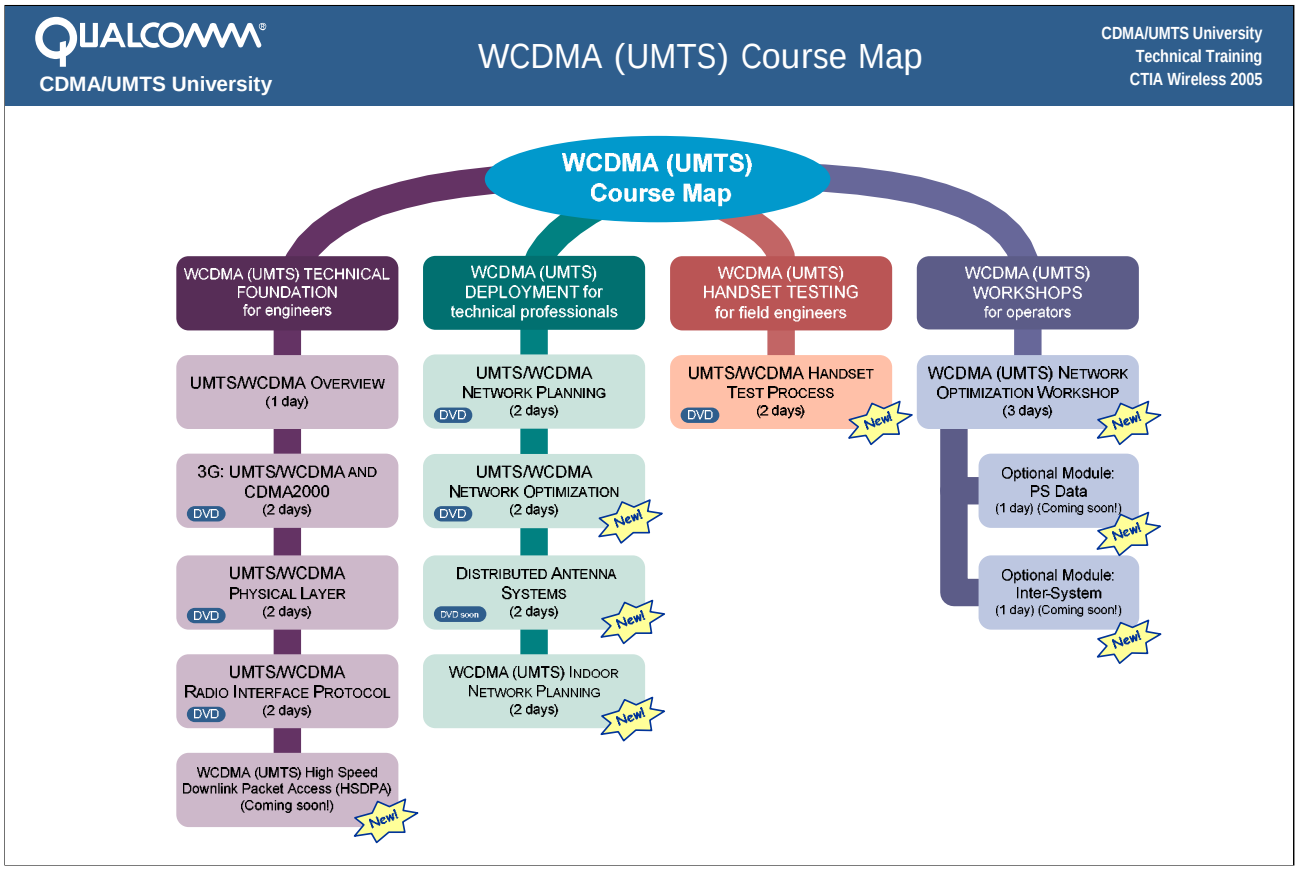
All courses are taught by domain experts from QUALCOMM, including the engineers who helped develop the CDMA technology.



CDMA University courses cover a wide range of CDMA2000 subjects and users:

- **Introductory** courses **–** for business professionals and non-engineers (many introductory courses are available as free PDFs that you can download from the Web)
- **Foundation** courses **–** for engineers
- **Network Deployment** courses **–** for technical professionals
- **Handset Testing** courses **–** for field engineers
- **Workshops** – for operators

To learn more about CDMA University, see CDMA course listings, or sign up for classes, go to **www.cdmauniversity.com/cdma/**.



UMTS University courses cover a wide range of WCDMA (UMTS) subjects and users:

- **Technical Foundation** courses **–** for engineers
- **Network Deployment** courses **–** for technical professionals
- **Handset Testing** courses **–** for field engineers
- **Workshops** – for operators

To learn more about UMTS University, see UMTS course listings, or sign up for classes, go to **www.cdmauniversity.com/umts/**.

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1xEV-DO Overview
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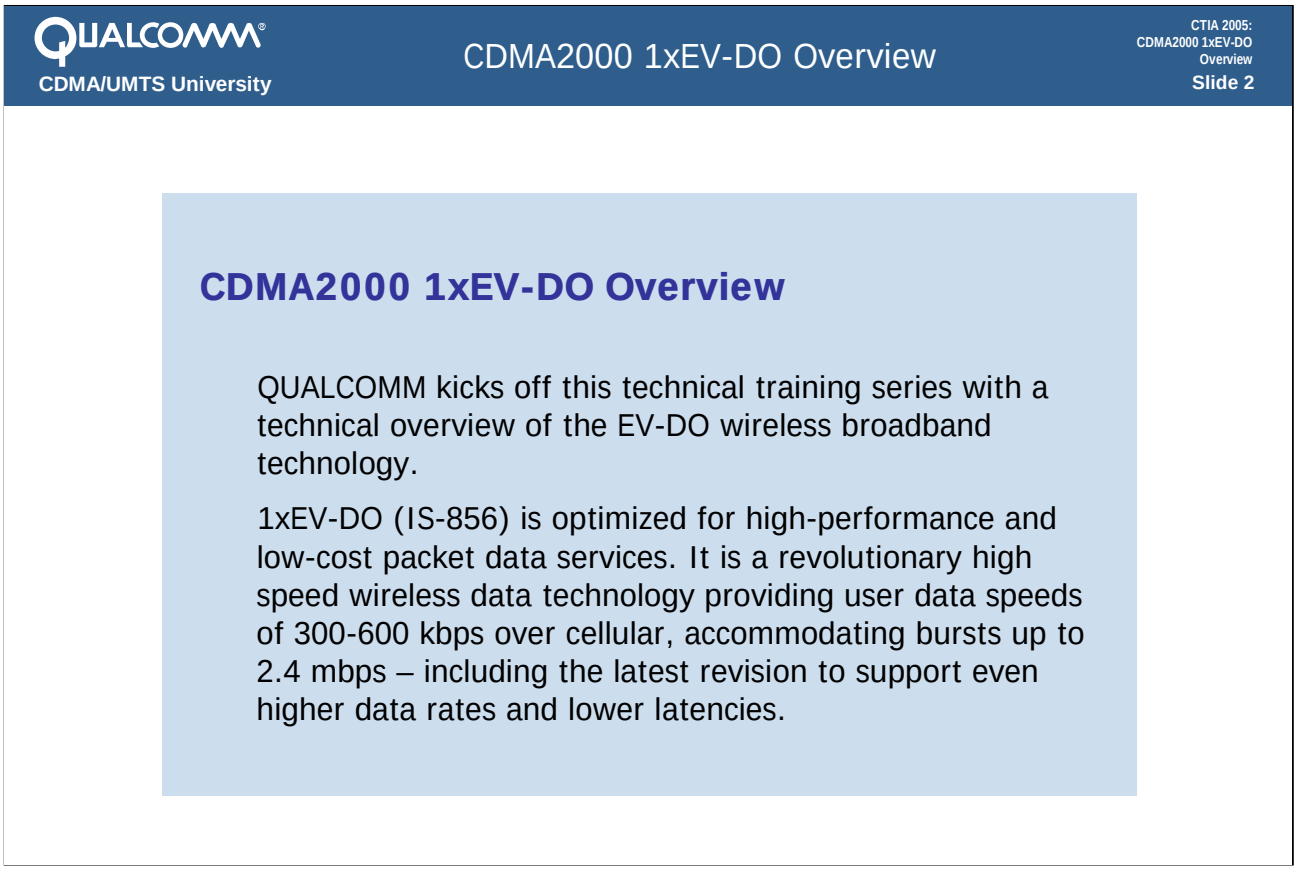
Slide 1
1xEV-DO
Overview

Notes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Overview
Slide 2
CDMA2000 1xEV-DO Overview
QUALCOMM kicks off this technical training series with a technical overview of the EV-DO wireless broadband technology.
1xEV-DO (IS-856) is optimized for high-performance and low-cost packet data services. It is a revolutionary high speed wireless data technology providing user data speeds of 300-600 kbps over cellular, accommodating bursts up to 2.4 mbps – including the latest revision to support even higher data rates and lower latencies.

Notes

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Seminar Learning Objectives

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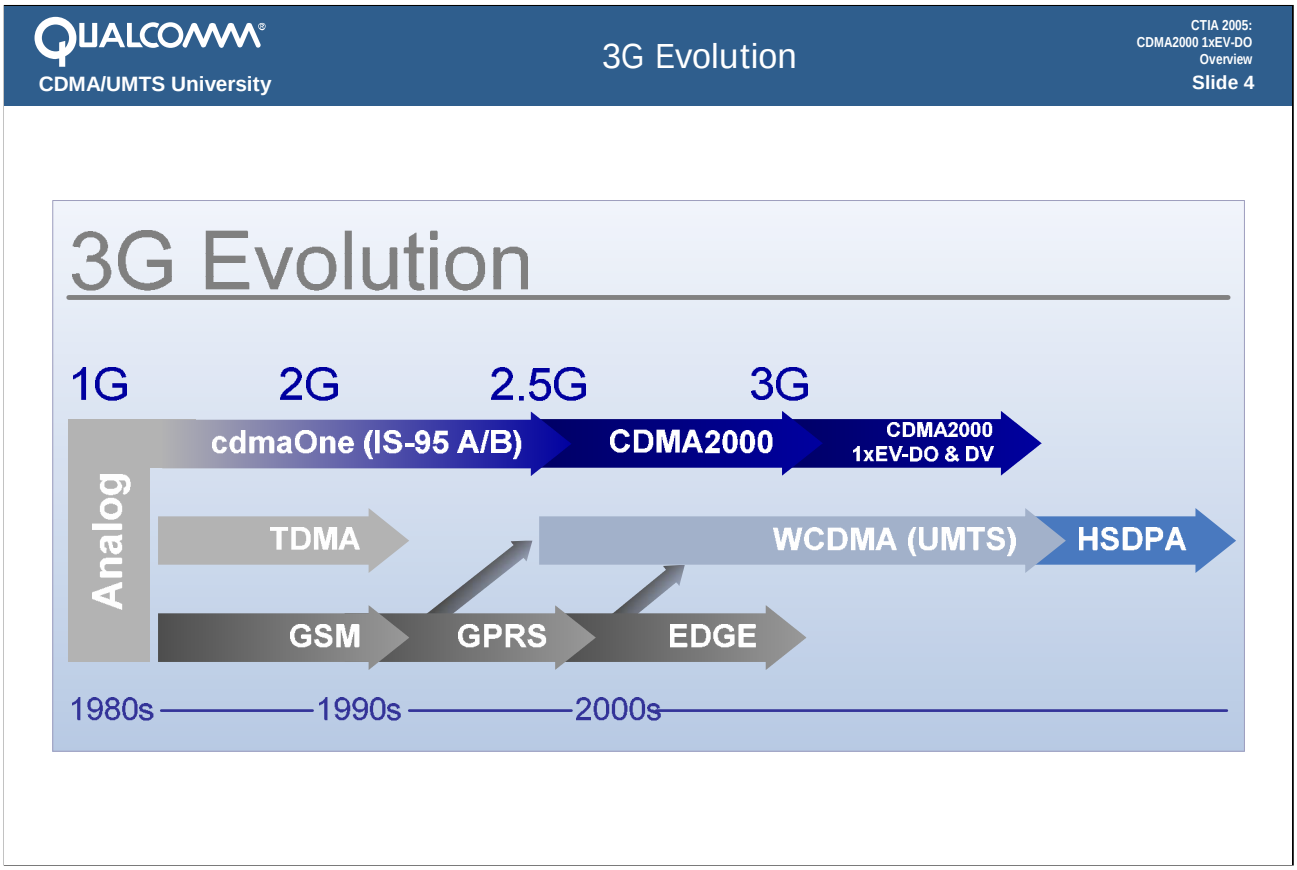
- Review 1xEV-DO timeline and roadmap.
- A brief look at EV-DO revision A enhancements.
- Further information.

Notes

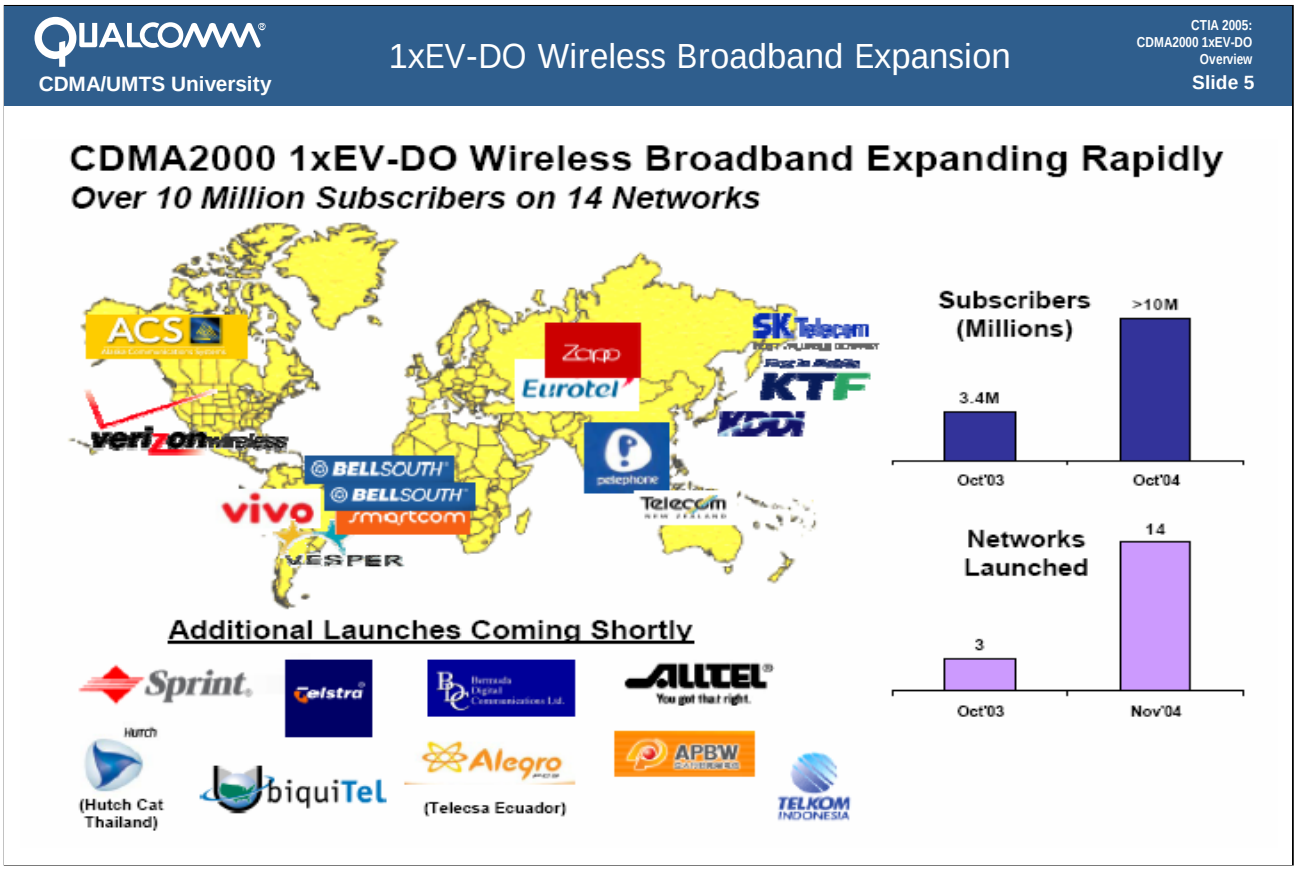


3G Evolution

An older, but more detailed version of this chart can be found at:

www.itu.int/osg/imt-project/docs/What_is_IMT2000-2.pdf

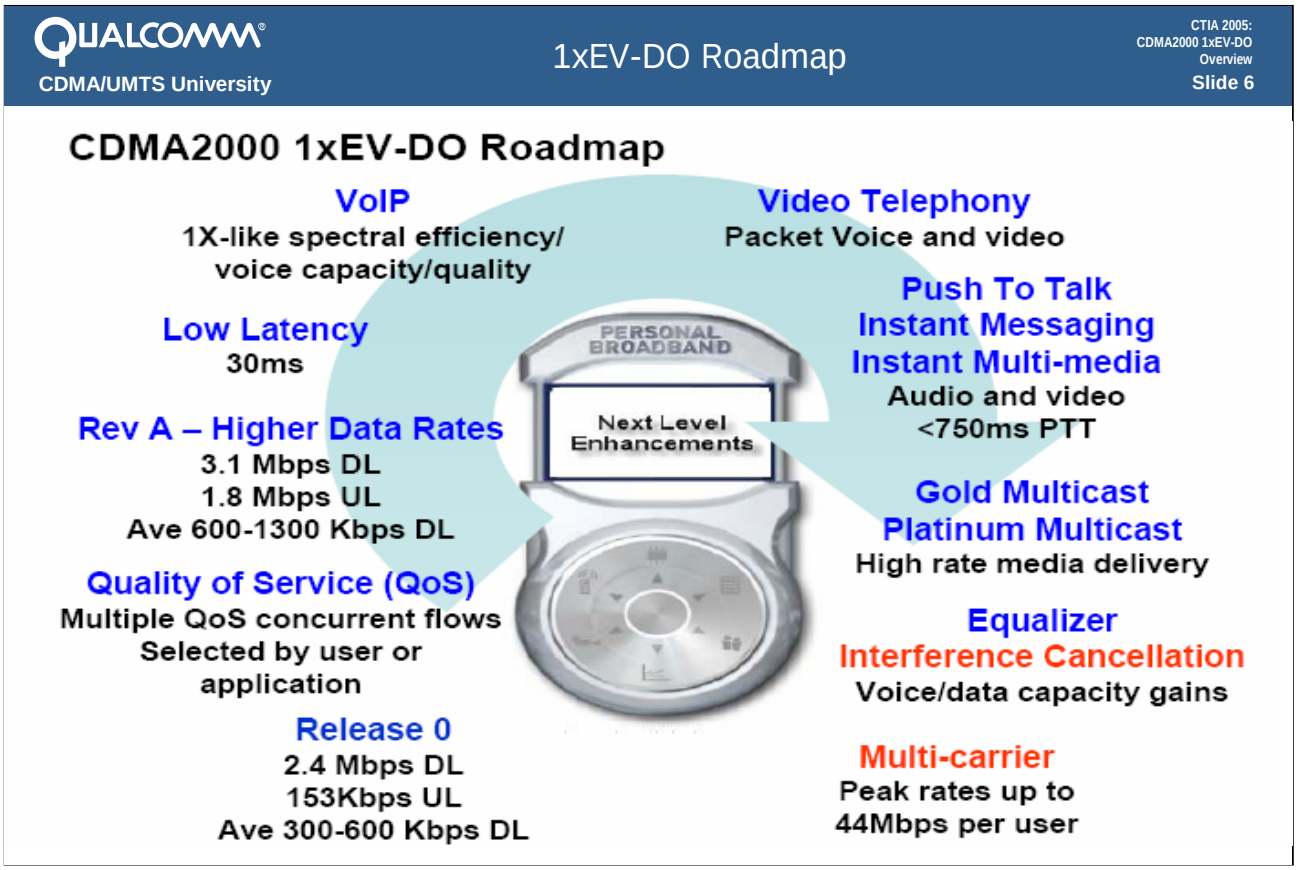
Note that the term “3G” is not formally defined.



1xEV-DO Wireless Broadband Expansion

For the most up-to-date version of this data, see:

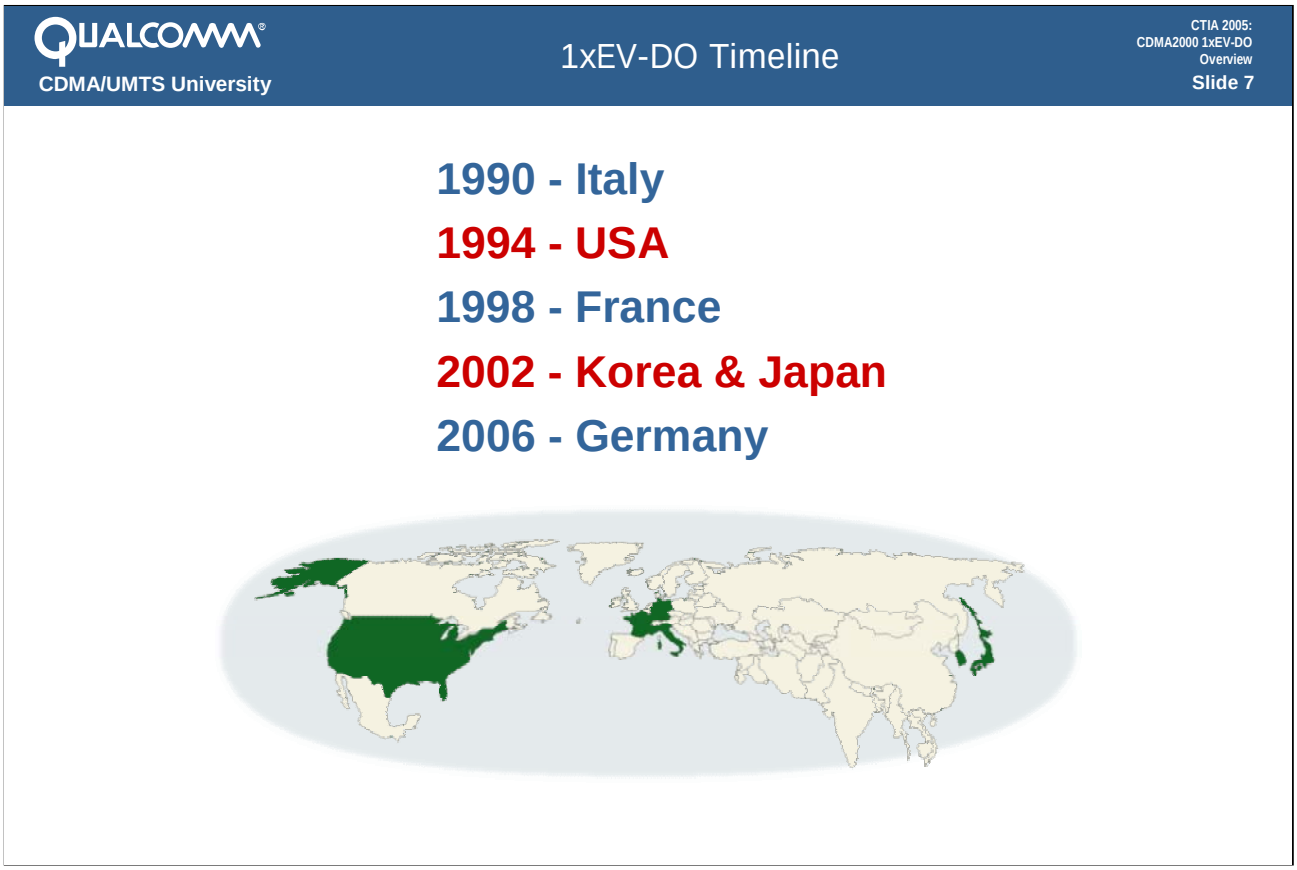
www.3gtoday.com/operators/index.html



1xEV-DO Roadmap

For the most current updates to this data, see:

www.qualcomm.com/ir/presentations.html



1xEV-DO Timeline

These dates are actually those of the FIFA World Cup competitions.

How does this relate to EV-DO?

EV-DO was commercial in 2002 in South Korea when they co-hosted the event with Japan.

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1xEV-DO Timeline (continued)

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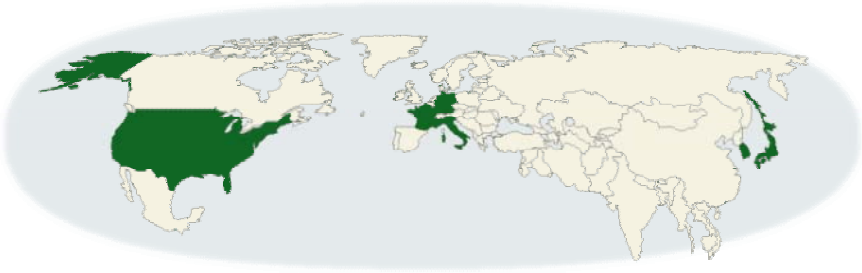
1990 – 2nd generation (digital) wireless being developed

1994 – 2nd generation voice systems commercialized

1998 – EV-DO prototypes demonstrated at PCS 1998 trade show

2002 – Korea and Japan co-host FIFA World Cup

2006 – Widespread EV-DO systems



1xEV-DO Timeline (continued)

- The EV-DO development can be traced back to 1996.
- Working prototypes were publicly shown in 1998.
- By 1999, large demonstrations of an over-the-air network loaded with working terminals were presented.
- In 2000, the IS-856 Air Interface specification was adopted and published.
- By 2001, commercial ASICs were available.
- Currently, there are over 10 million EV-DO subscribers around the world.

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1xEV-DO in Korea – SKT after Three Years

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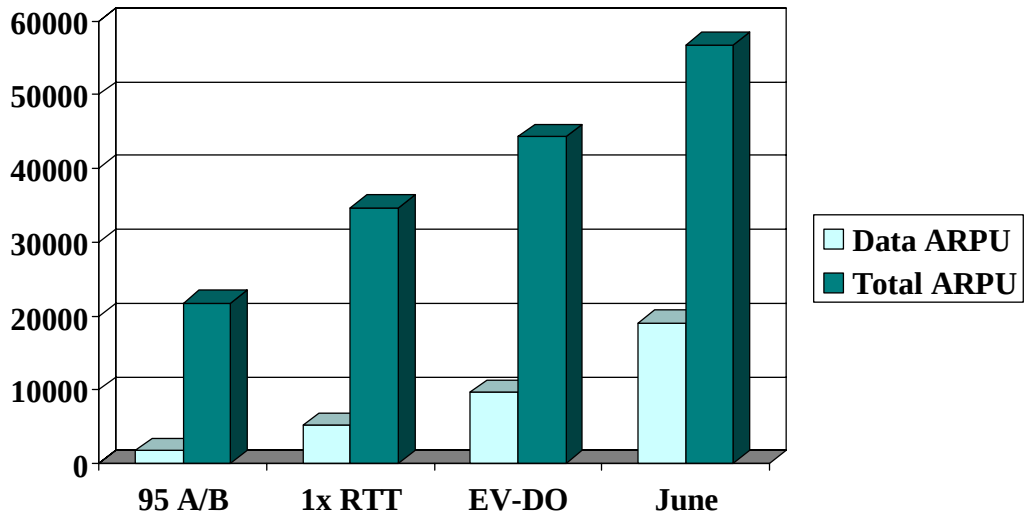

32% of subscribers have EV-DO or "June" handsets

EV-DO in Korea

The source of this graph is:

www.sktelecom.com/english/down/UBS_SKT.pdf

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1xEV-DO in Japan

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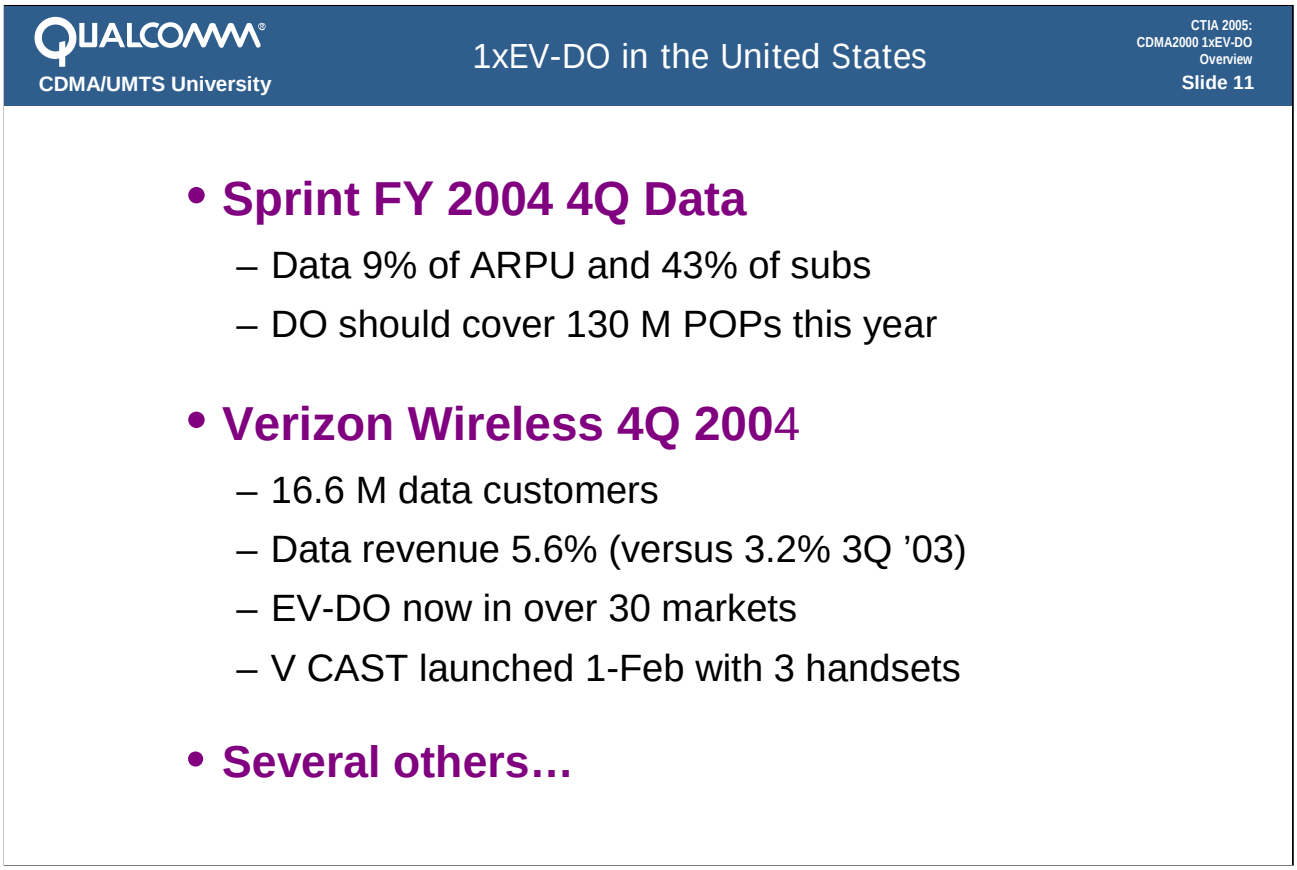
KDDI launched in late 2003

- Over **2 M EV-DO** subs one year later
  - Over 10% of total subs
- Over **3 M EV-DO** subs expected this quarter
  - Estimate increased from 3.0 to 3.2 million

EV-DO in Japan

The source of this information is:

www.kddi.com/english/corporate/ir/presentation/pdf/kddi_050127_e_main.pdf



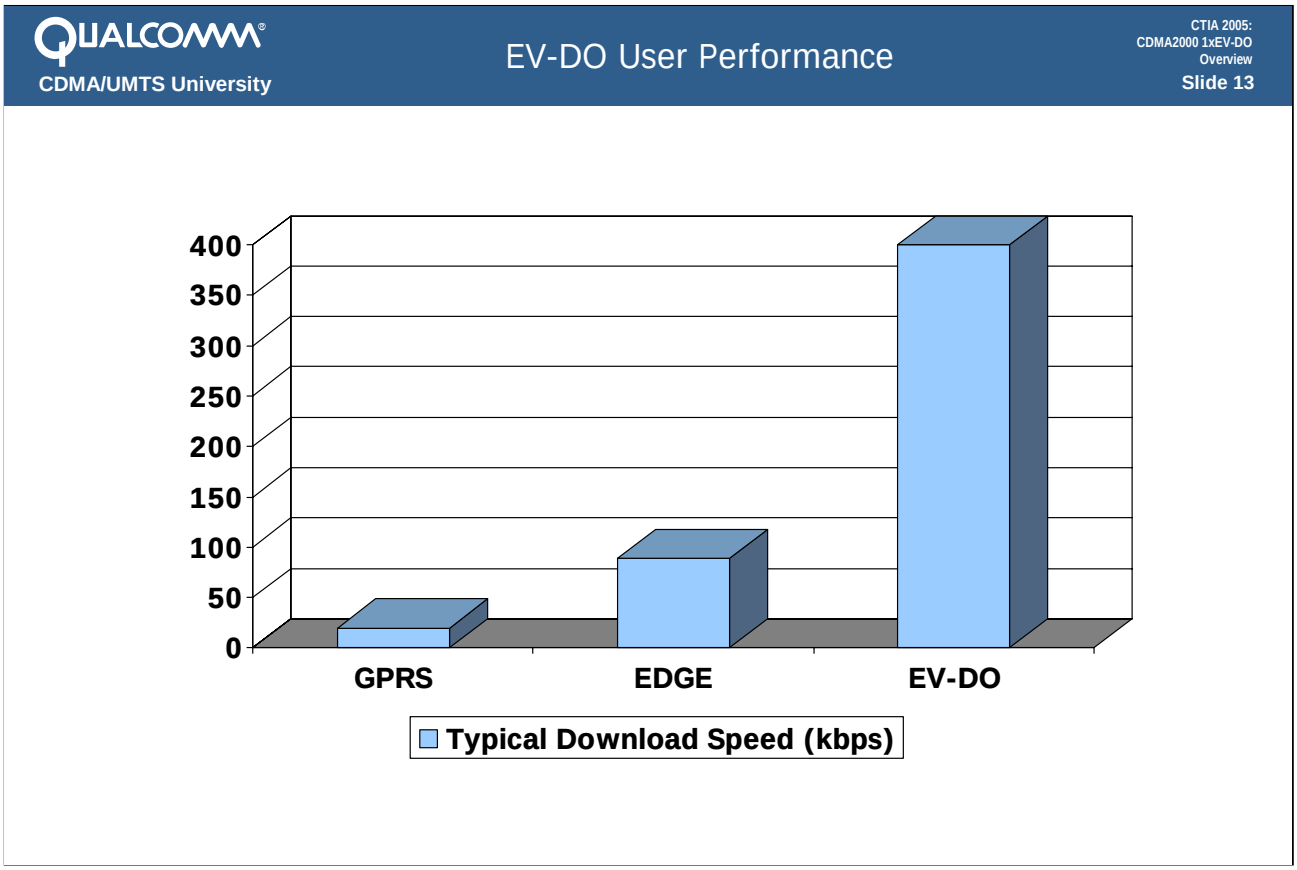
1xEV-DO in the United States

This information is from Sprint and Verizon investor reports.

Handsets

For the most recent updates, see:

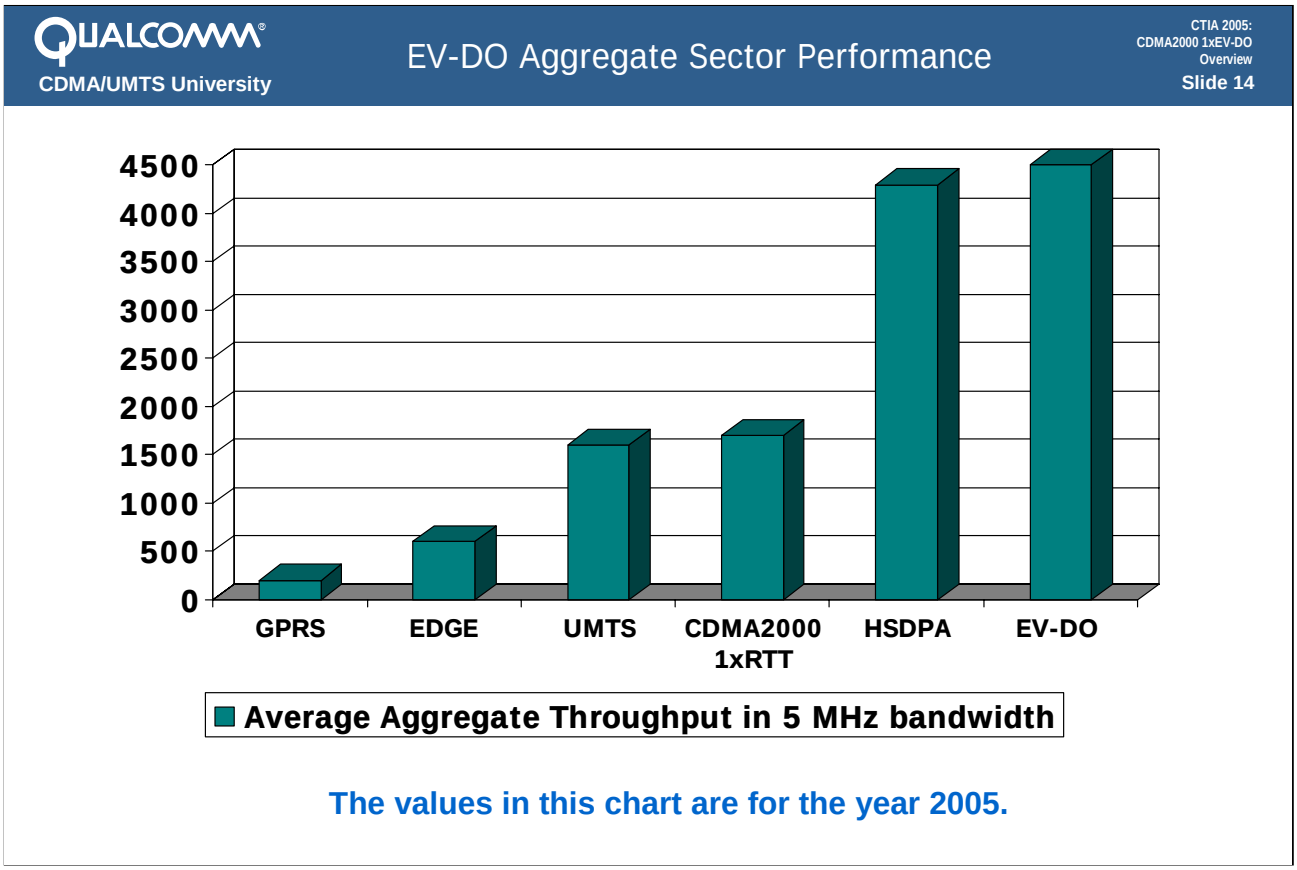
www.3gtoday.com/devices/DevicesByTechnology.html#CDMA2000%201xEV-DO



1xEV-DO User Performance

This graph depicts the download time for a 1 megabyte file.

The data shown here is from Exhibit 1 of Cingular's March 18th, 2004 Form 603 Filing to the FCC.



EV-DO Aggregate Sector Performance

The source of this information is Figure 2 in the following document:

www.cdg.org/resources/white_papers/files/Universal_Services_10-28-04.pdf

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Major Enhancements in HRPD Rev A (1xEV-DO Rev A)

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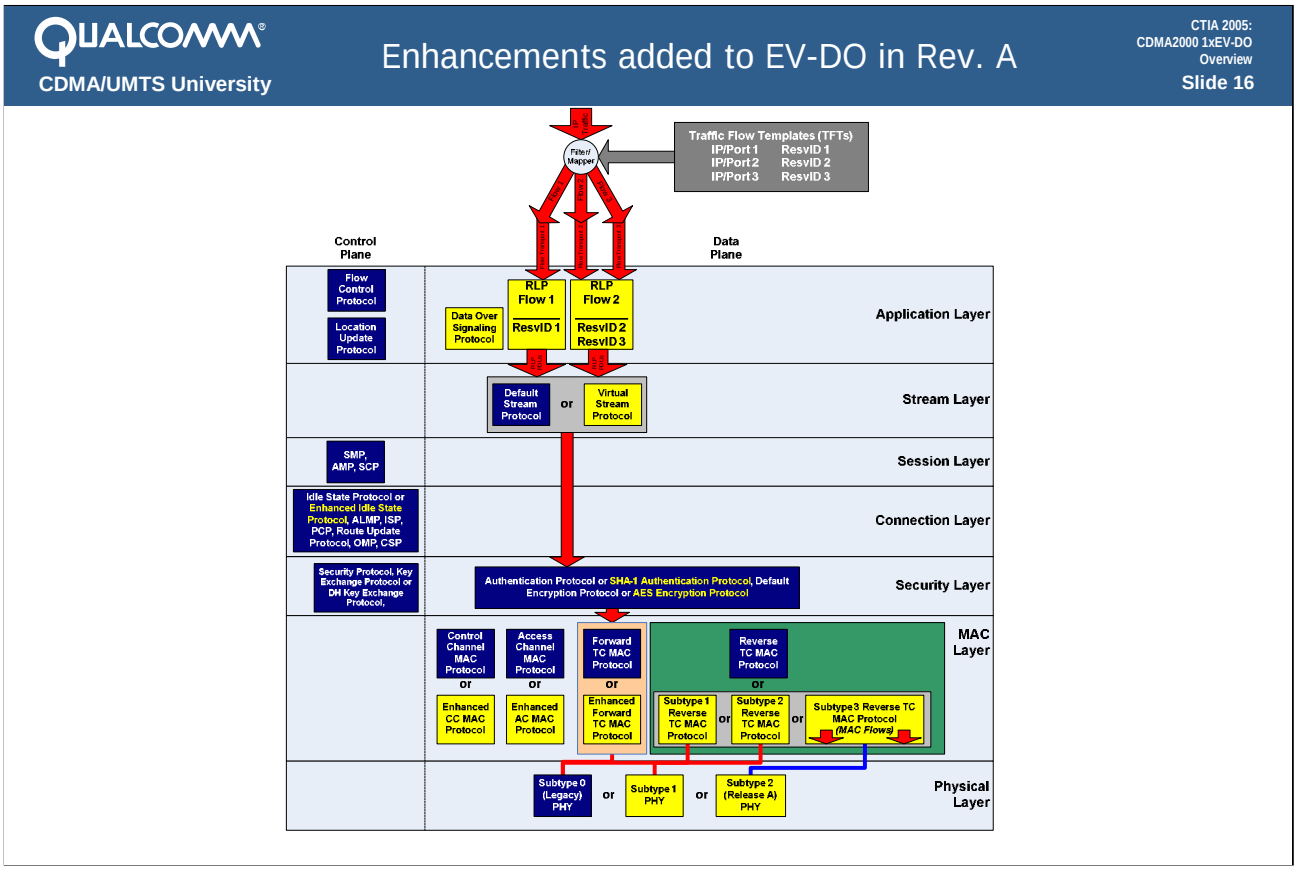
- **Enhanced Reverse link support**
  - Maximum sped of 1.8 Mbps
  - Shorter frames
  - Higher capacity
- **Forward link enhancements**
  - Higher peak data rate of 3.1 Mbps
  - Smaller packet sizes (128, 256, and 512 bits)
  - Multi-user packets
- **Improved slotted mode**
  - Shorter slot cycle for reduced activation time
  - Subsynchronous control channel for enhanced standby time
- **Enhanced multi-flow packet data application**
- **Reverse link MAC enhancements for QoS**
- **Data Source Control (DSC) for seamless cell selection**
- **Enhanced Generic Attribute Update protocol**

Major Enhancements in HRPD Rev A

The source of this data is:

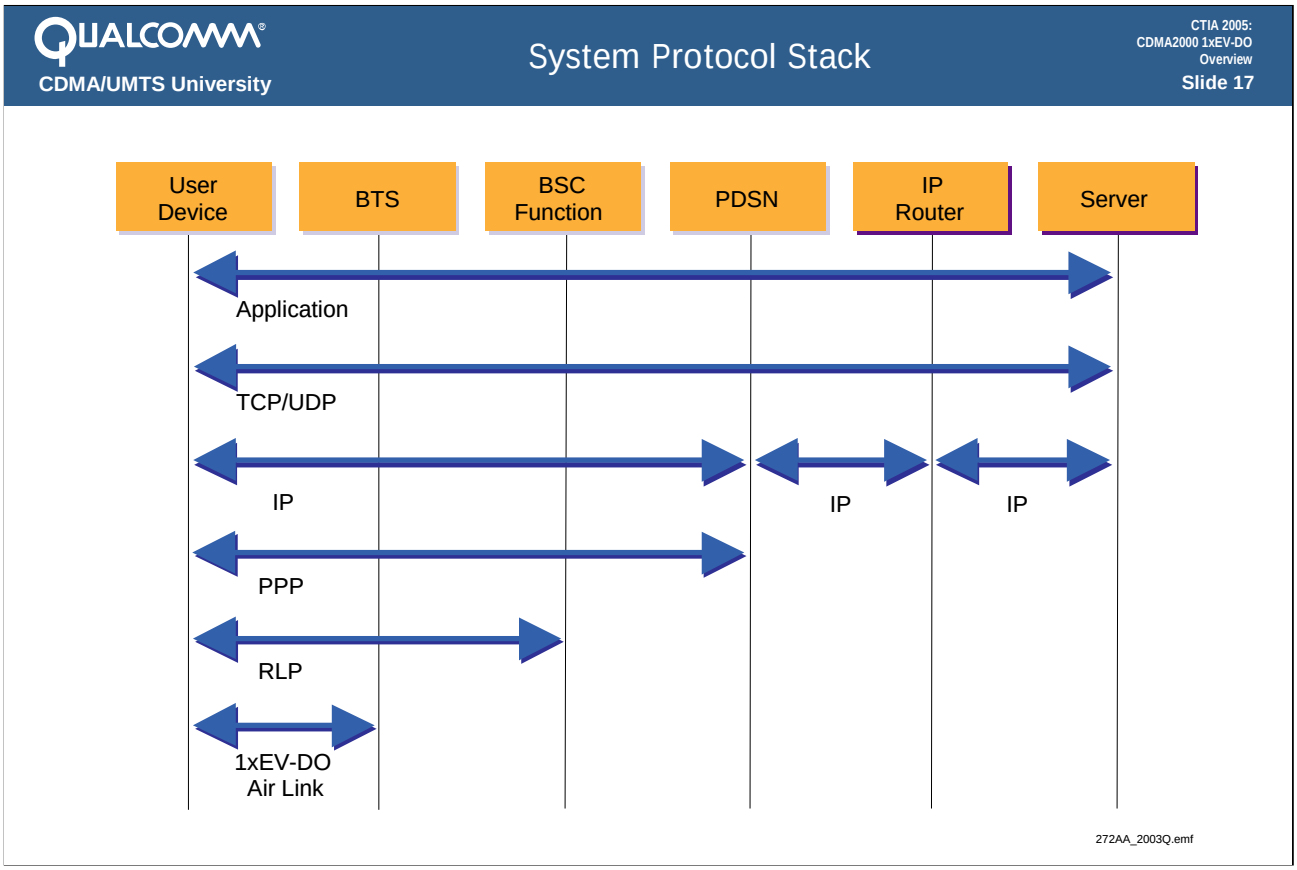
ftp://ftp.3gpp2.org/TSGC/Working/2005/2005-01/TSG-C-2005-01-Vancouver/WG3/C30-20040607-022R1%203GPP2_TSG-C%20Overview-IA450-040615_5.ppt



Enhancements added to EV-DO in Rev A

The source of this graph is:

ftp://ftp.3gpp2.org/TSGC/Working/2005/2005-01/TSG-C-2005-01-Vancouver/WG3/C30-20040607-022R1%203GPP2_TSG-C%20Overview-IA450-040615_5.ppt



System Protocol Stack

This figure shows the typical protocol stack for a 1xEV-DO system. Only the 1xEV-DO air link and RLP are specific to 1xEV-DO. The other protocols (PPP, IP, TCP, and User Datagram Protocol [UDP]) are based on Internet Engineering Task Force (IETF) standards.

Do not confuse the seven layers inside EV-DO with the classic, seven layer OSI networking model. The EV-DO layers are down at the Physical and Data Link layers.

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1xEV-DO Introduction

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- 1xEV-DO History
- 1xEV-DO Present and Future
- 1xEV-DO Physical Layer Features
- 1xEV-DO MAC Layer Features

Notes

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1xEV-DO History – Release 0

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1xEV-DO Release 0

- **Designed as a Wide-Area Mobile Wireless Ethernet**
  - Optimized support for Downlink intensive (asymmetric), delay-tolerant applications
    - Web browsing, file transfer, WAP, IM, etc.
- **Goals:**
  - Capacity and coverage enhancement
  - Support for QoS

1xEV-DO History – Release 0

Remember, this was designed way back in the late 20th Century!

1xEV-DO History – Capacity Enhancement

Capacity Enhancement

- **Larger packet sizes** enable gains due to use of Turbo codes
  - Approximately 3 dB coding gain
- **Forward link**
  - Physical Layer H-ARQ
  - Multi-user diversity scheduler
  - Diversity reception
- **Reverse link**
  - Stochastic control of AT behavior
  - Fast closed-loop Rise-over-Thermal (RoT) control using direct measurement of RoT at sector
    - Allows higher RoT operation (higher capacity) than IS-2000 systems with similar stability
    - More robust (stable) operation than IS-2000 systems for any operating point (RoT target)

Notes

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1xEV-DO History – Coverage Enhancement and QoS Control

Coverage Enhancement

- **Coverage equal to or better than IS-2000 systems** to leverage existing deployments
- **System optimization for asymmetric, delay-tolerant data services** results in higher spectral efficiency and better coverage

QoS Control

- **Centralized (AN) control of AT behavior**
  - Fair (P-fair, G-fair) scheduler on Forward link
    - Per-flow control on Forward link
  - AN control of Reverse traffic priority of a given AT by adjusting the rate transition probabilities or by imposing a rate limit
    - Per AT control on Reverse link

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1xEV-DO Present and Future

Demand is strong for:

- Delay-sensitive applications with symmetric data rates
  - VOIP, wireless gaming
- QoS support
  - Inter-AT and Intra-AT
- Precise AN control of AT behavior
- Broadcast services

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1xEV-DO Present and Future – Release 0

Release 0 provides:

- High spectral efficiency for Forward Link Best Effort traffic
  - HTTP, FTP, etc.
- Forward link broadcast and multi-cast services
- QoS support (Inter-AT)
- Basic AN control of AT behavior

Release 0 is not competitive with IS-2000 for applications with strict delay requirements.

- Not designed to support large numbers of delay-sensitive, symmetric, low rate applications
- Outage due to server selection on Forward link

Notes

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1xEV-DO Features – Physical Layer

Improved support for QoS-sensitive services

- **Rapid connection setup** with improved terminal battery life
  - Higher rate Access Channel (up to 38.4 kbps) with shorter preamble (4 slots)
  - Short inter-transmit interval on control channel
  - Short packet control channel (4-slots) in Idle state
- **Efficient resource allocation** for both low latency and delay tolerant data sources
  - AN controlled tradeoff (per flow) between capacity and latency
- **Finer rate quantization**
  - Additional data rates on Forward link and Reverse link
  - Latency target determines effective data rate
- **Improved packing efficiency**
  - Multi-user packets on Forward link
    - A single Physical Layer packet can carry data for multiple ATs

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1xEV-DO Features – Physical Layer (continued)

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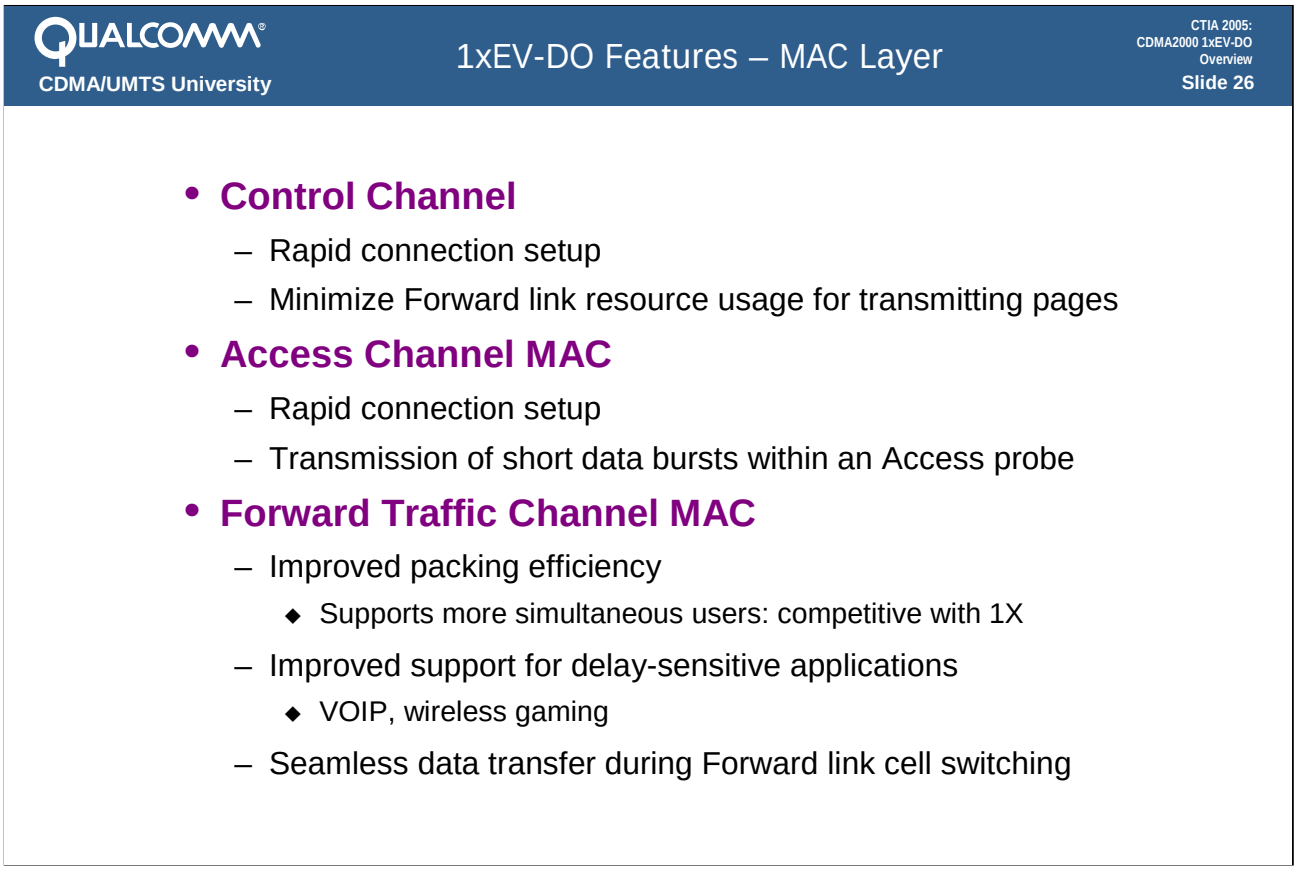
- **Higher spectral efficiency**
  - Physical Layer Hybrid ARQ (on RL)
  - Support for MAC Layer ARQ (on RL)
    - 1xEV-DO Revision A supports Physical Layer and MAC Layer ARQ on both Forward and Reverse links
- **Higher peak data rates**
  - 3.1 Mbps on Forward link (2.45 Mbps in 1xEV-DO Release 0)
  - 1.8 Mbps on Reverse link (153.6 Kbps in 1xEV-DO Release 0)
- **Moderate Link Budget improvement**
  - 1.5 dB improvement over 1xEV-DO Release 0 systems
  - 14.4 kbps (RL) supported at cell edge versus 9.6 kbps for 1xEV-DO Release 0

Notes



1xEV-DO Features – MAC Layer

EV-DO has always supported sub-second connection setup. With EV-DO Revision A, many additional enhancements have been added.

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1xEV-DO Features – MAC Layer (continued)

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- **Reverse Traffic Channel MAC**
  - Efficient utilization of high-capacity Physical Layer
  - Efficient support for latency-sensitive and delay-tolerant applications
    - Ability to trade-off capacity and latency
  - QoS-sensitive resource allocation among multiple flows at an AT
  - Comprehensive AN control over AT behavior
  - Improved Reverse link stability at high RoT

1xEV-DO Features – MAC Layer (continued)

RoT is the *Rise over Thermal* – the fundamental limit on Reverse link capacity.

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Basic Concepts – Physical Layer

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Traffic Channel

- RL Physical Layer ARQ
- RL Capacity/Latency Trade-off
- RL Transmission Start Delay
- Rapid Connection Setup
- FL Seamless Server Selection
- Short Packets

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Basic Concepts – Physical Layer: RL Physical Layer ARQ

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- **1xEV-DO Release 0 Reverse link packets are transmitted over a contiguous 16-slots.**
  - Excess E_b/N_t – packets can be decoded in fewer slots.
- **Excess E_b/N_o due to:**
  - Imperfect power control
  - Traffic Channel gains chosen to ensure target PER in worst case channel conditions
- **Hybrid ARQ (H-ARQ) introduced with Release A**
  - AN can attempt early termination of packets.
  - Staggered transmission from AT

Reverse Link Physical Layer ARQ

The EV-DO slot time is 1.67 milliseconds.

The initial release of EV-DO used Reverse link frames that were always 26.67 milliseconds in length.

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Basic Concepts – Physical Layer: RL Physical Layer ARQ (continued)

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- **Staggered transmission of 16-slot packet in 4-slots (sub-packet) increments**
  - Transmission terminated if AN decodes packet OR entire packet transmitted.
- **AN soft-combines sub-packets**
  - Until packet successfully decodes OR maximum number of sub-packets of a packet are transmitted.
- **ARQ bits transmitted on the FL MAC channel**
  - Design simplicity
  - Latency requirements
  - The FL MAC channel (TDM'd with Pilot and data transmissions) power is inadequate to transmit 600 Hz Reverse power control, Reverse Activity (RA) channel, and ARQ channel information for a large number of simultaneous users.
- **Decimated power control along with H-ARQ**
  - Excess E_b/N_o due to decimated power control is used advantageously by H-ARQ to terminate packets early.
  - Reduced interference variance may lead to improved overhead channel performance.

Reverse Link Physical Layer ARQ (continued)

In EV-DO Revision A, a Reverse link subpacket can be completed in under 8 milliseconds.

The added bits to support H-ARQ on the Reverse link need to be transmitted on the Forward link. These are shared with the Reverse Power Control (RPC) bits.

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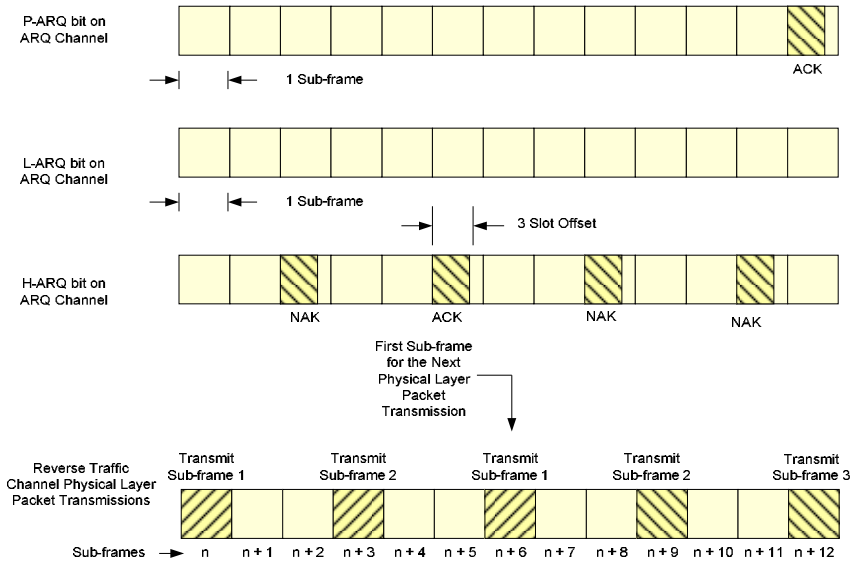
Basic Concepts – Physical Layer: RL Physical Layer ARQ (continued)

Channel Operation – Reverse Traffic Channel Packet transmission with early termination



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Basic Concepts – Physical Layer: RL Physical Layer ARQ (continued)

- Slower power control sometimes results in a higher Pilot E_c/N_t.
- However, a combination of slower power control and H-ARQ results in a **significantly lower E_b/N_t for ALL channel models.**

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Basic Concepts – Physical Layer: RL Capacity/Latency Trade-off

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Controlling the number of subpackets of transmission required to ensure a target PER provides control on the Physical Layer latency and capacity.

- **Longer latency target: Higher capacity and larger delay**
- **Shorter latency target: Lower capacity and lower delay**

Payload Size (bits)	Effective Data Rate (kbps)			
	After 4 slots	After 8 slots	After 12 slots	After 16 slots
128	19.2	9.6	6.4	4.8
256	38.4	19.2	12.8	9.6
512	76.8	38.4	25.6	19.2
768	115.2	57.6	38.4	28.8
1024	153.6	76.8	51.2	38.4
1536	230.4	115.2	76.8	57.6
2048	307.2	153.6	102.4	76.8
3072	460.8	230.4	153.6	115.2
4096	614.4	307.2	204.8	153.6
6144	921.6	460.4	307.2	230.4
8192	1228.8	614.4	409.6	307.2
12288	1843.2	921.6	614.4	460.8

Notes

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Basic Concepts – Physical Layer: RL Capacity/Latency Trade-off (continued)

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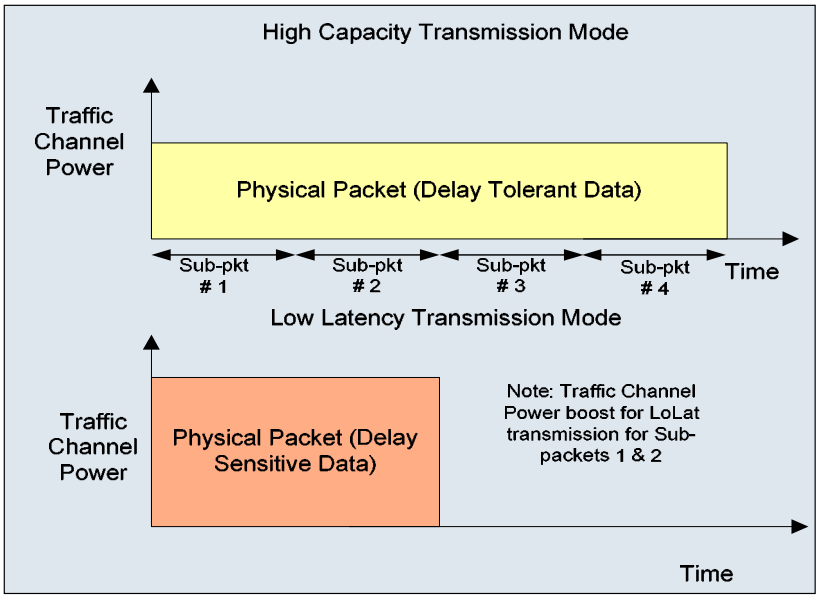

- **Typical T2P profiles for High Capacity mode and Low Latency mode**
- **Packets transmitted in Low Latency mode are power boosted to ensure earlier termination**

Packet transmissions shown contiguous for illustrative purposes only.

RL Capacity/Latency Trade-off

T2P refers to controlling the relative power of the Data Channel (traffic) compared to the Pilot Channel.

The subpackets are actually spaced out long enough for the H-ARQ operation to function as shown on the earlier slide.

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Basic Concepts – Physical Layer: Reduced RL Transmission Start Delay

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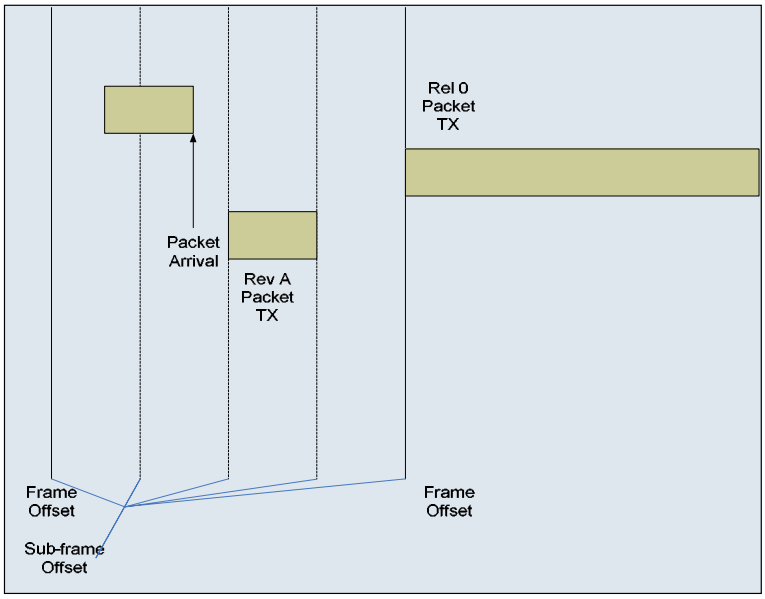
- **Release 0** packet transmission start times are limited to start of frame boundaries.
  - **Worst-case** packet start delay: 26.66 ms
  - **Average** packet start delay: 13.33 ms
- **Release A** RL transmissions can start at sub-packet boundaries.
  - **Worst-case** packet start delay: 6.66 ms
  - **Average** packet start delay: 3.33 ms
- **Assumptions:**
  - Packet is at head of queue.
  - 1xEV-DO Release 0: Physical Layer is idle.
  - 1xEV-DO Revision A: The desired interlace offset is idle.



Reduced RL Transmission Start Delay

This assumes:

- Packet is at head of queue
- 1xEV-DO Release 0: Physical Layer is idle
- 1xEV-DO Revision A: The desired interlace offset is idle

Release 0 Access Channel

- System designed for delay-tolerant applications
  - **Connection setup time not optimized**
  - **Conservative Access Channel preamble design**
- Fixed Access Channel data rate = 9.6 kbps
  - Highest rate Access Channel capsule would require 160 ms transmission

Notes

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Basic Concepts – Physical Layer: Rapid Connection Setup (continued)

Revision A Access Channel

- **System design expanded to support delay-sensitive applications.**
  - Connection setup time optimized to support applications that require "instant-connect."
  - Avoid use of Traffic Channel if transmitting small amounts of data sporadically (AN controlled).
- **AN controlled max AT Access Channel data rate**
  - Up to 38.4 kbps
  - Highest rate Access Channel capsule would require 33.33 ms transmission
- **Lower connection setup delay**
  - Required for delay-sensitive applications
  - Allows shorter dormancy timers, which reduces RL interference and enables support for larger number of users

Notes

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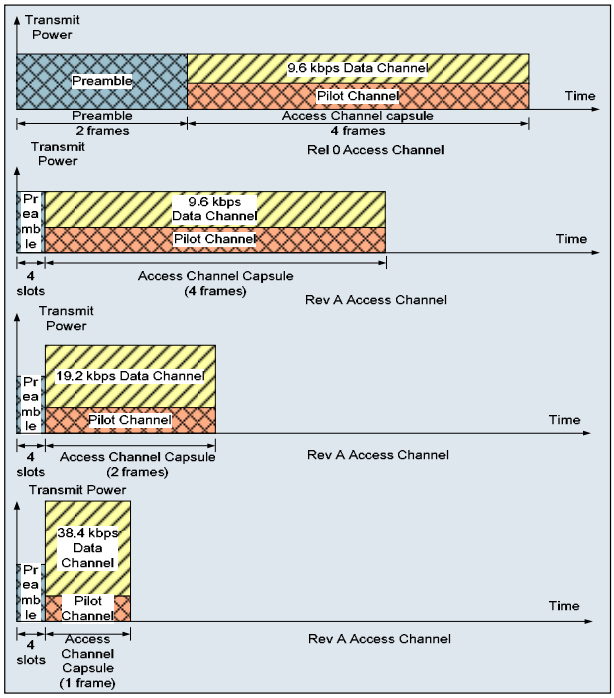
Basic Concepts – Physical Layer: Rapid Connection Setup (continued)

Release 0 Access Channel

- Preamble size = 1 frame or longer
  - Typical size = 2 frames
  - 4-slot preamble adequate for reliable detection
- 1024-bit transmission requires 160 ms

Revision A Access Channel

- Higher rate Access Channel transmissions
  - Per AT Access Network control: additional tool for user differentiation
  - Significant reduction in connection setup time
- 1024-bit transmission requires
  - 33.33 ms (38.4 kbps)
  - 60 ms (19.2 kbps)
  - 113.33 ms (9.6 kbps)



Notes

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Basic Concepts – Physical Layer:
Rapid Connection Setup (continued)

CTIA 2005:
CDMA2000 1xEV-DO
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Release 0

- **Control Channel packet Transmission Formats**
  - [1024, 8, 512] (38.4 kbps) OR [1024, 16, 1024] (76.8 kbps)
- **Synchronous Control Channels (SCC)**
  - transmitted every 256 slots
- **Asynchronous Control Channels (AC)**
  - Transmitted at any time

Rapid Connection Setup

EV-DO Release 0 supported one of two rates for the Control Channel: 38.4 or 76.8 kbps.

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Basic Concepts – Physical Layer: Rapid Connection Setup (continued)

Revision A

- **Release 0 Control Channel packets + Short packets**
  - [128, 4, 1024], [256, 4, 1024], OR [512, 4, 1024]
- **Sub-sync Control Channel packets allow significantly lower inter-packet transmit delay**
  - As low as 4 slots; Typical value = 64 slots
  - Allows trade-off between connection setup time and battery life.
- **Improved packing efficiency**
  - Short packets transmitted using SCC to a terminal in Idle state.
- **Improved utilization of Forward link resources**
  - Low rate packet provides E_b/N_o margin.
  - Worst-case usage = 4-slots compared to 16 slots for 38.4 kbps SCC or AC.
- **Rapid system access**
  - Allow ATs to get quick access into the system and obtain control signaling information.
  - Useful for delay-sensitive applications.

Notes

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Basic Concepts – Physical Layer: FL Seamless Server Selection

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1xEV-DO Release 0

- Forward link server selection results in service outage.
- Outage duration approximately the time interval required for FL queue transfer following AT indication of server change.

1xEV-DO Revision A

- Data Source Channel (DSC) facilitates seamless FL cell switching.
- AT uses DSC to provide an early indication of server (cell) change to AN.
- Improved detection of server change indication and precise knowledge of instant of server change minimizes (eliminates) outage due to server change on FL.

FL Seamless Server Selection

The Data Source Channel (DSC) is a key enhancement in EV-DO Revision A.

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Basic Concepts – Physical Layer: FL Seamless Server Selection (continued)

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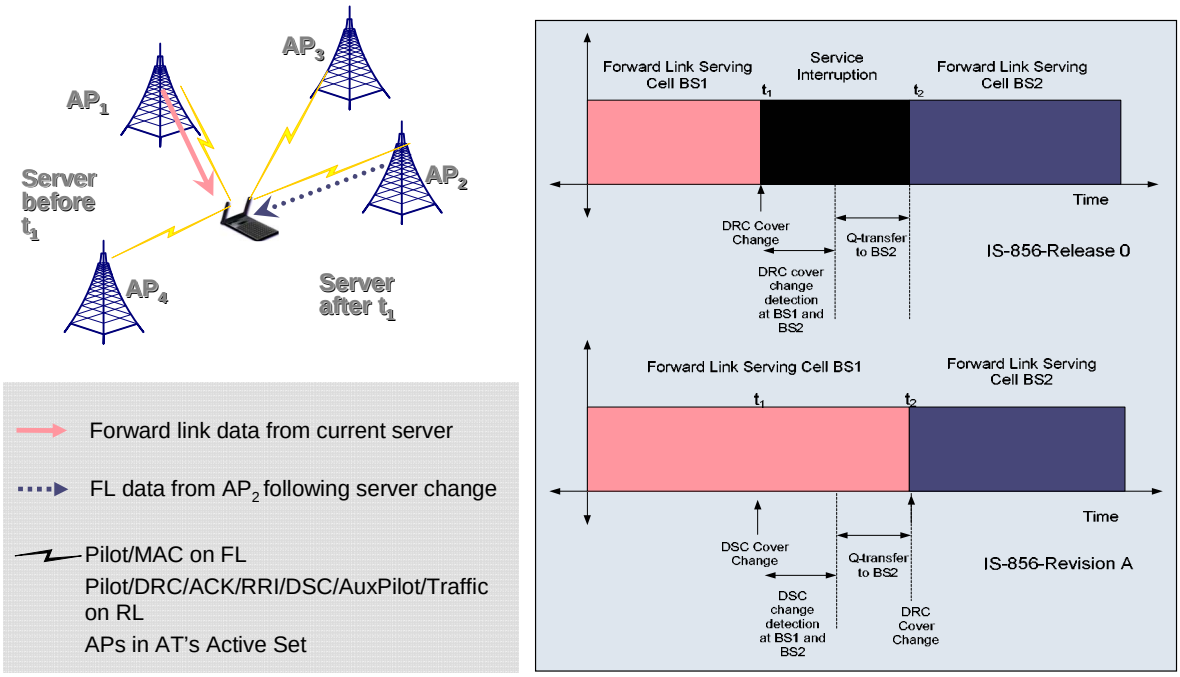

FL Seamless Server Selection (continued)

This slide shows the improved sever selection (Forward link handoff) with EV-DO Revision A.

There are several other important points to notice. Although the Forward link data traffic is sent from only one sector at a time, the forward MAC channel is transmitted from every sector in the terminal's current Active Set. This supports the Reverse Power Control (RPC) bits that control the terminal transmit power.

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Basic Concepts – Physical Layer: Short Packets

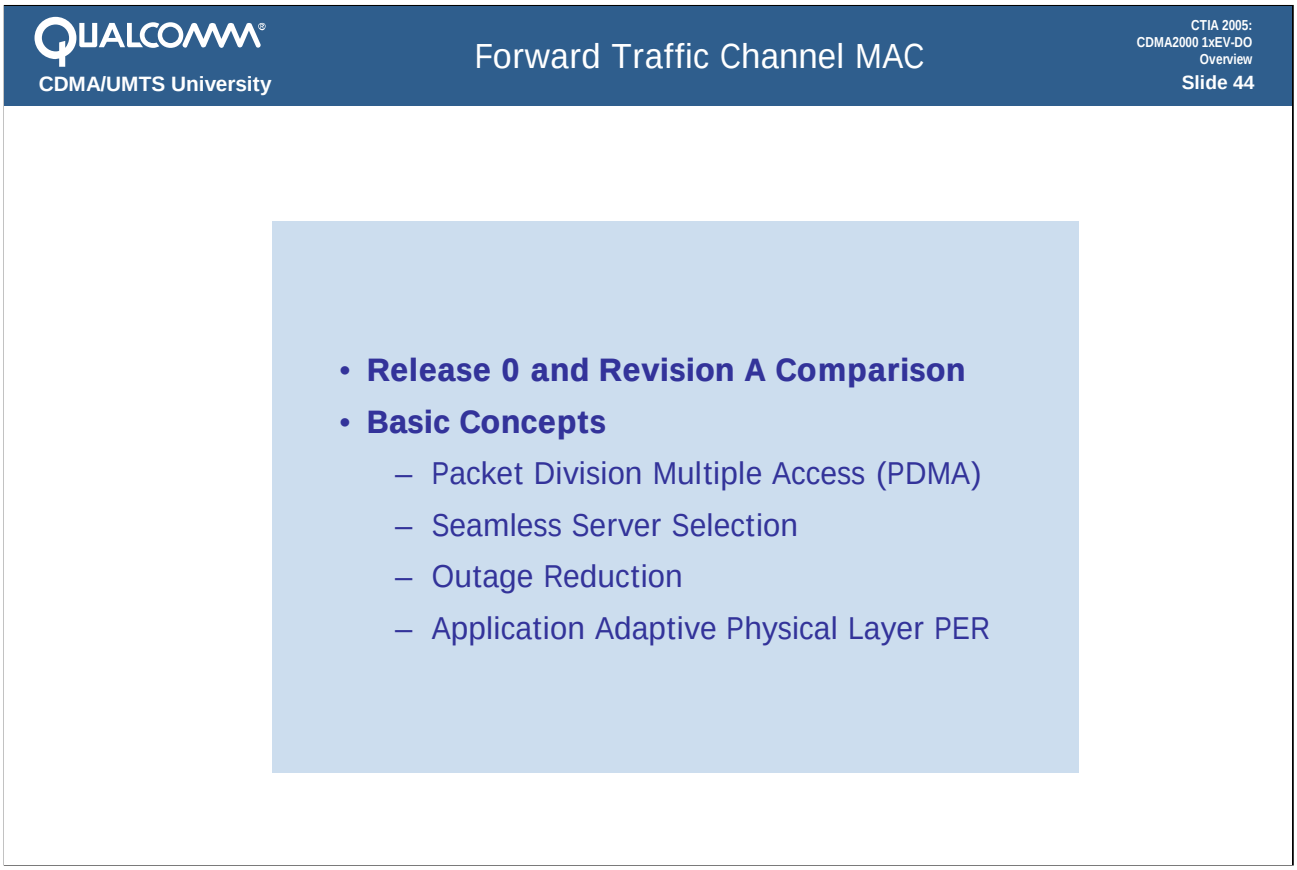
1xEV-DO Release 0

- Smallest Physical Layer packet size = 1024 bits
  - Poor packing efficiency if data inadequate to fill Physical Layer packets.
  - Inefficient data transport for applications with small, latency-sensitive of data bursts.
    - Uses more Forward link resources
    - Users in poor channel conditions
      - Worst-case latency: 100 ms
      - 16-slots of transmission for payload size less than 1024 bits

1xEV-DO Revision A

- Support for shorter packets [128-bits, 256-bits, and 512-bits and non-canonical single-user packets]
  - Used by AN to serve low-rate, low-latency traffic to ATs in poor channel conditions.
  - More efficient use of Forward link resources
- Lower latencies can be achieved for delay-sensitive applications without the resource utilization penalty of 1xEV-DO Release 0.

Notes



Forward Traffic Channel MAC

Now we will move up one layer to the MAC layer.

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Forward Traffic Channel MAC – Release 0 versus Revision A

Release 0

- Entire Traffic Channel allocated to a single user at any given time.
  - Large packet sizes
  - Suitable for delay-tolerant applications, which can be buffered until there is enough data to fill an entire packet
- Interruptions in transmission due to cell switching are acceptable.
- Provides a PER ~ 1%, irrespective of channel/loading conditions, application.
- Always exploit multi-user diversity.

Revision A

- Serve multiple terminals within a single MAC Layer packet.
  - Accomplish CDM (fractional power allocation and simultaneous transmission) as in IS-2000 by TDM (fractional time allocation within a single packet).
  - Improved packing efficiency allows the sector to support more users.
- Eliminate outages due to cell switching.
- Application adaptive Physical Layer PER.
- Exploit multi-user diversity where applicable.

Notes

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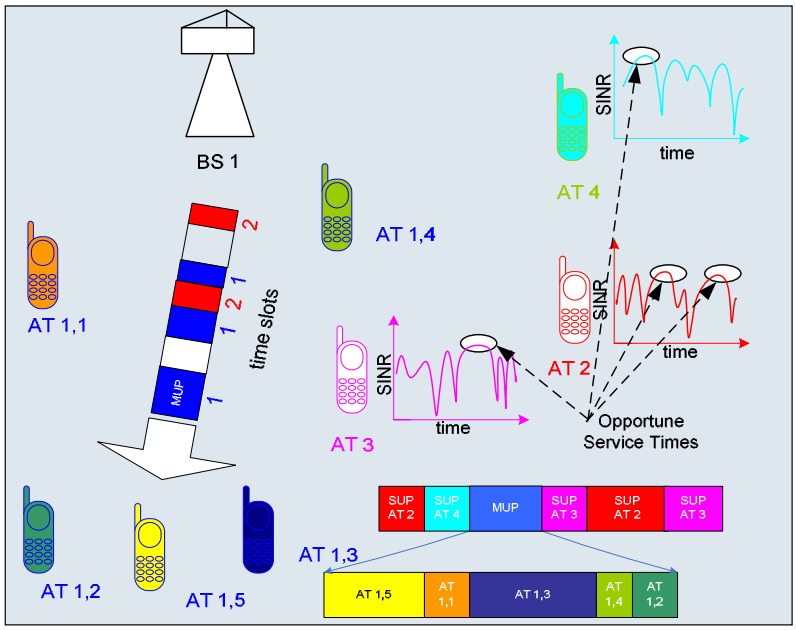
Forward Traffic Channel MAC – Packet Division Multiple Access

Packet Division Multiple Access (PDMA)

- TDM'd transmission and opportunistic scheduling under fairness constraints
- AN can serve multiple ATs within the same Physical Layer packet
- **Improved packing efficiency**
- **Improved latency performance**



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Forward Traffic Channel MAC – Seamless Server Selection

Release 0

- **Steps**
  - AT changes DRC cover to indicate serving sector/cell change.
  - "From cell" and "To cell" must detect change.
  - BSC performs queue transfer.
- **Outage**
  - AT cannot be served a new packet once BSC starts queue transfer.

Revision A

- DSC (Data Source Control) Channel provides early indication of cell switching instant to minimize (or eliminate) service outage for delay-sensitive flows.
- Since serving cell change instant is precisely known "From cell" knows exactly when to stop transmission and "To cell" knows exactly when to start transmission.

Notes

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Forward Traffic Channel MAC – Outage Reduction

Release 0

- Minimum data rate of 38.4 kbps.
- Larger outages for terminals in poor channel conditions, such as requested data rate less than 38.4 kbps.

Revision A

- Null-rate DRC conversion
  - Null-rate DRC indices are converted to DRC index = 1 (Nominal Rate = 38.4 kbps).
  - Required to minimize outage for terminals in poor channel conditions.
  - Following Null-rate DRC conversion, terminals in poor channel conditions can also be served using short packets.

Outage Reduction

DRC is the *Data Rate Control* that is sent from the terminal to indicate the current channel conditions.

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Forward Traffic Channel MAC – Application Adaptive Physical Layer PER

DRC Remapping/Translation

- Adds ARQ cycles (additional slots of transmissions) to a Physical Layer packet to reduce the effective Physical Layer PER
- Only 1% of packets in error require additional ARQ cycles
  - Requested DRC (called Transmitted DRC in IS-856A) is mapped from Predicted DRC (called Tentative DRC in IS-856A) as an extended packet version; no loss of throughput if a packet is early terminated.
- Minimal effect on system capacity
- DRC remapping is controlled by AN
  - Per access terminal
    - A function of the flow composition at the access terminal
  - Specified for every DRC value (rate)

Notes

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Reverse Traffic Channel MAC

- T2P Control versus Rate Control
- Intra-AT QoS
- Multi-flow Reverse Traffic Channel MAC with Token-bucket Based Access Control
- Sector Load Dependent T2P Allocation
- Flow-specific Short-term Sector Loading
- System Stability at High RoT Operation
- Latency Control
- Centralized Control
- Explicit Interference Control
- MAC Layer ARQ

Notes

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Reverse Traffic Channel MAC – T2P Control Versus Rate Control

1xEV-DO Release 0

- Rate used as an indicator of sector resource usage.
  - Rate is the measure of RoT contribution of an AT.
- No H-ARQ
  - One-one Rate to T2P mapping.
  - T2P constant for entire packet.
- No latency-capacity trade-off.

1xEV-DO Revision A

- T2P used as an indicator of sector resource usage.
  - T2P is a more accurate measure of RoT contribution of each flow.
- H-ARQ and different termination goals; no one-one mapping between Rate and T2P.
  - T2P is a function of latency target and payload size.
  - T2P may not be constant for entire packet.
  - For a fixed termination goal, T2P increases roughly linearly with flow transmission rate.
- T2P allocation to AT allows trade-off between capacity and latency.

Notes

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Reverse Traffic Channel MAC – Intra-AT QoS

1xEV-DO Release 0

- No Intra-User QoS.
- All packets transmitted in delay-tolerant mode.
- Performance of delay-sensitive flows may be affected by presence of delay-tolerant flows.

1xEV-DO Revision A

- Intra-User QoS support.
- Performance of delay-sensitive flows unaffected by presence of delay-tolerant flows.
  - Example: Concurrent “ping” and “File Transfer” at AT: “ping delay” is unaffected by presence of File Transfer.
  - Improved performance of bursty data sources.
- MAC flow priority is a function of the average resource (T2P) used by that flow.

A ***flow*** is a source with transmission requirements associated with an application, e.g., videotelephony, VoIP, gaming, Web-browsing, and file transfer.

Notes

Reverse Traffic Channel MAC with Token-based Access Control

- **Merging**
  - Rules for merging concurrent flows into a packet, depending on flow priorities and sector loading.
    - Merge flows with non-homogeneous latency targets if network is lightly loaded.
    - Merge a delay-tolerant flow with a delay-sensitive flow if the delay-tolerant flow has not transmitted within a specified time threshold.
  - Explicit AN control allows modifications.
- **AT power headroom**
  - Design philosophy: Unless PA headroom is limited, always allocate the assigned resources to all flows regardless of flow location.
  - If AT cannot support transmission of all flows concurrently due to PA headroom limitations, priority functions specify precise rules for arbitration among concurrent flows within an AT.

Notes

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Reverse Traffic Channel MAC – Sector Load Dependent T2P Allocation

1xEV-DO Revision A

- Filtered RA Bit (FRAB) provides a measure of sector loading.
- T2P Increase/Decrease functions are functions of sector loading. They allow:
  - Rapid ramping in lightly loaded sectors.
  - Smooth filling in of sector capacity.
  - Slower ramping as the sector load increases reduces RoT variation
    - Lesser impact on system stability
  - Decoupling of unloaded T2P ramping dynamics from loaded steady-state T2P dynamics.
- Effective sector loading of the most loaded sector in an access terminals Active Set.

Notes

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Reverse Traffic Channel MAC – Flow-specific Short-term Sector Loading

Effective sector loading of the most loaded sector in an access terminals Active Set

- **Release 0**
  - If effective sector loading = “busy,” ALL flows reduce their allocation.
  - Issues:
    - Active Set size is based on FL SINR (sectors with Forward link SINR > -9 dB may be in the Active Set).
    - ATs Reverse link load/interference contribution to some sectors in the Active Set may be negligible.

Notes

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Reverse Traffic Channel MAC – Flow-specific Short-term Sector Loading (continued)

- **Revision A**
  - Sector loading set is different for each MAC flow.
  - Use conservative approach (1xEV-DO Release 0) delay-tolerant flows.
  - Determine short-term sector loading for delay-sensitive flows.

Notes

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Reverse Traffic Channel MAC – System Stability at High RoT

Key factors to ensure stable CDMA system operation:

- **Control Access terminal data rates and overall sector load.**
  - 1xEV-DO Release 0
    - Closed-loop load control via direct RoT measurement.
    - With direct RoT measurement and closed-loop rate control, system stability can be achieved at higher RoT operating point than in a CDMA2000 system.
- **Pay attention to loop bandwidth**
  - 1xEV-DO Release 0: RAB is updated once every frame (26.66 ms).
    - If ROT operating point is too high, interference variations may lead to instability; can be minimized by using a conservative RoT operating point.
  - 1xEV-DO Revision A: RAB is updated once every slot (1.66 ms).
    - Permits a higher RoT operating point

Notes

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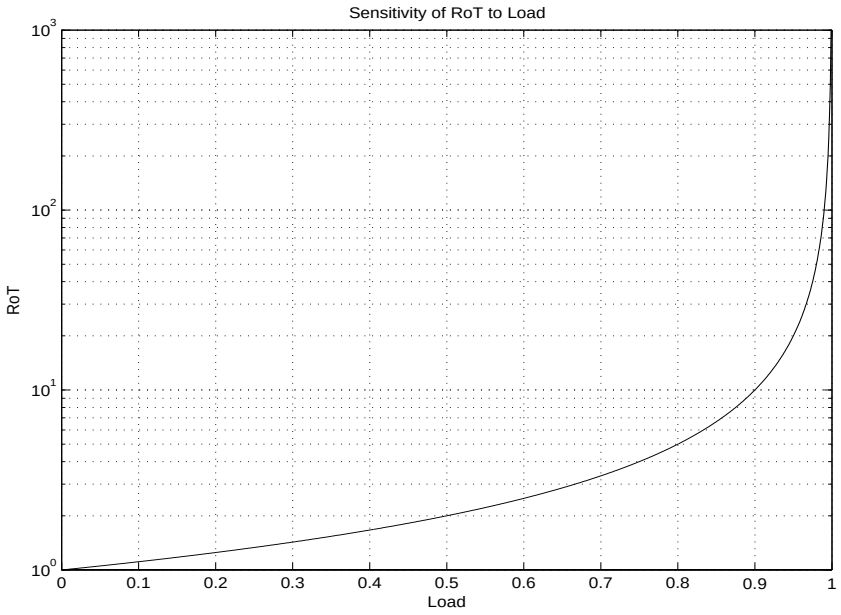
Reverse Traffic Channel MAC – System Stability at High RoT (continued)



System operation at high RoT may lead to instability in CDMA systems because changes in load at high operating points result in large variations in RoT.

Load changes can be caused by:

- **Terminal transmit power**
- **Channel variations**

Notes

Reverse Traffic Channel MAC – Latency Control

Packet selection for application flow based on delay requirement

- Data from **delay-sensitive** application flows typically is sent using Low Latency (LoLat) Transmission mode.
- Data from **delay-tolerant** application flows typically is sent using High Capacity (HiCap) Transmission mode.

Notes

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Reverse Traffic Channel MAC – Latency Control (continued)

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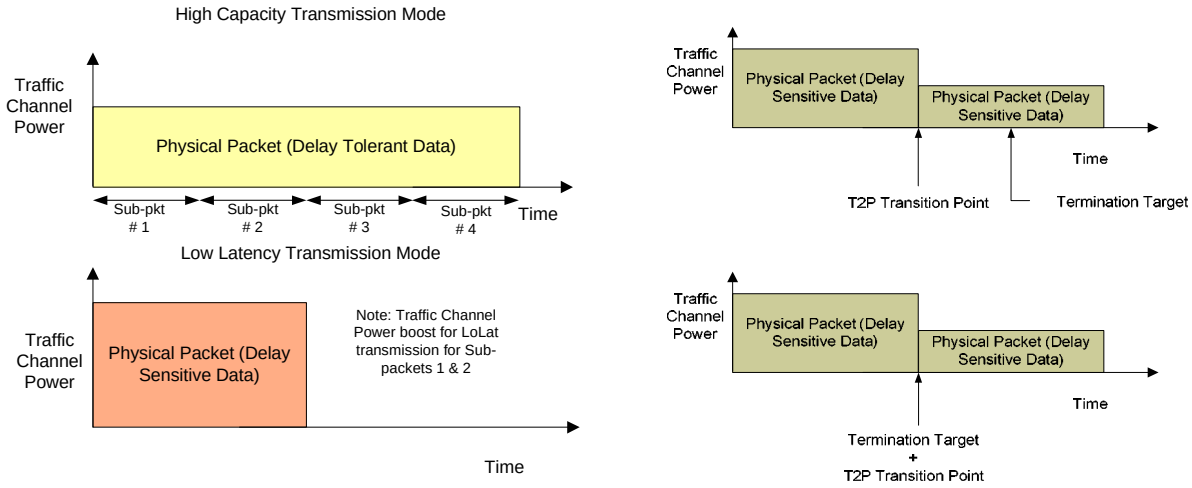

Sub-packets of a packet are depicted as contiguous for illustrative purposes only.
Sub-packet transmissions of a packet are separated by two sub-frames.

Notes

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Reverse Traffic Channel MAC – Centralized Control

AN can control performance of all flows belonging to an AT using the following tools:

1xEV-DO Release 0

- Rate transition probabilities
- RA-bit control
- Max allowed rate

1xEV-DO Revision A

- Per-flow priority functions based on FRAB and Forward Channel
- RA bit control
- Max allowed TxT2P
- Transmission mode
- Termination target per payload size for each transmission mode
- Per-flow RA-bit control parameters – sensitivity of a flow to sector loading
- Rules for conversion of HiCap flow to LoLat flow
- Peak rate transmission – allow or disallow peak rate transmission for ATs capable of transmitting at peak rate
- Explicit Request and Grant
- Interference control

Notes

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Reverse Traffic Channel MAC – Explicit Interference Control

IS-856 provides the following explicit interference control mechanisms to the AN:

1xEV-DO Release 0

- BroadcastRateLimit message
- Unicast RateLimit message

1xEV-DO Revision A

- TxT2Pmax attribute
- PermittedPayload attribute
  - Payload size transmitted in sub-frame n is a function of the minimum of payload sizes transmitted in sub-frames n-1, n-2, and n-3
- T2PInflow scaling

Notes

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Reverse Traffic Channel MAC – Explicit Interference Control (continued)

Reverse Link Rate Shaping

- Can **reduce adjacent sector interference** by reducing priority of flows at cell edge
  - Preferential sharing of air link resources
- Achieved by **adjusting T2P Increase/Decrease** based on Forward link Pilot strength
  - Pilot strength is mapped to a shift in effective T2P allocation.
  - Mapping is specified for each flow.
  - High-priority flows may not be shifted.
- **Benefits:**
  - Improved AN control over AT performance
  - Improved sector performance (degraded performance for ATs in poor channel conditions)

Notes

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Reverse Traffic Channel MAC – MAC Layer ARQ

Used in addition to Physical Layer ARQ

- Contents of retransmitted packets may be different
- Retransmitted packets not soft-combined with original packet
- Applicable only to packets transmitted in HiCap mode

Mechanism:

- AN indicates erased Physical Layer packets to the AT
- AT may re-transmit packets prior to higher layer detection

Gains:

- Improved Application layer performance due to lower erasure rate of upper layer
- Ping round-trip delay improvement

Notes

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IS-856-A Specification

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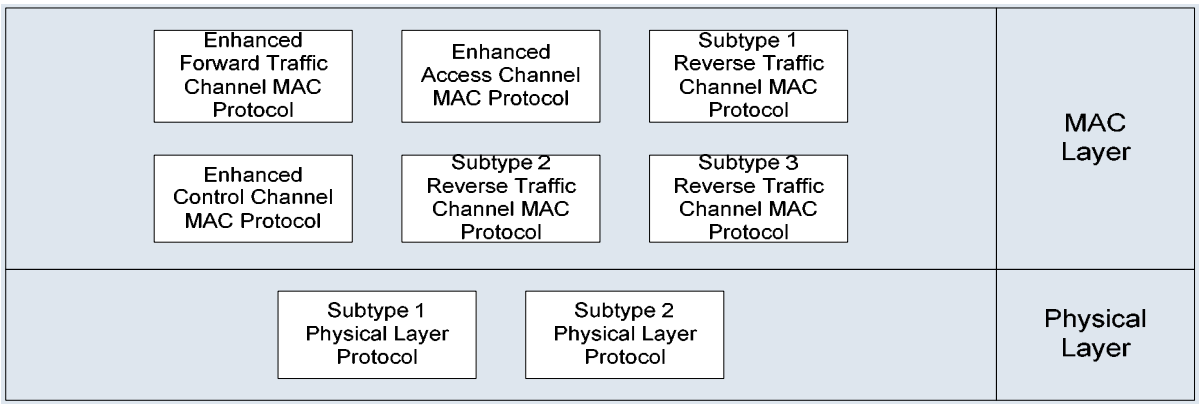

Notes

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Organization of the Standard

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New Physical Layer Protocols

- Subtype 1 Physical Layer Protocol
  - IS-856-Release 0 Physical Layer
  - Support for Enhanced Access Channel MAC Protocol
- Subtype 2 Physical Layer Protocol
  - IS-856-Revision A Physical Layer

Notes

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Organization of the Standard (continued)

MAC Layer and Physical Layer Protocol Dependencies

- Enhanced (Subtype 1) Control Channel MAC Protocol requires
  - Subtype 2 Physical Layer Protocol
- Enhanced (Subtype 1) Forward Traffic Channel MAC Protocol requires
  - Subtype 2 Physical Layer Protocol
- Enhanced (Subtype 1) Access Channel MAC Protocol requires
  - Subtype 2 Physical Layer Protocol OR
  - Subtype 1 Physical Layer Protocol
- Subtype 3 Reverse Traffic Channel MAC Protocol requires
  - Subtype 2 Physical Layer Protocol

Notes

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IS-856-Revision A Specification – Protocol List

- **Physical Layer**
  - Default (Subtype 0) Physical Layer Protocol
    - IS-856-Release 0 Physical Layer
  - Subtype 1 Physical Layer Protocol
  - Subtype 2 Physical Layer Protocol
- **MAC Layer**
  - Default (Subtype 0) Control Channel MAC Protocol
    - IS-856-Release 0 Control Channel MAC Protocol
  - Enhanced (Subtype 1) Control Channel MAC Protocol
    - Default Control Channel MAC Protocol + Short packet Sub-sync CC
  - Default (Subtype 0) Access Channel MAC Protocol
    - IS-856-Release 0 Access Channel MAC Protocol
  - Enhanced (Subtype 1) Access Channel MAC Protocol
    - Default Access Channel MAC Protocol + Higher Rate Access Channel

Notes

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IS-856-Revision A Specification – MAC Layer

- Subtype 0
  - IS-856-Release 0 Reverse Traffic Channel MAC Protocol
  - Default Physical Layer
- Subtype 1
  - Default Reverse Traffic Channel MAC
  - Subtype 0 and Subtype 1 Physical Layer
  - Transition Probabilities can be changed during a session
- Subtype 2
  - IS-856-Revision A Reverse Traffic Channel MAC
  - Subtype 0 and Subtype 1 Physical Layer
- Subtype 3
  - IS-856-Revision A Reverse Traffic Channel MAC
  - Subtype 2 Physical Layer Protocol

Notes

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Physical Layer Channels – Reverse Link

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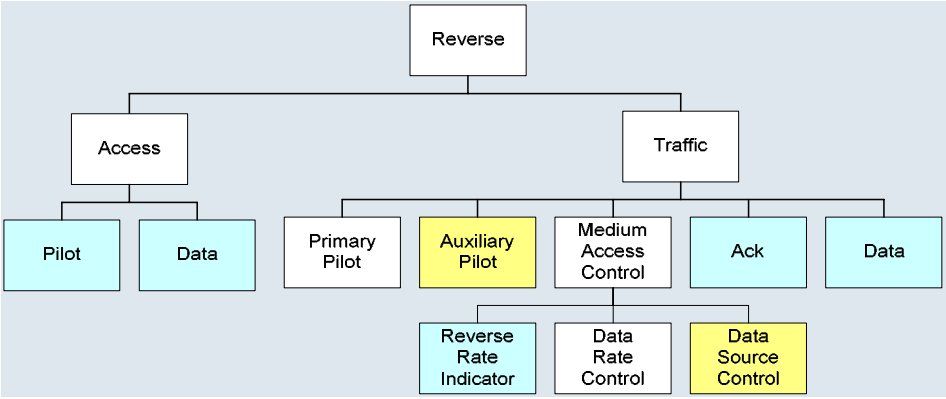

New channels in IS-856 Revision A (shown in yellow)

- Auxiliary Pilot Channel
- Data Source Control (DSC) Channel

Modified channels in IS-856 Revision A (shown in blue)

- RRI
- ACK
- Data (Preamble + Traffic)
- Pilot (Preamble)

Notes

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1xEV-DO Overview – What We Learned

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- The 1xEV-DO timeline and roadmap.
- EV-DO Revision A enhancements.
- Further information.

Notes

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References

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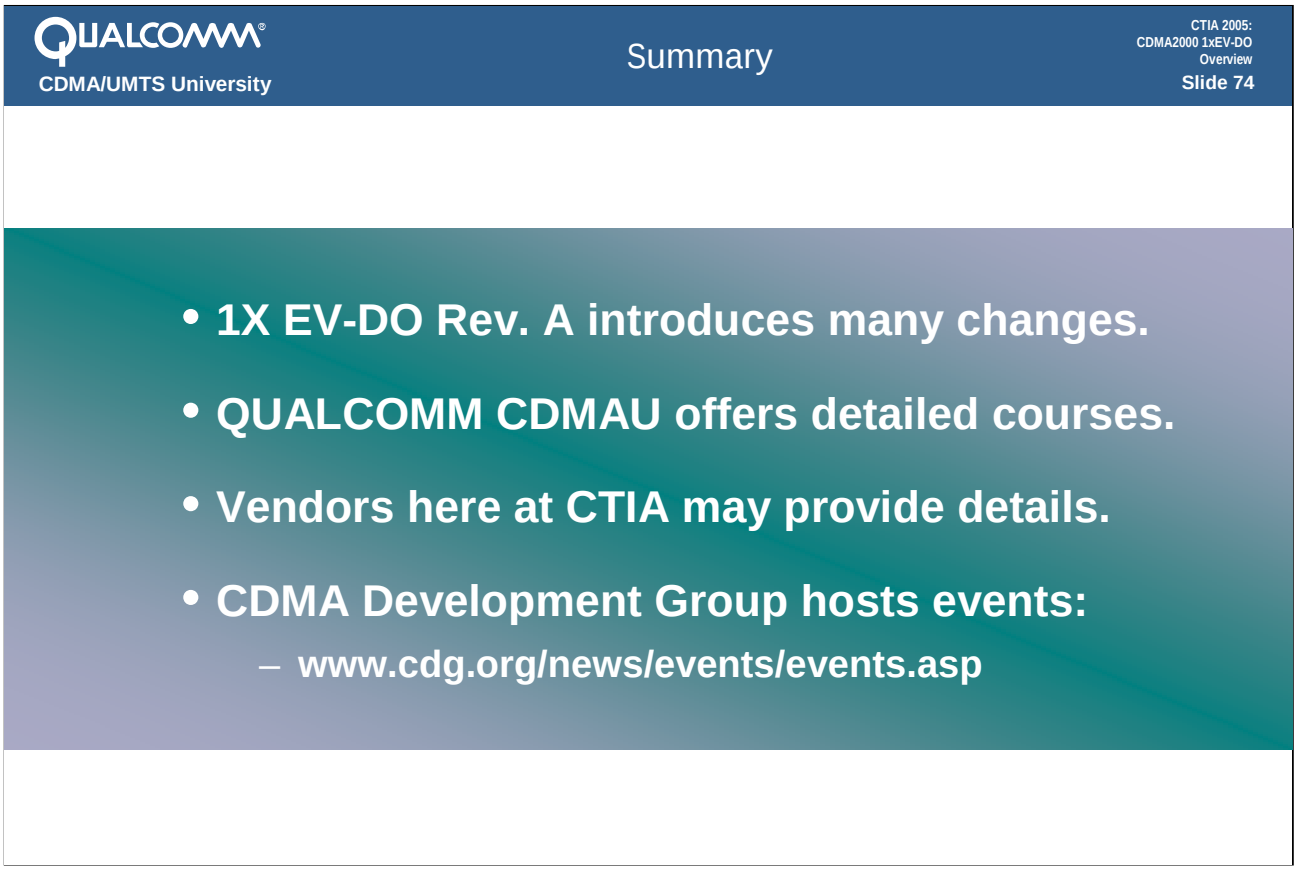

Summary

Several interesting presentations available at:

www.cdg.org/news/events/CDMASeminar/050208_VoIP_Summit/index.asp