QUALCOMM®
cdma university

CDMA2000 1x
RC1 & RC2

CDMA2000 1x RC1 & RC2

Student Guide

80-31566-1 Rev C

QUALCOMM®

Material Use Restrictions

QUALCOMM Incorporated
5775 Morehouse Drive
San Diego, CA 92121
U.S.A.

QUALCOMM cdma university | CDMA.HELP | CDMA2000 1x RC1 & RC2

CDMA.HELP@QUALCOMM.COM

- Email hotline resource to assist our CDMA customers worldwide.
- Experienced CDMA engineers in our Engineering Services Group will answer your technical questions on topics including:

  - –Industry Standards
  - –Infrastructure Design
  - –Voice Quality
  - –System Design
  - –Network Planning
  - –Network Optimization
  - –Test Engineering
  - –Training

This page left blank intentionally.

Table of Contents

Acronyms and Abbreviations xv
Course Overview 1-1

Section 1: CDMA2000 1x RC1 & RC2 Introduction 1-3
Section Introduction 1-4
Section Learning Objectives 1-5
Reference Documentation 1-6
Multiple Access Methods 1-7
Overview of CDMA 1-9
CDMA2000 1-10
TIA/EIA-95 1-11
The 2000 Family of Standards 1-12
CDMA2000 Physical Layer 1-13
Spreading Rate 1 and Spreading Rate 3 1-14
Radio Configurations 1-15
    Forward Link 1-16
    Reverse Link 1-17
Where are the Standards? 1-18
Questions? 1-19
What We Learned in This Section 1-20
RC1 & RC2 Introduction – Review 1-21

Section 2: Design Considerations 2-1
Section Introduction 2-2
Section Learning Objectives 2-3
Wireless Architecture 2-4
The Mobile Radio Channel
    Fading 2-5
    Flat Fading and Frequency Selective Fading 2-6
    Multipath-Associated Problems: Flat Fading 2-7
System Requirements 2-8
Frequency Reuse
    FDMA and TDMA Systems 2-9
    Reuse Pattern of 7 2-10
    CDMA 2-11
Frequency Allocations
    Analog System Constraints 2-12
    U.S. PCS Allocations 2-13
The PCS CDMA Channel 2-14
Power Control
    Effective Power Control is Required 2-16
    Solutions to Maximize Capacity 2-17
    Small Scale Path Loss: Fast Fading 2-18
    From the Reverse Link 2-19

Soft Handoffs 2-20
Multipaths 2-21
Mobile Rake Receiver 2-23
Variable Rate Vocoder 2-24
Spread Spectrum Techniques
Frequency Hopped Spread Spectrum 2-25
Direct Sequence Spread Spectrum 2-26
View of the CDMA Concept 2-27
Capacity – Reverse Capacity Estimate 2-29
What We Learned in This Section 2-31
Design Considerations – Review 2-32

Section 3: Codes in CDMA 3-1
Section Introduction 3-2
Section Learning Objectives 3-3
Code Basics
AND Function 3-4
XOR Function 3-5
Correlation 3-6
Orthogonal Sequences
Orthogonal Functions 3-7
Generating Orthogonal Codes 3-8
Walsh Codes 3-9
Orthogonal Spreading 3-10
Channelization Using Orthogonal Spreading 3-11
Recovery of Spread Symbols 3-12
Recovery of Spread Symbols using Wrong Function 3-13
Example of Spreading with Three Users 3-14
Despreading Example 3-15
Walsh Usage 3-16
Walsh Space 3-17
PN Codes 3-18
PN Balance 3-19
One-Zero Distribution 3-20
Code Isolation 3-21
Generation 3-22
Masking 3-24
Autocorrelation of a PN Code 3-26
Short and Long 3-27
Short PN 3-28
Chips vs. Distance 3-29
Search Windows 3-30
What We Learned in This Section 3-31
Codes in CDMA – Review 3-32

Section 4: CDMA Physical Layer 4-1
Section Introduction 4-2
Section Learning Objectives 4-3
CDMA Overview & Terminology – Bits, Symbols, and Chips 4-4
CDMA2000 Spreading Rate 1 and Spreading Rate 3 4-6
CDMA2000 Frequency Allocations 4-7
Band Classes 4-8
Band Class 0 and Spreading Rate 1 4-9
Band Class 0 and Spreading Rate 3 4-10
Band Class 0 Preferred Channels 4-11
Band Class 1 and Spreading Rate 1 4-12
Band Class 1 and Spreading Rate 3 4-13
CDMA2000 Physical Layer 4-14
RC1 and RC2 4-15
CDMA2000 Channels
Logical Channel Naming 4-16
Physical Channel Naming 4-17
Logical-to-Physical Channel Mapping 4-18
FL Physical Layer Changes for RC>2 4-19
Dedicated Channels and Standard Services 4-21
Radio Configurations 4-22
Forward Link Radio Configurations 4-23
Reverse Link Radio Configurations 4-24
Forward CDMA Code Channels for RC1 and RC2 4-25
Backward Compatible Forward Link Code Channels 4-26
New Forward Link Common Channels 4-27
New Forward Link Dedicated Channels 4-28
Pilot Channel Generation 4-29
Pilot Demodulation 4-30
Forward Traffic Channel Generation
Quadrature Spreading 4-31
Filtering and Up Conversion 4-32
1x Filter Mask 4-33
Transmitter Filter 4-34
Sync Channel Generation 4-35
Paging Channel Generation 4-36
Paging Channel Long Code Mask 4-37
Rate Set 1 Vocoder Frame Format 4-38
Rate Set 2 Vocoder Frame Format 4-39
Channel Overview 4-40
Rate Set 1 Symbol Repetition 4-41
Rate Set 2 Symbol Repetition 4-42
Symbol Repetition 4-43
Convolutional Coding 4-44
Rate ½ Coding 4-45
Rate 3/4 Coding (Rate Set 2) 4-46

Coding Gain 4-47
Interleaving 4-48
Interleaver 4-49
Interleaving at Full Rate........ 4-50
Scrambling the Signal 4-51
Signal Scrambled Using the Long Code 4-52
Data Scrambling Decimator........ 4-53
Puncturing the Power Control Sub-Channel........ 4-54
Puncturing the Power Control Bits 4-55
Orthogonal Spreading 4-56
PN Offset Cell Identification 4-57
Forward CDMA Channel I & Q Mapping........ 4-58
Forward CDMA Channel Demodulation 4-59
Reverse Link Characteristics
RC1 and RC2 4-60
RC>2 4-61
Reverse Traffic Channel Generation
RC1 and RC2 4-63
Reverse Channel Separation 4-64
System Time Line 4-65
Reverse Link Code Channels........ 4-66
Reverse Common and Dedicated Channels........ 4-67
Convolutional Coding........ 4-68
Rate 1/3 Encoding........ 4-69
Interleaving 4-70
Orthogonal Modulation........ 4-71
Walsh Lookup Table........ 4-72
Data Burst Randomizer........ 4-73
Pseudorandom Selection of Power Control Groups 4-74
Direct Sequence Spreading........ 4-75
Reverse Traffic Channel Mask 4-76
Quadrature Spreading 4-77
Filtering and Up Conversion........ 4-78
Access Channel Generation........ 4-79
Access Channel Long Code Mask 4-80
Reverse CDMA Channel Demodulation 4-81
Medium Data Rate Option
Overview........ 4-82
Fundamental, Supplemental Code Channels 4-83
Code Channel Summary 4-84
Forward/Reverse Multi-Channel Spreading 4-85
Data Channels for RC>2........ 4-86
What We Learned in This Section........ 4-87
CDMA Physical Layer – Review 4-88

Section 5: Power Control... 5-1
Section Introduction.. 5-2
Section Learning Objectives 5-3
Characteristics of the Architecture
Forward Link 5-4
Reverse Link 5-5
Power Control Requirements... 5-6
The Design Choice
Closed Loop Power Control.. 5-8
TIA/95-A/B vs. CDMA2000 RL Power Control.................................... 5-9
Power Control in CDMA2000 5-10
Reverse Power Control
Reverse Open Loop Process 5-11
Open Loop Equation.. 5-12
Mobile Access Channel Modes 5-13
Common Channels... 5-14
Access Probes 5-15
Open Loop Response Time.. 5-16
Open Loop Power Control in TIA/EIA-95 5-17
Open Loop Interference Correction 5-18
Fast Reverse Closed Loop Power Control 5-19
Mobile Transmits Bursts.. 5-20
Puncturing the Power Control Bits 5-21
Pseudorandom Bit Placement 5-22
Impact on Apparent Voice Activity.. 5-23
Reverse Link Interference.. 5-24
Typical Closed Loop Histogram.. 5-25
Power Control Response.. 5-26
Power Control During Soft Handoff... 5-27
Reverse Outer Loop Power Control.. 5-28
Inner Loop... 5-29
Outer Loop 5-30
Minimum Transmit Power... 5-31
CDMA2000 Data Flow.. 5-32
Forward Power Control
Process 5-33
Rate Set 1 5-34
Rate Set 2 5-35
Forward Link Closed Loop Methods.. 5-36
CDMA2000 Data Flow.. 5-37
Malfunction Control.. 5-38
What We Learned in This Section 5-40
Power Control – Review.. 5-41

Section 6: Call Processing 6-1
Section Introduction 6-2
Section Learning Objectives 6-3
Call Processing Overview
States 6-4
Block Diagram of Call Processing 6-5
Initialization State
Part 1 6-6
Part 2 6-7
System Determination 6-8
Pilot Channel Processing 6-9
Sync Channel Frame 6-10
Sync Channel (F-SYNCH) Structure 6-11
Sync Channel Message 6-12
Sync Channel Timing 6-16
Sync Channel Example 6-17
Sync Channel Message for Release 0 6-18
Sync Channel Rel A 6-19
Mobile Idle State
Idle State Functions 6-20
Protocol Revisions in Cellular & PCS Bands 6-21
Paging Channel Frames 6-22
Paging Channel Overhead Messages 6-23
CDMA2000 Overhead Messages 6-24
Paging Channel Structure 6-25
Slotted Paging 6-26
Paging Slot Determination 6-27
Slotted and Quick Paging 6-28
System Parameters Message 6-29
System Parameters Example 6-30
Extended System Parameters Message 6-31
Access Parameters Message 6-32
Access Parameters Example 6-33
Neighbor List Message 6-34
Neighbor List Example 6-35
Extended Neighbor List 6-36
CDMA Channel List Message 6-37
Channel List Example 6-38
Paging Channel Messages 6-39
Channel Assignment Message 6-40
Traffic Channel State – ASSIGN_MODE Variations 6-41
Mobile Idle State – Assignment Example 6-42
Mobile System Access State
Flow Diagram 6-43
Access Channel Procedures 6-44

Access Channel Frames 6-45
Access Channel Structure 6-46
Access Channel (R-ACH) Procedures 6-47
Access Procedure 6-49
Access Channel Parameters 6-50
Access Channel Failure Mechanisms 6-51
Traffic Channel State
Substates 6-52
Traffic Channel Message Structure 6-53
Multiplex Option 2 6-54
Forward Traffic Channel Messages 6-55
Reverse Traffic Channel Messages 6-56
Mobile Station Origination Example 6-57
Origination Example 6-58
Service Connect Message Example 6-59
Failure Mechanisms 6-60
Mobile Acknowledgment Failure 6-61
Mobile Fade Timer 6-62
Mobile Bad Frames 6-63
What We Learned in This Section 6-64
Call Processing – Review 6-65
Call Processing Example (Sample Log File) 6-67

Section 7: Handoffs 7-1
Section Introduction 7-2
Section Learning Objectives 7-3
Types of CDMA Handoffs
Overview 7-4
Multi-Cell "Soft" Handoff 7-5
Multi-Cell "Softer" Handoff 7-6
Multi-Cell/Multi-Sector Handoff 7-7
Soft Handoff Gain 7-8
Soft Handoff Increases Capacity 7-9
The Pilot Searching Process 7-10
Pilot Sets 7-11
Searcher Window Sizes 7-12
Multipath Arrivals 7-13
Handoff Signaling 7-14
Regulating Parameters 7-15
The Comparison Threshold 7-16
Handoff Drop Timer Expiration Values 7-17
Pilot Strength Measurement Message 7-18
PSMM Example 7-19
Extended Handoff Direction Message 7-20
Handoff Direction Message Example 7-21

Handoff Completion Message 7-22
Handoff Completion Example 7-23
Transitioning Between Pilot Sets 7-24
Moving Pilots from the Active Set 7-25
Moving Pilots from the Candidate Set 7-26
Moving Pilots from the Neighbor Set 7-27
Moving Pilots from the Remaining Set 7-28
Call Processing During Handoff 7-29
TIA/EIA-95B Unnecessary Handoff 7-30
TIA/EIA-95B Necessary Handoff 7-31
Dynamic T_ADD 7-32
Dynamic T_DROP 7-33
Adding a Pilot to the Active Set 7-34
Call Processing During Handoff
Soft Handoff Comparison 7-35
CDMA to Analog Hard Handoff 7-36
Intersystem Hard Handoff 7-37
Frame-Offset Hard Handoffs 7-38
Frequency Change Hard Handoffs 7-39
Hard Handoff Techniques 7-41
Pilot Beacons 7-42
Hard Handoff Performance 7-43
Improved Inter-Frequency Hard Handoff 7-44
New Inter-Frequency HHO Messages 7-45
Inter-Frequency Handoff Failure Recovery 7-46
Power Control 7-48
Single/Periodic Search 7-50
Periodic Search with Receive Thresholds 7-51
Inter-Frequency Handoff Call Flow 7-52
Idle Handoff Region 7-53
Call Set Up 7-55
Access Handoffs
IS-95A Text on Handoffs During Access 7-56
Challenges 7-57
TIA/EIA-95 Changes 7-58
Access Entry Handoff 7-59
Access Probe Handoff 7-60
Access Handoff 7-61
Summary of Handoffs During Access 7-62
Extended System Parameters Message 7-63
Channel Assignment into Soft Handoff 7-64
What We Learned in This Section 7-65
Handoffs – Review 7-66

Section 8: Registration 8-1
Section Introduction 8-2
Section Learning Objectives 8-3
Registration Overview
Registration Updates a Database 8-4
The Registration Message 8-5
Systems and Networks 8-6
Roaming
Determining Roaming States 8-7
The Mobile's "Home" 8-8
Roaming Status 8-9
Types of Registrations
TIA/EIA-95 8-10
CDMA2000 8-11
Autonomous Methods 8-12
Non-Autonomous Methods 8-13
Non-Autonomous: Request Order 8-14
Non-Autonomous: Parameter Change 8-15
Non-Autonomous: Implicit 8-17
The Origination Message 8-18
Mobile on a System Boundary 8-19
System Parameters Message 8-21
Registration Parameters
Access Parameters Message 8-22
Access Probing 8-23
Mobile Parameters 8-24
Authentication 8-25
Global Challenge 8-26
Unique Challenge-Response 8-27
Updating the SSD 8-28
Encryption 8-29
Cellular Message Encryption Algorithm 8-30
Voice Privacy 8-31
What We Learned in This Section 8-32
Registration – Review 8-33

Section 9: Course Summary 9-1
What We Learned
Section 1: Course Introduction 9-3
Section 2: Design Considerations 9-4
Section 3: Codes in CDMA 9-5
Section 4: CDMA Physical Layer 9-6
Section 5: Power Control 9-7
Section 6: Call Processing 9-8
Section 7: Handoffs 9-9
Section 8: Registration 9-10

This page left blank intentionally.

Acronyms and Abbreviations

2G	Second Generation
3G	Third Generation
AAA	Authentication, Authorization, and Accounting
AC	Authentication Center
ACH	Access Channel
ACK	Acknowledgement
A/D	Analog-to-Digital
AFC	Automatic Frequency Control
ALI	Automatic Location Information
AMPS	Advanced Mobile Phone Service
ANI	Automatic Number Identification
ANSI	American National Standards Institute
AOA	Angle of Arrival
ARQ	Automatic Repeat Request
ASIC	Application Specific Integrated Circuit
ATIS	Alliance for Telecommunications Industry Solutions
ATM	Asynchronous Transfer Mode
AUX	Auxiliary Equipment
AWGN	Additive White Gaussian Noise
BA	Basic Access
BCCH	Broadcast Control Channel
BER	Bit Error Rate
bps	Bits Per Second
BPSK	Binary Phase Shift Keying
BS	Base Station
BSC	Base Station Controller
BSMAP	Base Station Management Application Part
BSS	Base Station Subsystem
BTS	Base station Transceiver Subsystem
C/A	Clear/Acquisition
CDG	CDMA Development Group
CDGIOS	CDG Interoperability Specification
CDMA	Code Division Multiple Access
C/N	Carrier-to-Noise
COA	Care of Address
COST	Cooperation in the Field of Scientific and Technical Research
CRC	Cyclic Redundancy Code
CTIA	Cellular Telecommunications Industry Association
dB	Decibel
dBm	Decibel referenced to 1 milliwatt
DCCH	Dedicated Control Channel
DCE	Data Communications Equipment
DECT	Digital European Cordless Telecommunication

DMH	Data Message Handler
DN	Directory Number
DTAP	Direct Transfer Application Part
DTMF	Dual Tone Multi-Frequency
DTX	Discontinuous Transmission Mode
E-911	Enhanced 911
EACAM	Early Acknowledgement Channel Assignment Message
ECAM	Extended Channel Assignment Message
EDGE	Enhanced Data Services for Global Evolution
EIA	Electronic Industries Association
EIB	Erasure Indicator Bit
EIRP	Effective Isotropic Radiated Power
E-OTD	Enhanced Observed Time Difference
ERP	Effective Radiated Power
ESN	Electronic Serial Number
EVRC	Enhanced Variable Rate Codec
F-APICH	Forward Auxiliary Pilot Channel
F-ATDPICH	Forward Auxiliary Transmit Diversity Pilot Channel
F-BCCH	Forward Broadcast Control Channel
F-CACH	Forward Common Assignment Channel
FCC	Federal Communications Commission
F-CCCH	Forward Common Control Channel
FCH	Fundamental Channel
F-CPCCH	Forward Common Power Control Channel
F-CPCSH	Forward Common Power Control Subchannel
f-csch	Forward Common Signaling Channel
F-DCCH	Forward Dedicated Control Channel
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
F-DPHCH	Forward Dedicated Physical Channel
f-dsch	Forward Dedicated Signaling Channel
f-dtch	Forward Dedicated Traffic Channel
FEC	Forward Error Correction
FER	Frame Error Rate
F-FCH	Forward Fundamental Channel
FHT	Fast Hadamard Transform
FIR	Finite Impulse Response
FL	Forward Link
FLT	Forward Link Triangulation
FM	Frequency Modulation
F-PCH	Forward Paging Channel
F-PICH	Forward Pilot Channel

F-QPCH	Forward Quick Paging Channel
F-SCCH	Forward Supplemental Code Channel
F-SCCHT	Forward Supplemental Code Channel Type
F-SCH	Forward Supplemental Channel
F-SCHT	Forward Supplemental Channel Type
F-SYNC	Forward Sync Channel
F-TDPICH	Forward Transmit Diversity Pilot Channel
GHz	Gigahertz
GSM	Global System for Mobile Communications
GPRS	General Packet Radio System
GPS	Global Positioning System
HA	Home Agent
HCS	Hierarchical Cell Structure
HDR	High Data Rate
HHO	Hard Handoff
HLR	Home Location Register
HO	Handoff
PSK	Hybrid Phase Shift Keying
HSCSD	High-Speed Circuit Switched Data
HSD	High-Speed Data
Hz	Hertz
ID	Identification
IEEE	Institute of Electrical and Electronic Engineers
IMSI	International Mobile Susbcriber Identity
IMT	International Mobile Telecommunications
I and Q	In-Phase and Quadrature
IP	Internet Protocol
IS	Interim Standard
ISDN	Integrated Services Digital Network
ISO	International Standards Organization
ISP	Internet Service Provider
ITU	International Telecommunications Union
IWF	Inter-Working Function
kbps	Kilobits Per Second
kcps	Kilochips Per Second
km	Kilometer
ksps	Kilosymbols Per Second
LAC	Link Access Control
LAN	Local Area Network
LOS	Line of Sight
LTU	Logical Transmission Unit
m	Meter
MABO	Mobile Assisted Burst Operation
MAC	Medium Access Control

MAP	Mobile Application Part
Mbps	Megabits Per Second
MC	Multicarrier
Mcps	Megachips Per Second
MDR	Medium Data Rate
MF	Multifrequency
MHz	Megahertz
MIN	Mobile Identification Number
MPEG	Motion Picture Expert Group
mph	Miles Per Hour
ms	Milliseconds
MS	Mobile Station
MSM	Mobile Station Modem
MSC	Mobile Switching Center
MT	Mobile Terminal
MUD	Multi-User Detection
µs	Microsecond
Mux	Multiplex
MuxPDU	Multiplex Protocol Data Unit
NID	Network Identification
NLOS	Non-Line of Sight
NMT	Nordic Mobile Telephone
ns	Nanoseconds
OFDM	Orthogonal Frequency Division Multiplexing
OHG	Operator Harmonization Group
OS	Operating System
OSI	Open Systems Interconnection
OTASP	Over the Air Service Provision
OTD	Orthogonal Transmit Diversity, Observed Time Difference
PACA	Priority Access and Channel Assignment
PC	Personal Computer, Power Control
PCCAM	Power Control Channel Assignment Message
PCF	Packet Control Function
PCH	Paging Channel
PCS	Personal Communications System
PD	Persistence Delay
PDA	Personal Digital Assistant
PDC	Personal Digital Cellular
PDE	Position Determination Equipment
PDSN	Packet Data Service Node
PDU	Protocol Data Unit
PHS	Personal Handset System
PIN	Personal Identification Number

PLMN	Public Land Mobile Network
PMRM	Power Measurement Report Message
PN	Pseudorandom Noise
PPP	Point-to-Point Protocol
PSAP	Public Safety Answering Point
PSPDN	Packet Switched Public Data Network
PSMM	Pilot Strength Measurement Message
PSTN	Public Switched Telephone Network
QIB	Quality Indicator Bit
QOF	Quasi-Orthogonal Functions
QoS	Quality of Service
QPCH	Quick Paging Channel
QPSK	Quadrature Phase Shift Keying
RA	Reservation Access
R-ACH	Reverse Access Channel
RAND	Random Challenge Data
RC	Radio Configuration
R-CCCH	Reverse Common Control Channel
R-CPHCH	Reverse Common Physical Channel
r-csch	Reverse Common Signaling Channel
R-DCCH	Reverse Dedicated Control Channel
R-DPHCH	Reverse Dedicated Physical Channel
r-dsch	Reverse Dedicated Signaling Channel
r-dtch	Reverse Dedicated Traffic Channel
R-EACH	Reverse Enhanced Access Channel
RF	Radio Frequency
R-FCH	Reverse Fundamental Channel
RLP	Radio Link Protocol
R-PICH	Reverse Pilot Channel
R-SCCH	Reverse Supplemental Code Channel
R-SCCHT	Reverse Supplemental Code Channel Type
R-SCH	Reverse Supplemental Channel
R-SCHT	Reverse Supplemental Channel Type
RL	Reverse Link
RLP	Radio Link Protocol
rms	Root Mean Square
R-PICH	Reverse Pilot Channel
RRC	Radio Resources Control
RSSI	Received Signal Strength Indicator
Rx	Receive
SAP	Service Access Point
SAR	Segmentation and Reassembly
SCCH	Supplemental Code Channel
SCH	Supplemental Channel

SCI	Synchronized Capsule Indicator, Slot Cycle Index
SDU	Service Data Unit
sec	Second
SHO	Soft Handoff
SI	Segmentation Indicator
SID	Systems Identification
SMR	Specialized Mobile Radio
SMS	Short Message Service
S/N	Signal-to-Noise
SNR	Signal to Noise Ratio
SOM	Start of Message
SR	Spreading Rate
SRBP	Signaling Radio Burst Protocol
SS7	Signaling System 7
SSD	Shared Secret Data
STS	Space Time Spreading
TACS	Total Access Communications System
TD	Transmit Diversity
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TD-SCDMA	Time Division Synchronous Code Division Multiple Access
TE	Terminal Equipment
TIA	Telecommunications Industry Association
TIQ	Telrate International Quotations
TOA	Time of Arrival
TSB	Telecommunications System Bulletin
Tx	Transmit
UDP	User Datagram Protocol
UMTS	Universal Mobile Telecommunications System
UTRA	UMTS Terrestrial Radio Access
UWCC	Universal Wireless Communications Consortium
V	Volt
VLR	Visitor Location Register
VPM	Voice Privacy Mask
VPN	Virtual Private Network
WAP	Wireless Application Protocol
W-CDMA	Wideband Code Division Multiple Access
WPT	Wireless Personal Terminal
W/R	Bandwidth-to-Data Rate
WWW	World Wide Web

QUALCOMM cdma university

CDMA2000 1x RC1 & RC2 – Course Overview

1) Introduction
2) Design Considerations
3) Codes in CDMA
4) CDMA Physical Layer
5) Power Control
6) Call Processing
7) Handoffs
8) Registration

Section 1: Introduction

Provides an overview of the entire course as well as the overall learning objectives for each section.

Section 2: Design Considerations

Describes the factors that were considered when designing the CDMA waveforms, protocols, and algorithms. Key factors include the characteristics of the channel and user requirements.

Section 3: Codes in CDMA

Describes the codes used in generating the CDMAOne signals. Also defines and discusses Pseudorandom Noise codes and orthogonal (Walsh) codes.

Section 4: CDMA Physical Layer

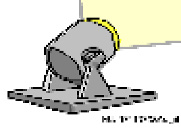
Describes the processes involved in the generation of the Forward link and Reverse link CDMA waveforms.

QUALCOMM cdma university

CDMA2000 1x RC1 & RC2 – Course Overview (continued)

CDMA2000 1x RC1 & RC2 Section 1-2

1) Introduction
2) Design Considerations
3) Codes in CDMA
4) CDMA Physical Layer
5) Power Control
6) Call Processing
7) Handoffs
8) Registration



Section 5: Power Control

Describes the operation of Open and Closed Loop Power Control for the Reverse link, and the slow Forward Power Control available on the Forward link for RC1 and RC2. Introduces the new Forward link modes for RC>2.

Section 6: Call Processing

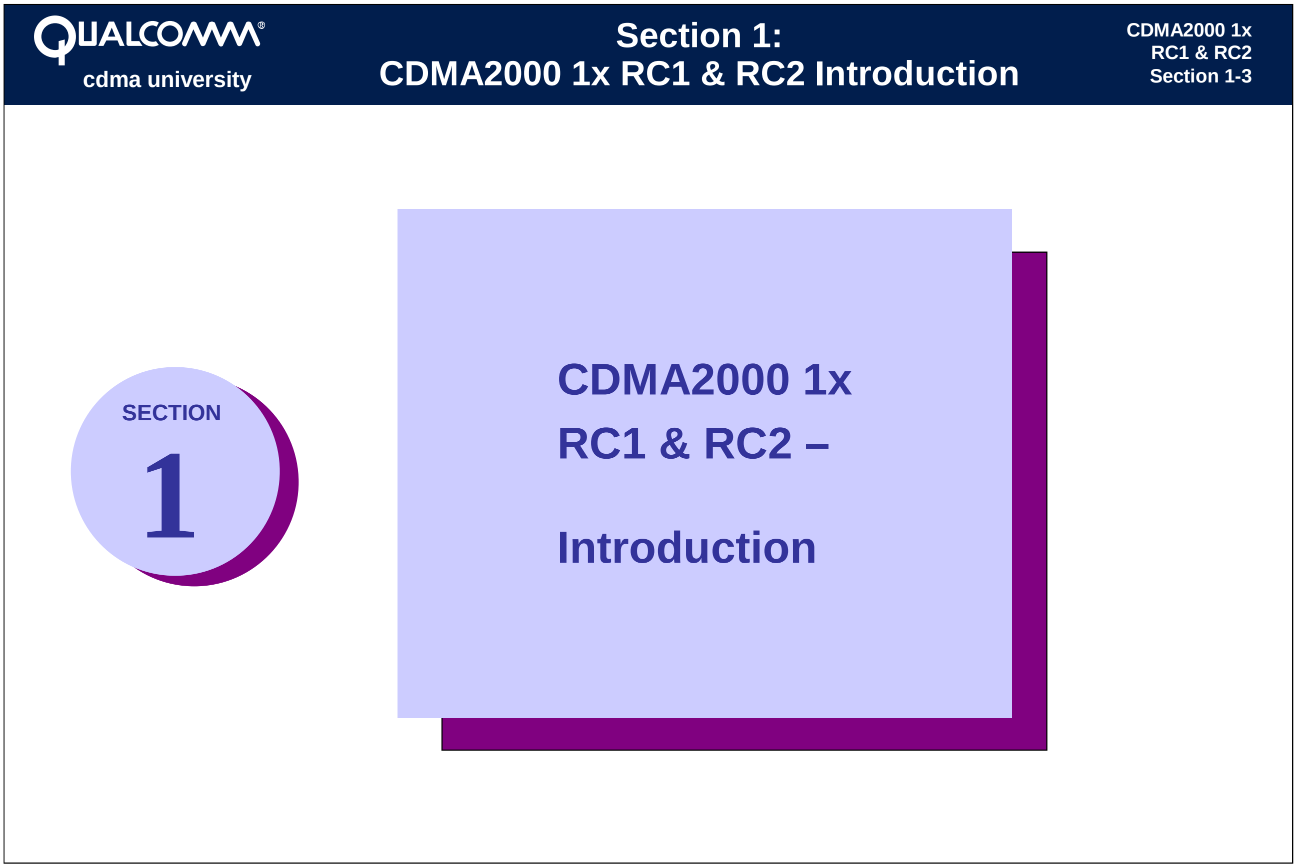
Describes the signaling formats and messaging for synchronization and call control.

Section 7: Handoffs

Describes the various types of handoffs supported in a CDMA system and the signaling involved in the control of handoffs.

Section 8: Registration

Describes the registration techniques supported in a CDMA system and the parameters available to control those techniques.

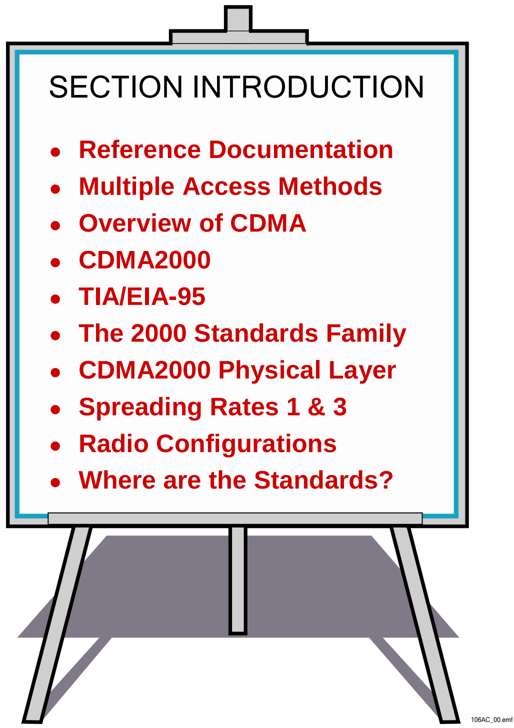

QUALCOMM
cdma university
Section 1:
CDMA2000 1x RC1 & RC2 Introduction
CDMA2000 1x
RC1 & RC2
Section 1-3
SECTION
1
CDMA2000 1x
RC1 & RC2 –
Introduction

Notes

QUALCOMM cdma university

Section Introduction

CDMA2000 1x RC1 & RC2 Section 1-4



Notes

QUALCOMM cdma university

Section Learning Objectives

CDMA2000 1x RC1 & RC2 Section 1-5

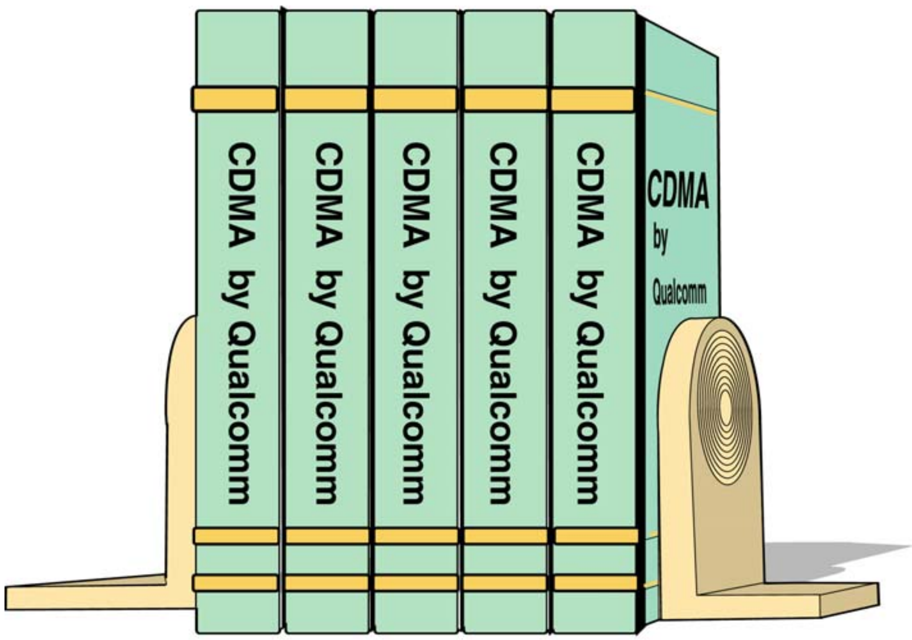
- Describe how TIA/EIA-95 relates to CDMA2000.
- List the new Physical Channels for CDMA2000.
- Describe the new Radio Configurations.
- Describe where the CDMA2000 standards can be found.

Notes

cdma university

Reference Documentation

CDMA2000 1x
RC1 & RC2
Section 1-6



964AB_00

Reference Documentation

[1] Viterbi, Andrew J. ***CDMA Principles of Spread Spectrum Communication***. Addison-Wesley, 1995. (ISBN 0-201-63374-4)

[2] Lee, William C.Y. ***Mobile Cellular Telecommunications***, 2nd Edition. McGraw Hill, 1995. (ISBN 0-07-038089-9)

[3] Kim, Kyoung. ***Handbook of CDMA System Design, Engineering, and Optimization***. Prentice Hall, 2000. (ISBN 0-13-017572-1)

[4] Rappaport, T.S. ***Wireless Communications Principles and Practice***. Prentice-Hall, 1996. (ISBN 0-13-375536-3)

[5] Yang, Samuel C. ***CDMA RF Systems Engineering***. Artech House Publishers, 1998. (ISBN 0-89006-991-2)

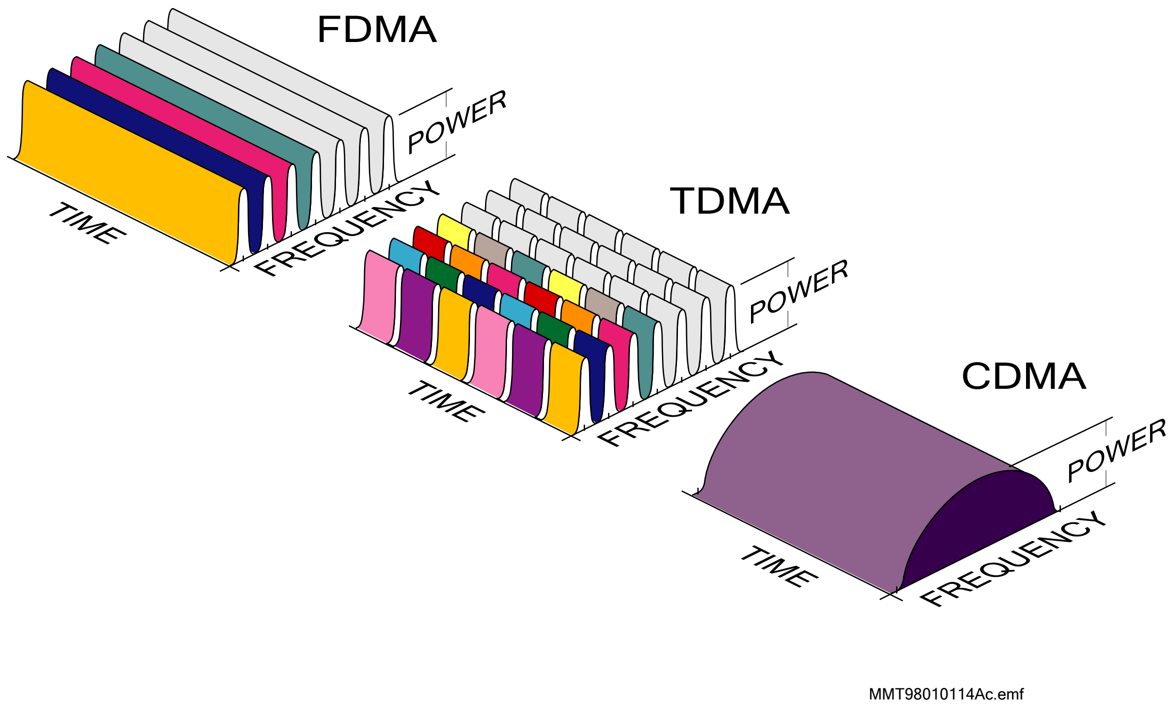
[6] TIA/EIA/IS-95, available through:

Global Engineering Documents
15 Inverness Way,
Englewood, CO 80112
1-800-854-7179
http://global.ihs.com

QUALCOMM cdma university

Multiple Access Methods

CDMA2000 1x
RC1 & RC2
Section 1-7

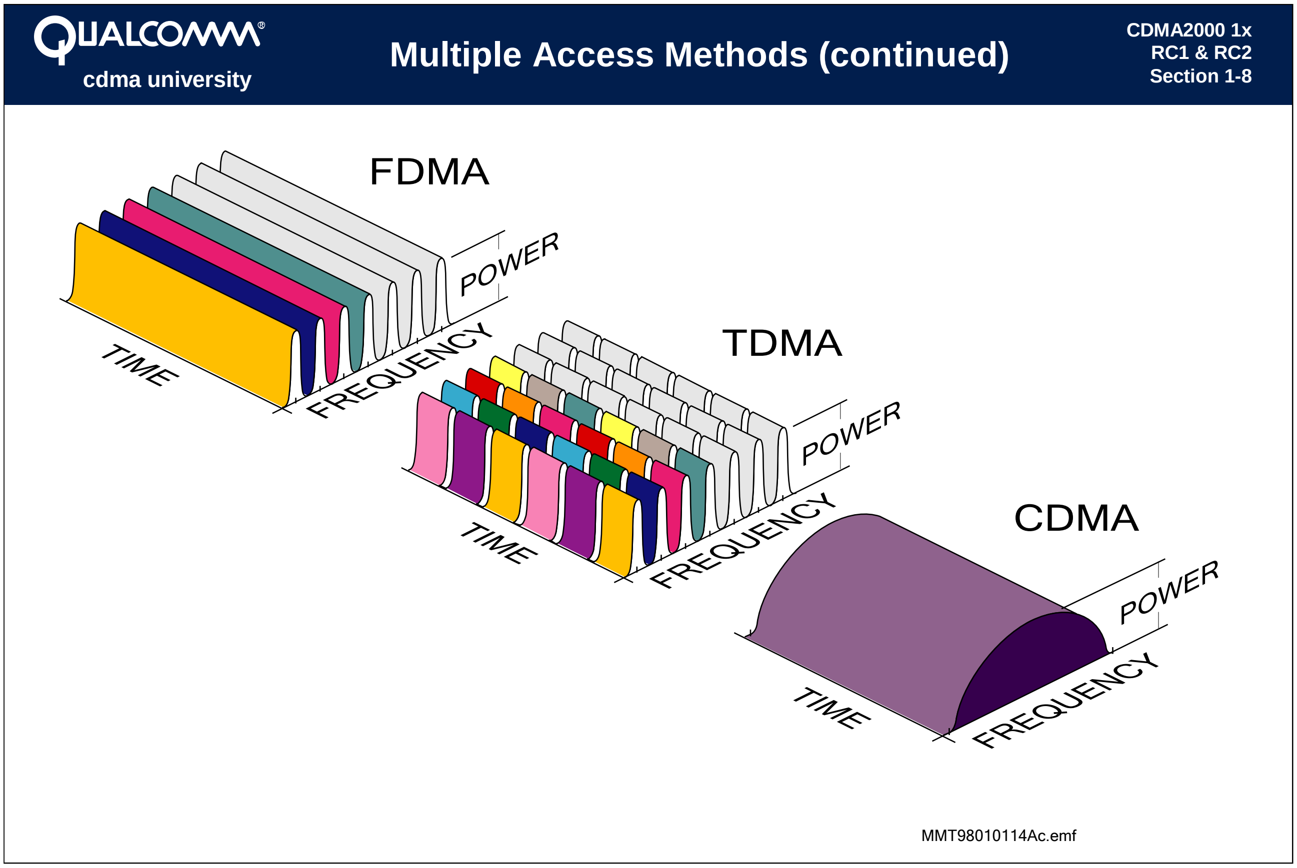


FDMA: Frequency Division Multiple Access

FDMA is a multiple access method in which users are assigned specific frequency bands. The user has sole right of using the frequency band for the entire call duration.

TDMA: Time Division Multiple Access

TDMA is an assigned frequency band shared among a few users. However, each user is allowed to transmit in predetermined time slots. Hence, channelization of users in the same band is achieved through separation in time.

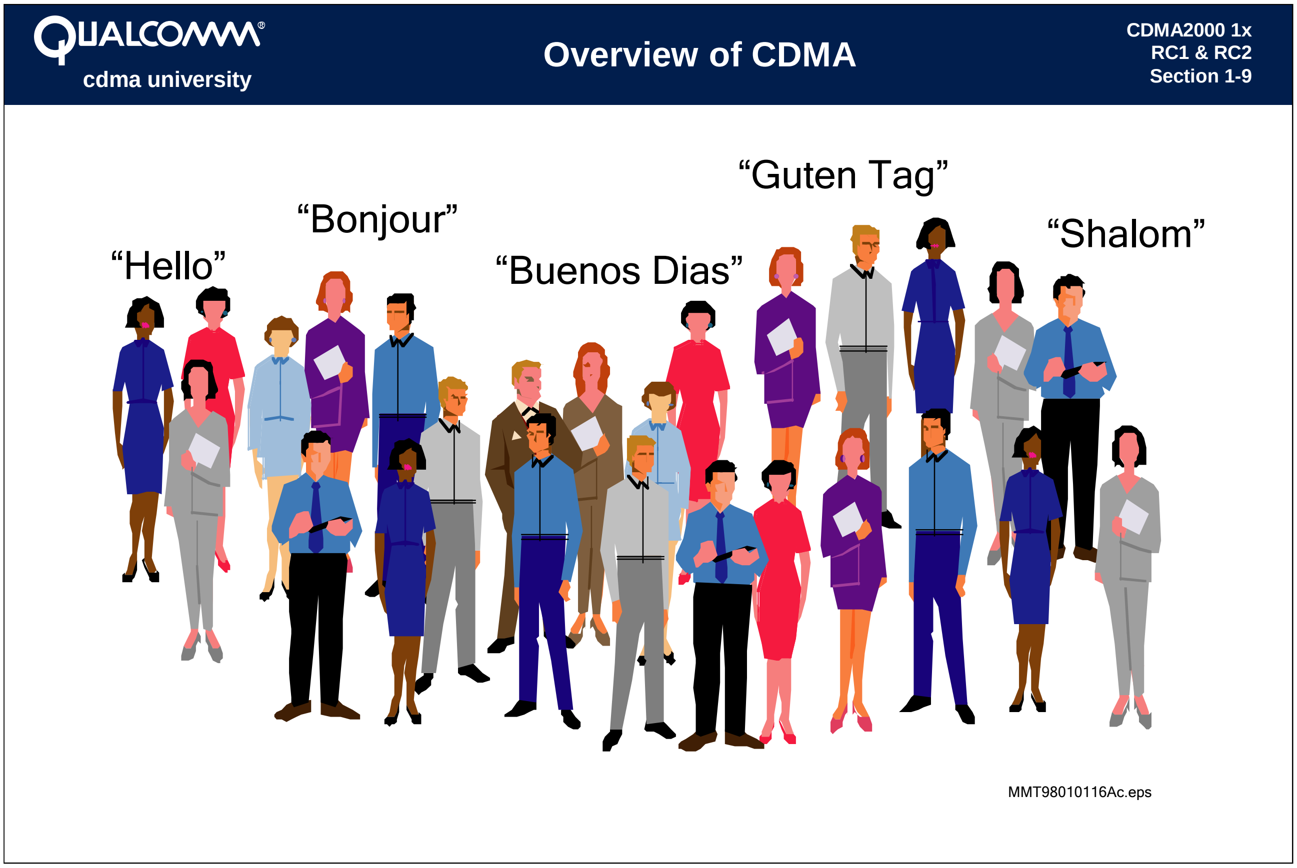


CDMA: Code Division Multiple Access

CDMA is a method in which users occupy the same time and frequency allocations, and are channelized by unique assigned codes. The signals are separated at the receiver by using a correlator that accepts only signal energy from the desired channel. Undesired signals contribute only to the noise.

In December of 1991, QUALCOMM presented to CTIA the results of some of the first CDMA field trials. Following these presentations, the CTIA Board of Directors unanimously adopted a resolution requesting that the Telecommunications Industry Association (TIA), prepare structurally to accept contributions regarding wideband cellular systems.

In March of 1992, a new subcommittee within the TR45 Committee was formed to develop spread spectrum cellular standards. That subcommittee published the first CDMA cellular standard, IS-95, in July 1993. CDMA systems based on the IS-95 standard and related specifications are referred to as *CDMAOne*™ systems. CDMAOne is a trademark of the CDMA Development Group (CDG).



The CDMA "Cocktail Party"

The CDMA concept is analogous to the situation encountered at a party. At the "CDMA Cocktail Party," all subscribers are talking in the same room together simultaneously. Imagine that every conversation in the room is being carried out in a different language that you do not understand. They would all sound like noise from your perspective.

If you "knew the code," the appropriate language, you could imagine filtering out the unwanted conversations and listening only to the conversation of interest to you. A CDMA system must filter the traffic in a similar way.

Even with knowledge of the appropriate language, the conversation of interest may not be completely audible. The listener can signal the speaker to speak more loudly and can also signal other people to speak more softly. A CDMA system uses a similar power control process.

Code Division Multiple Access (CDMA)

The frequency spectrum, in a practical sense, is a finite resource. To effectively support a large number of users, some technique for sharing the spectrum is required to minimize mutual interference. Several common techniques have focused on the use of directional antennas to carefully restrict propagation, the use of separate frequency slots, or time sharing. Code Division Multiple Access (CDMA) is a digital technique for sharing the frequency spectrum. CDMA is based on proven Spread Spectrum communications technology. There are several CDMA implementations that are currently deployed or under development.

CDMAOne

The first commercial and most widely deployed CDMA implementation is CDMAOne. The foundation of CDMAOne is the TIA/EIA IS-95 standard. The term CDMAOne intended to represent the end-to-end wireless system and all of the necessary specifications that govern its operation. CDMAOne technology provides a family of related services including cellular, PCS, and fixed wireless (wireless local loop).

CDMA2000

CDMA2000 is an improvement on TIA/EIA-95. It provides a significant improvement in voice capacity and expanded data capability, and is backward-compatible with IS-95 handsets.

TIA/EIA-95

TIA/EIA-95 =

IS-95A + TSB-74 + J-STD-008

- Analog Details

+ Corrections

+ New Capabilities

MMT98010115Ag.emf

Contents of TIA/EIA-95-B

The new revision, TIA/EIA-95-B, combined IS-95A and B, TSB-74, and ANSI J-STD-008 into a single document and eliminated much of the redundancy among the three documents. Most of the analog information was deleted and the standard referenced the existing analog standard IS-553A when applicable. Lastly, TIA/EIA-95-B added technical corrections and new capabilities.

TIA/EIA-95-B is Protocol Revision 5.

QUALCOMM cdma university — The 2000 Family of Standards — CDMA2000 1x RC1 & RC2 Section 1-12

CDMA2000 has multiple releases:

- **TIA/EIA-95**
  (covered by CDMA2000 radio configurations 1 & 2)
- **CDMA2000 Release 0**
  Uses TIA/EIA-95 Paging and Access Channels and new Traffic Channels
- **CDMA2000 Release A**
  New overhead channels
- **CDMA2000 Release B**
  Minor revisions plus rescue channel
- **CDMA2000 Release C**
  1x EVDV support

CDMA2000 Releases

The first revision of CDMA2000 was Release 0, developed by the Telecommunications Industry Association (TIA) standards body. The TR45 Committee completed the revision in July 1999.

Release A of CDMA2000 was developed by Third Generation Partnership Product 2 (3GPP2), a consortium of five standards bodies:

- TIA in North America
- Telecommunications Technology Association (TTA) in Korea
- Association of Radio Industries and Businesses (ARIB) and Telecommunications Technology Committee (TTC) in Japan
- China Wireless Telecommunication Standards Group (CWTS) in China.

Release A was completed in March 2000.

Release B of CDMA2000 was completed by 3GPP2 on April 19, 2002.

Release C of CDMA2000 was completed by 3GPP2 on May 28, 2002.

Note that the discussion of CDMA2000 in this course assumes CDMA2000 revision A unless otherwise stated.

New Concepts in the CDMA2000 Physical Layer

- Spreading Rate 1 (1x) and Spreading Rate 3 (3x)
- Logical Channels
- Radio Configurations
- Many new Physical Channels
- Transmit Diversity Pilot Channels
- Enhanced Access Channel Procedures
- Reverse Link Pilot Channel

CDMA2000 Physical Layer

Spreading rates for CDMA2000 include 1x (the same as TIA/EIA-95 with a code rate of 1.2288 Mcps) and the new 3x rate which is three times faster, or 3.6864 Mcps.

The CDMA2000 standard has been written in layers to simplify the system design, so the signaling has been divided into Logical Channels and Physical Channels.

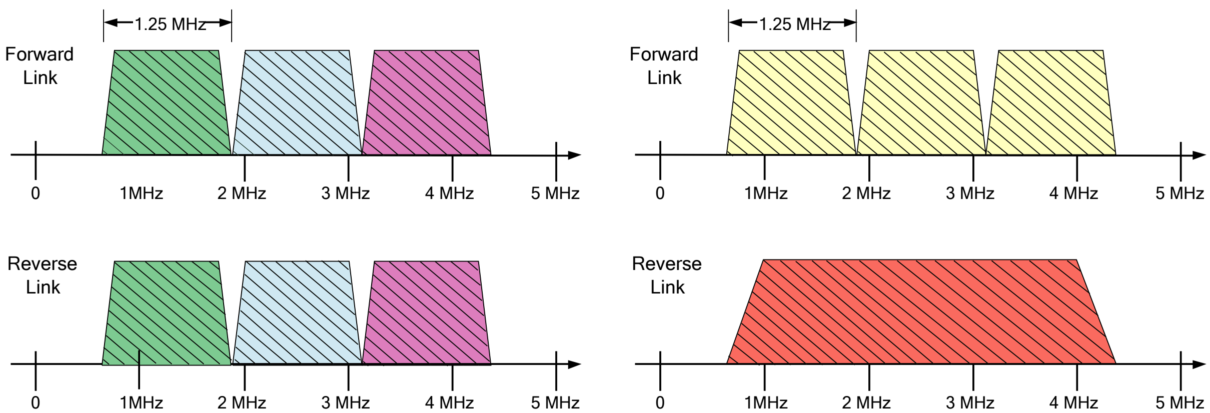
The new spreading rates and FEC rates require different hardware configurations, so there are many new Radio Configurations in CDMA2000.

New Physical Channels have been added to improve performance (transmit diversity), to improve capacity (Reverse Pilot) and call set up times (new overhead channels and access channels).

cdma university

Spreading Rate 1 and Spreading Rate 3

CDMA2000 1x
RC1 & RC2
Section 1-14



Spreading Rate 1 Spreading Rate 3

085AC_00-rev1.emf

Spreading Rates

CDMA2000 supports two different spreading rates:

- **Spreading Rate 1 —** also called “1x”
  - Both Forward and Reverse Channels use a single direct-sequence spread carrier with a chip rate of 1.2288 Mcps.
- **Spreading Rate 3 —** also called “3x” or MC (Multi-Carrier)
  - Forward Channels use three direct-sequence spread carriers each with a chip rate of 1.2288 Mcps.
  - Reverse Channels use a single direct-sequence spread carrier with a chip rate of 3.6864 Mcps.

Radio Configurations

RC1 ad RC2 are exactly backward-compatible to TIA/EIA-95-B Rate Set 1 and Rate Set 2.

The new Radio Configurations are RC3 and up, and these use new modulations, new FEC rates, and 1x or 3x spreading rates.

QUALCOMM cdma university

Radio Configurations – Forward Link

CDMA2000 1x RC1 & RC2 Section 1-16

Radio Configuration	Spreading Rate	Max Data Rate* (kbps)	Effective FEC Code Rate	OTD Allowed	FEC Encoding	Modulation
1	1	9.6	1/2	No	Conv	BPSK
2	1	14.4	3/4	No	Conv	BPSK
3	1	153.6	1/4	Yes	Conv and Turbo	QPSK
4	1	307.2	1/2	Yes	Conv and Turbo	QPSK
5	1	230.4	3/8	Yes	Conv and Turbo	QPSK
6	3	307.2	1/6	Yes	Conv and Turbo	QPSK
7	3	614.4	1/3	Yes	Conv and Turbo	QPSK
8	3	460.8	1/4 or 1/3	Yes	Conv and Turbo	QPSK
9	3	1036.8	1/2or 1/3	Yes	Conv and Turbo	QPSK

* Maximum data rate for a single Supplemental Channel

Forward Link Radio Configurations

Radio Configurations 1 and 2 correspond to TIA/EIA-95-B Rate Set 1 and Rate Set 2, respectively. These are backward-compatible Radio Configurations.

Radio Configurations 3, 4, and 5 use Spreading Rate 1, while Radio Configurations 6, 7, 8, and 9 use Spreading Rate 3. Turbo coding or convolutional coding may be used. RC3, RC4, RC6, and RC7 are based on Rate Set 1 (multiples of 9.6 kbps), while RC5, RC8 and RC9 are based on Rate Set 2 (multiples of 14.4 kbps).

Max Data Rate refers to the maximum data rate for a single Supplemental Channel. Since up to two Supplemental Channels may be used for a single Traffic Channel, the total maximum data rate is twice the value shown in the table.

QUALCOMM cdma university

Radio Configurations – Reverse Link

CDMA2000 1x
RC1 & RC2
Section 1-17

Radio Configuration	Spreading Rate	Max Data Rate* (kbps)	Effective FEC Code Rate	FEC Encoding	Modulation
1	1	9.6	1/3	Conv	64-ary ortho
2	1	14.4	1/2	Conv	64-ary ortho
3	1	153.6 (307.2)	1/4 (1/2)	Conv or Turbo	QPSK
4	1	230.4	3/8	Conv or Turbo	QPSK
5	3	153.6 (614.4)	1/4 (1/3)	Conv or Turbo	QPSK
6	3	460.8 (1036.8)	1/4 (1/2)	Conv or Turbo	QPSK

*** Maximum data rate for a single Supplemental Channel**

Reverse Link Radio Configurations

Radio Configurations 1 and 2 correspond to TIA/EIA-95-B Rate Set 1 and Rate Set 2, respectively. These are backward-compatible Radio Configurations.

Radio Configurations 3 and 4 use Spreading Rate 1, while Radio Configurations 5 and 6 use Spreading Rate 3. Turbo or convolutional coding may be used.

RC3 and RC5 are based on Rate Set 1, while RC4 and RC6 are based on Rate Set 2.

Where are the Standards?

3gpp2 is a collaborative third generation (3G) telecommunications standards-setting project comprising North American and Asian interests, developing global specifications for ANSI/TIA/EIA-41 "Cellular Radio Telecommunication Intersystem Operations network evolution to 3G," and global specifications for the radio transmission technologies (RTTs) supported by ANSI/TIA/EIA-41.

QUALCOMM cdma university | Questions? | CDMA2000 1x RC1 & RC2 Section 1-19

Questions?

If you have a question about CDMA2000, send email to:

CDMA.HELP@QUALCOMM.COM

Notes

QUALCOMM cdma university

What We Learned in This Section

CDMA2000 1x
RC1 & RC2
Section 1-20

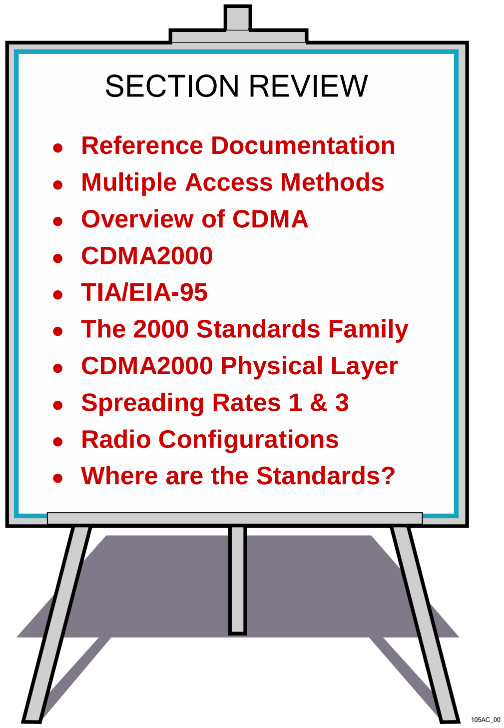
- ✓ TIA/EIA-95 is a subset of CDMA2000.
- ✓ New Physical Channels for CDMA2000.
- ✓ Many new Radio Configurations.
- ✓ CDMA2000 standards are available from *3gpp2*.

Notes

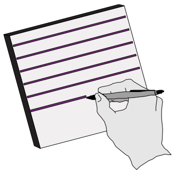
QUALCOMM cdma university

RC1 & RC2 Introduction – Review

CDMA2000 1x RC1 & RC2 Section 1-21



Notes



Comments/Notes

cdma university

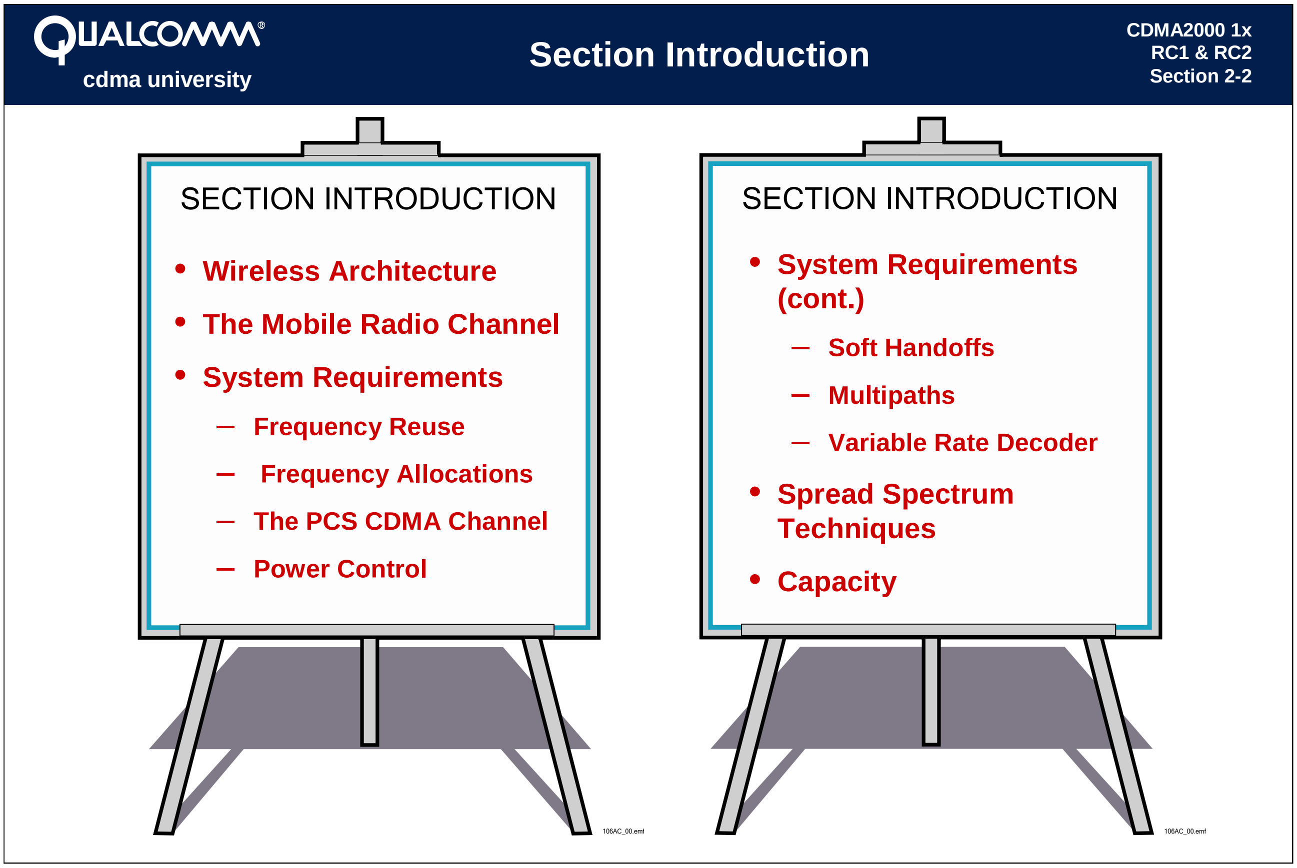
Section 2: Design Considerations

CDMA2000 1x
RC1 & RC2
Section 2-1

SECTION
2

Design Considerations

Notes



Section Introduction

The design of a wireless system requires the consideration of many factors. This section examines some of the important factors that influenced the design of the IS-95 CDMA system.

QUALCOMM cdma university

Section Learning Objectives

CDMA2000 1x RC1 & RC2 Section 2-3

Given instructor lecture and appropriate documentation, you will be able to:

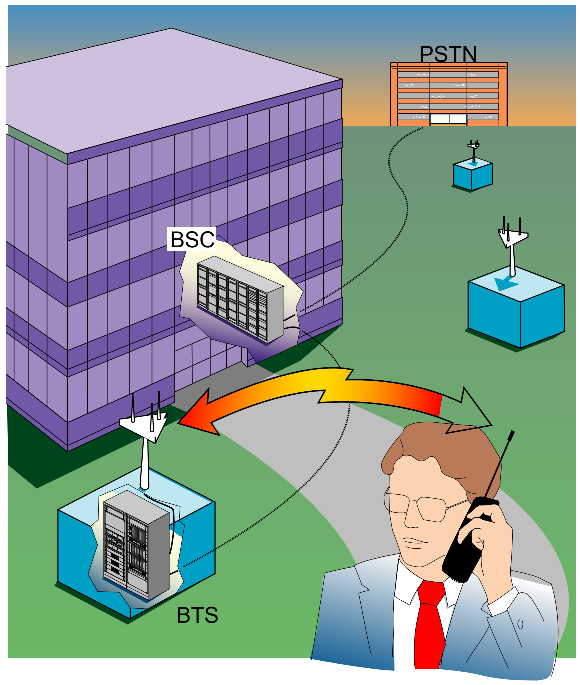
- Identify the elements of a wireless architecture.
- Describe the characteristics of the mobile radio channel.
- List the mobile subscribers' requirements.
- List the limitations of conventional approaches to mobile communications.
- Describe the basic principles of spread spectrum communications.

Notes

QUALCOMM cdma university

Wireless Architecture

CDMA2000 1x
RC1 & RC2
Section 2-4



Mobiles (Subscriber Units)

Mobiles (sometimes called mobile stations or subscriber units) encode the user's voice, generate the Reverse CDMA Channel waveforms, and demodulate the Forward CDMA Channel.

Base Transceiver Subsystem (BTS)

The BTS generates the Forward CDMA Channel and demodulates the mobile transmissions, producing vocoded frames.

Base Station Controller (BSC)

The BSC converts the landline voice signals into vocoded frames, then sends them to an appropriate BTS. The BSC also receives vocoded frames from the BTSs and converts these frames into PCM signals.

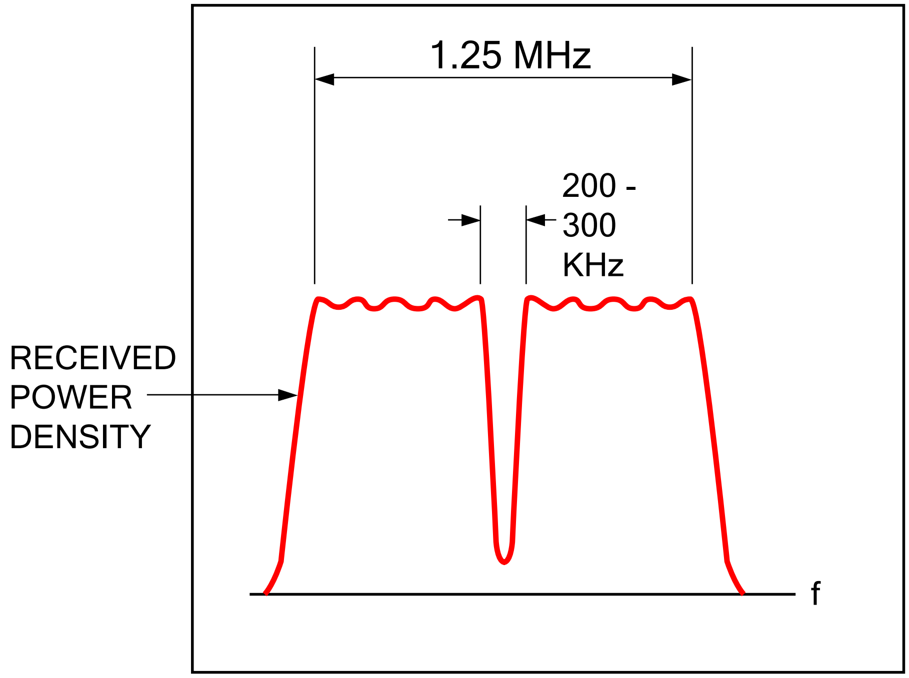
Public Switched Telephone Network (PSTN)

The PSTN links the BSC and the BTSs in the system. It also interfaces the land phone system with the wireless system.

cdma university

The Mobile Radio Channel – Fading

CDMA2000 1x
RC1 & RC2
Section 2-5



MMT98010171Ac.emf

Frequency Selective Fading

In the frequency domain, a fade can appear as a notch that moves back and forth across the spectrum as channel conditions change. The width of the notch is proportional to the difference in the arrival times of the multipath signals. For a bandwidth of 1.23 MHz, only those multipaths arriving less than 1 microsecond apart can cause the signal to experience a deep fade. The figure is a simple illustration. In practice, several notches can exist with varying levels of depth.

Flat Fading

Flat fading is a fade of the entire bandwidth. This is far less likely to occur in the wideband CDMA system than in narrowband systems. This kind of fading can happen when there is substantial multipath interference arriving too close together in time to be distinguishable.

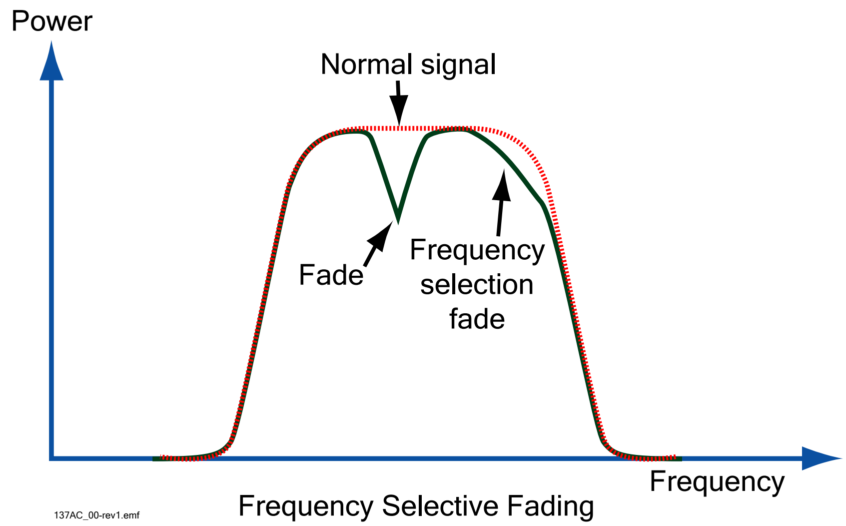
QUALCOMM cdma university

The Mobile Radio Channel – Flat Fading and Frequency Selective Fading

CDMA2000 1x RC1 & RC2 Section 2-6

When the coherence bandwidth is ***greater than or equal*** *to* the transmitted signal's bandwidth, the received signal will undergo **flat fading.**

When the coherence bandwidth is ***less than*** the transmitted signal's bandwidth, the received signal will undergo **frequency selective fading.**



Frequency Selective Fading

Flat Fading and Frequency Selective Fading

When the symbol energy duration of a transmitted signal is greater than the delay spread of a channel that the transmitter uses to transmit the signal, the receiver will experience flat fading. This delay is inversely proportional to bandwidth.

One of the key factors that differentiates third-generation CDMA from second-generation CDMA is the wider bandwidth. In addition to the ability to provide wideband services, the increased bandwidth makes it possible to resolve more multipath components in a mobile radio channel.

If the transmission bandwidth is wider than the coherence bandwidth of the channel, the receiver can separate multipath components. This brings more diversity and higher capacity.

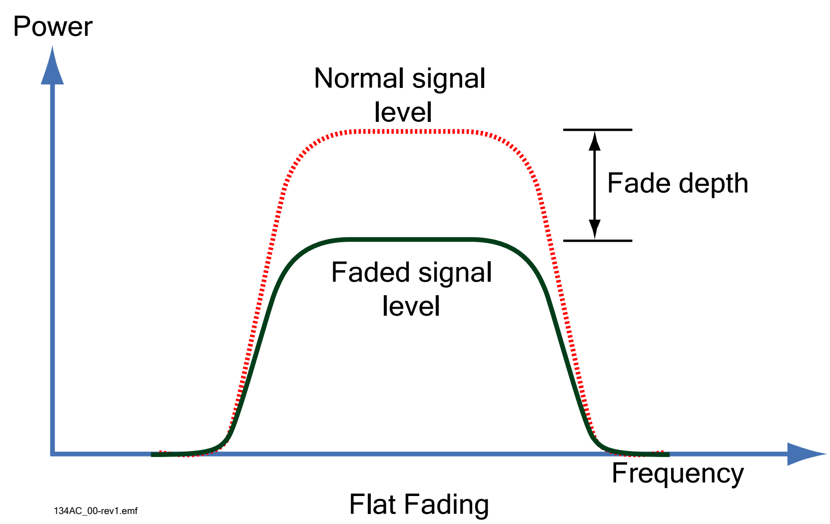
Diversity and capacity will be discussed later in this section.

QUALCOMM cdma university

The Mobile Radio Channel – Multipath-Associated Problems: Flat Fading

CDMA2000 1x RC1 & RC2 Section 2-7

If multipath delays are less than one CDMA spreading chip, the receiver will experience **flat fading**. In flat fading, the amplitude of the signal changes with time, but the spectral characteristics of the transmitted signal are preserved at the receiver.



Flat Fading

What is the effect of the flat fading?

The answer is complex and is different in the Forward and Reverse links. It also depends on the fading rate, which in turn depends on the velocity of the mobile. Generally, fading increases the average signal-to-noise ratio needed for a particular error rate. The increase can be as much as perhaps 6 dB.

In both the Reverse link and Forward links of a CDMA2000 system, power control mitigates the effects of fading at low speed; at high speed it has little effect. At high speed, and in both links, the Forward Error Correction (FEC) coding and interleaving become more effective as the characteristic fade time becomes less than the interleaver span.

QUALCOMM cdma university

System Requirements

CDMA2000 1x
RC1 & RC2
Section 2-8

- Frequency Reuse
- Frequency Allocations
- The PCS CDMA Channel
- Power Control
- Soft Handoffs
- Multipaths
- Variable Rate Vocoder

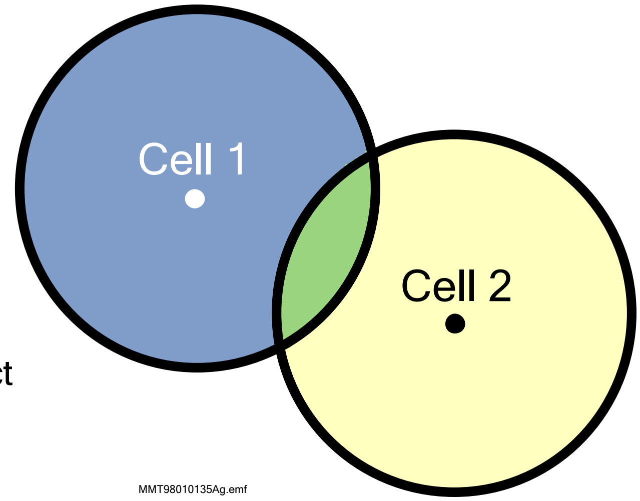
Notes

QUALCOMM cdma university

Frequency Reuse – FDMA and TDMA Systems

CDMA2000 1x RC1 & RC2 Section 2-9

If Cell 1 and Cell 2 were both on the same frequency in conventional cellular systems, the overlap area would have a frequency conflict



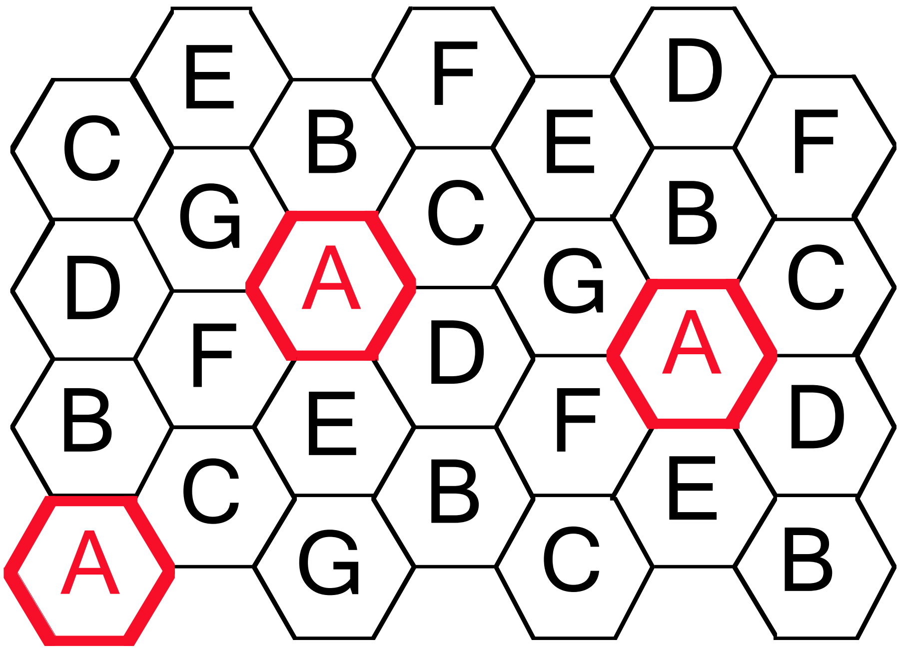
Frequency Reuse in FDMA and TDMA Systems

When multiple access is achieved by providing disjoint slots in frequency and time, users in adjacent cells must also be provided disjoint slots; otherwise their mutual interference would become intolerable. This leads to limited frequency reuse, where typically a slot is used only once in a certain geographic area.

cdma university

Frequency Reuse – Reuse Pattern of 7

CDMA2000 1x
RC1 & RC2
Section 2-10



MMT98010136Ac-rev2.emf

Frequency Reuse Pattern of 7

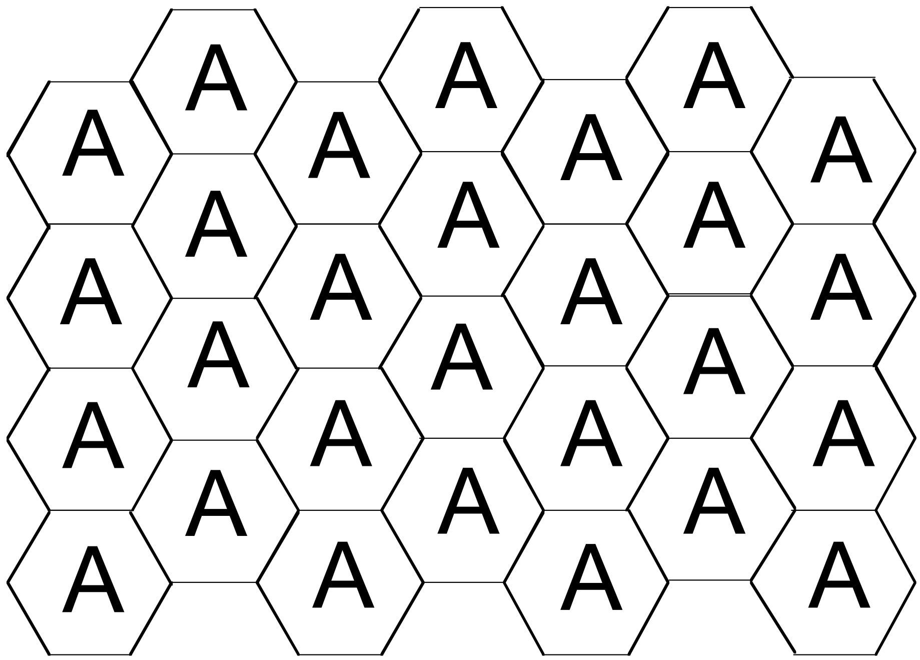
A reuse pattern of 7 is common in cellular systems. Only 1/7 of a carrier’s frequency allocation is used in any one cell.

In sectorized cells, a reuse pattern of 21 is common (3 sectors per cell x 7 cells). When a new cell is introduced, a revision of the frequency plan is required.

cdma university

Frequency Reuse – CDMA

CDMA2000 1x
RC1 & RC2
Section 2-11



MMT98010137Ag.emf

Universal Frequency Reuse — CDMA

The principal attribute of a CDMA System is that *all subscribers can use the same frequency*. This underlies all other attributes.

With spread spectrum, universal frequency reuse applies not only to users in the same cell, but also to those in all other cells. The advantage here is that complicated reuse patterns are not necessary.

Frequency Allocations – Analog System Constraints

System	Valid CDMA Frequency Assignments	Analog channel Count	CDMA Channel Number	Transmitter Frequency Assignment (MHz) Mobile	Base
A" (1 MHz)	/////////	22	991 1012	824.040 824.670	869.040 869.670
	CDMA	11	1013 1023	824.700 825.000	869.700 870.000
A (10 MHz)	CDMA	311	1 311	825.030 834.330	870.030 879.330
	/////////	22	312 333	834.360 834.990	879.360 879.990
B (10 MHz)	/////////	22	334 355	835.020 835.650	880.020 880.650
	CDMA	289	356 644	835.680 844.320	880.680 889.320
	/////////	22	645 666	844.350 844.980	889.350 889.980
A' (1.5 MHz)	/////////	22	667 688	845.010 845.640	890.010 890.640
	CDMA	6	689 694	845.670 845.820	890.670 890.820
	/////////	22	695 716	845.850 846.480	890.850 891.480
B (2.5 MHz)	/////////	22	717 738	846.510 847.140	891.510 892.140
	CDMA	39	739 777	847.170 848.310	892.170 893.310
	/////////	22	778 799	848.340 848.970	893.340 893.970

Analog System Constraints

For the cellular allocation at 800 Mhz, the frequency allocation for CDMA is the same as for Analog. Some channels are not valid for CDMA because the out-of-band emissions from the CDMA waveform would cause interference in a neighboring band. One CDMA channel occupies the same bandwidth as about 42 Analog channels.

QUALCOMM cdma university

Frequency Allocations – U.S. PCS Allocations

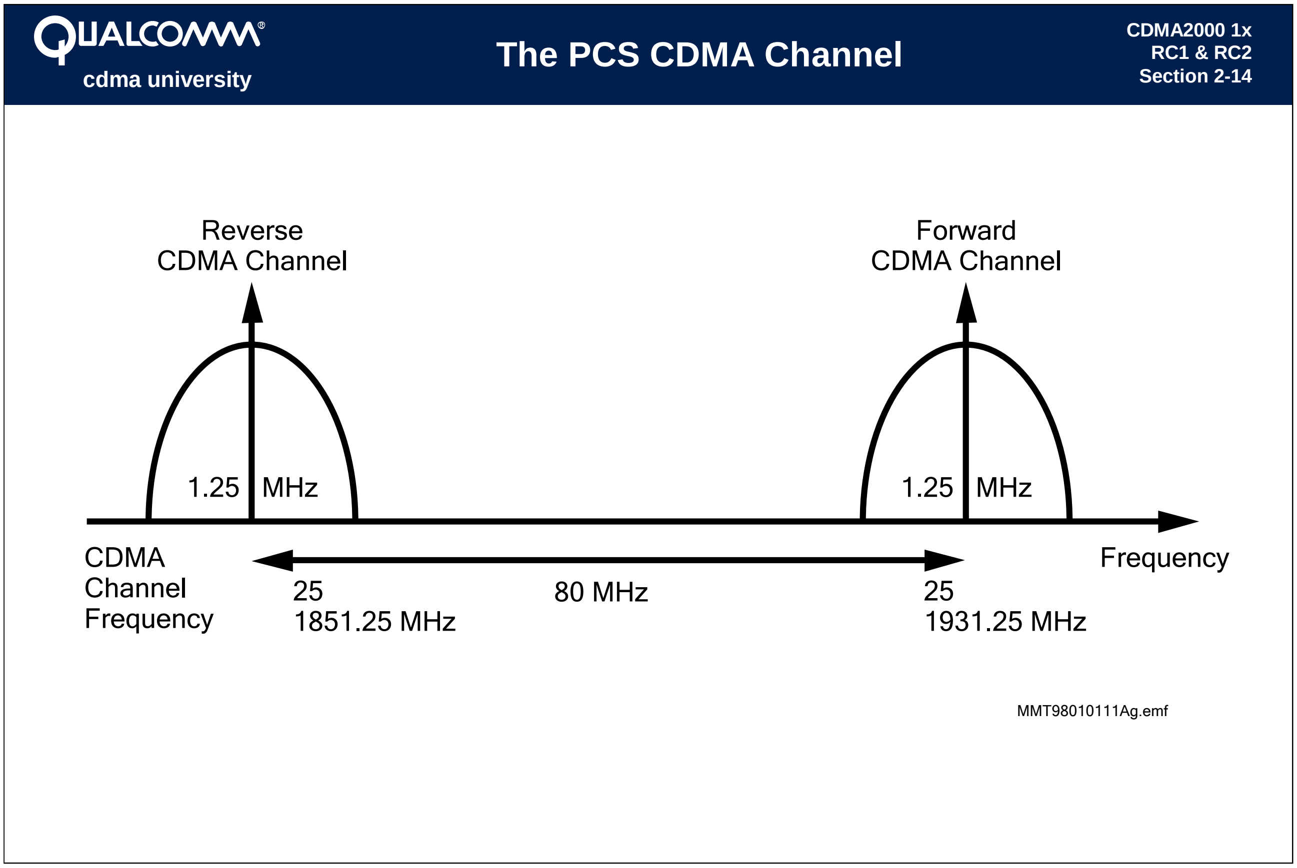
CDMA2000 1x RC1 & RC2 Section 2-13

Block Designator	Valid CDMA Frequency Assignments	CDMA Channel Number	Transmitter Frequency Band (MHz) Personal Stations	Transmitter Frequency Band (MHz) Base Station
A (15 MHz)	Not Valid	0-24	1850.000-1851.200	1930.000-1931.200
	Valid	25-275	1851.250-1863.750	1931.250-1943.750
	Cond. Valid	276-299	1863.800-1864.950	1943.800-1944.950
D (5 MHz)	Cond. Valid	300-324	1865.000-1866.200	1945.000-1946.200
	Valid	325-375	1866.250-1868.750	1946.250-1948.750
	Cond. Valid	376-399	1868.800-1869.950	1948.800-1949.950
B (15 MHz)	Cond. Valid	400-424	1870.000-1871.200	1950.000-1951.200
	Valid	425-675	1871.250-1883.750	1951.250-1963.750
	Cond. Valid	676-699	1883.800-1884.950	1963.800-1964.950
E (5 MHz)	Cond. Valid	700-724	1885.000-1886.200	1965.000-1966.200
	Valid	725-775	1886.250-1888.750	1966.250-1968.750
	Cond. Valid	776-799	1888.800-1889.950	1968.800-1969.950
F (5 MHz)	Cond. Valid	800-824	1890.000-1891.200	1970.000-1971.200
	Valid	825-875	1891.250-1893.750	1971.250-1973.750
	Cond. Valid	876-899	1893.800-1894.950	1973.800-1974.950
C (15 MHz	Cond. Valid	900-924	1895.000-1896.200	1975.000-1976.200
	Valid	925-1175	1896.250-1908.750	1976.250-1988.750
	Not Valid	1176-1199	1908.800-1909.950	1988.800-1989.950

U.S. PCS Allocations

For the US PCS allocations, some channels at the band edge are either Not Valid or Conditionally Valid:

- The *Not Valid* channels lie on the edge of the spectrum allocation, and out-of-band emissions would always fall into a different (non-cellular) service, so these allocations are never allowed.
- The *Conditionally Valid* channels are dependent on the holder of the spectrum license. For example, if a licensee owns both E and F bands, then the channels 776–824 would be valid for service, but the channels 700-724 and 876–899 would not be valid because they could cause interference in channels that the licensee does not own.



The PCS CDMA Channel

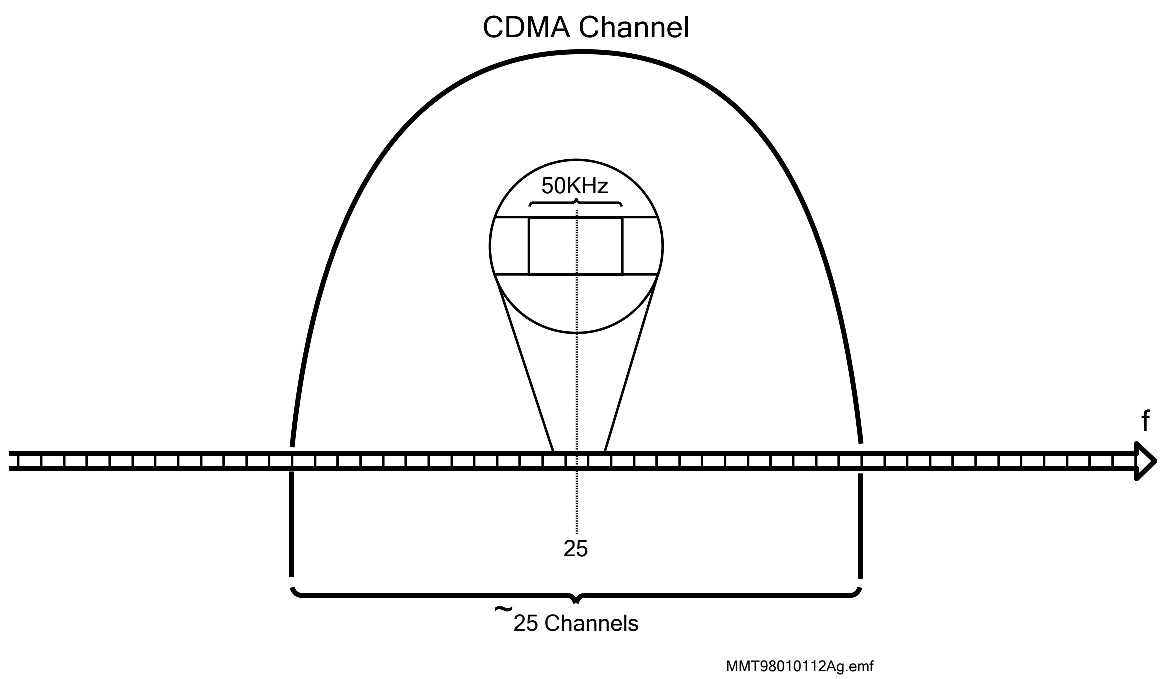
The Channel Number (25 in the picture above) uniquely identifies both a Forward link frequency (Base Station to mobile) and a Reverse link frequency (mobile to Base Station).

For PCS operation the channels are always separated by 80 MHz. For operation in the Cellular band at 800 Mhz the separation is always 45 MHz.

QUALCOMM cdma university

The PCS CDMA Channel (continued)

CDMA2000 1x
RC1 & RC2
Section 2-15



PCS Spectrum

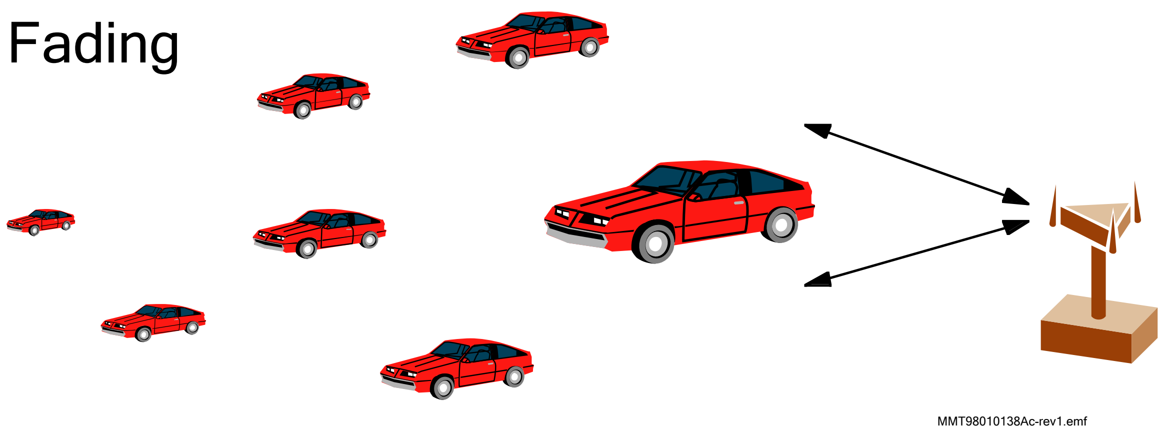
The PCS spectrum in the US is channelized in 50 KHz increments to be fair to all radio technologies. The 50 KHz channel is much smaller than the CDMA waveform and the channel number identifies only the center of the CDMA waveform.

QUALCOMM cdma university

Power Control – Effective Power Control is Required

CDMA2000 1x RC1 & RC2 Section 2-16

- Near-Far Problem
- Path Loss
- Fading



Power Control and the Near-Far Problem

CDMA will not work without an effective power control, because of the *near-far problem*. The near-far problem arises when a mobile user near a cell jams a user that is distant from the cell (assuming both are transmitting at the same power). This problem may be present despite high processing gain. An effective method to eliminate the near-far effect is therefore necessary.

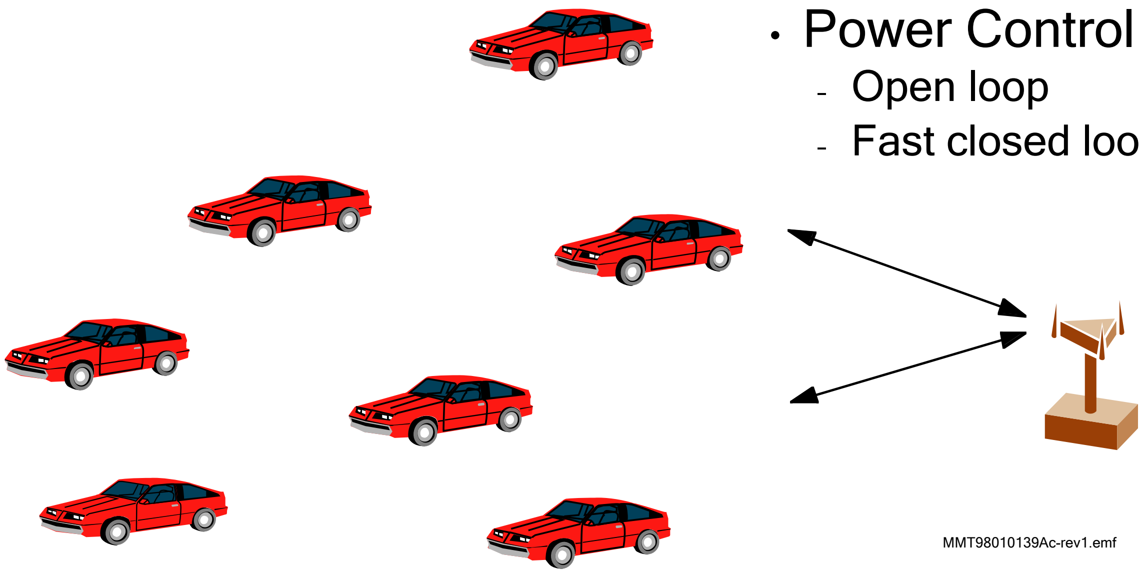
Other factors such as varying path loss and fading also result in the need to control the mobile's transmission power.

QUALCOMM cdma university

Power Control – Solutions to Maximize Capacity

CDMA2000 1x
RC1 & RC2
Section 2-17

- Power Control
  - Open loop
  - Fast closed loop



The Power Control Solution

It can be shown that capacity is maximized if all users are controlled so that their signals reach the Base Station at approximately the same power level.

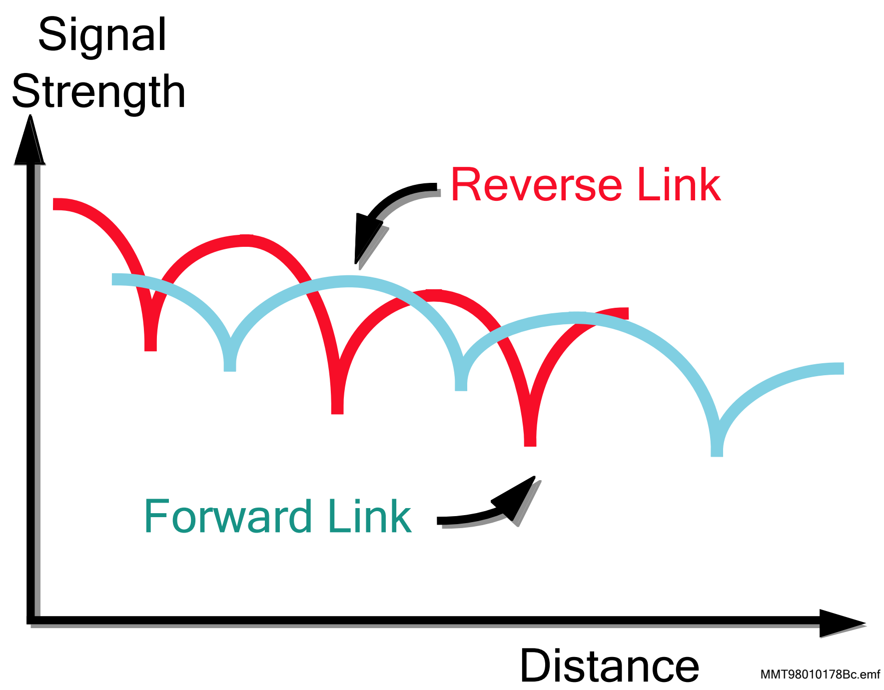
CDMA2000 systems use a two-step approach to achieve this:

- An original estimate is made by the mobile (***open loop power control***).
- A faster correction is made to this estimate, based on instructions provided to the mobile by the Base Station (***closed loop power control***).

cdma university

Power Control – Small Scale Path Loss: Fast Fading

CDMA2000 1x RC1 & RC2 Section 2-18



Small Scale Path Loss and Fast Fading

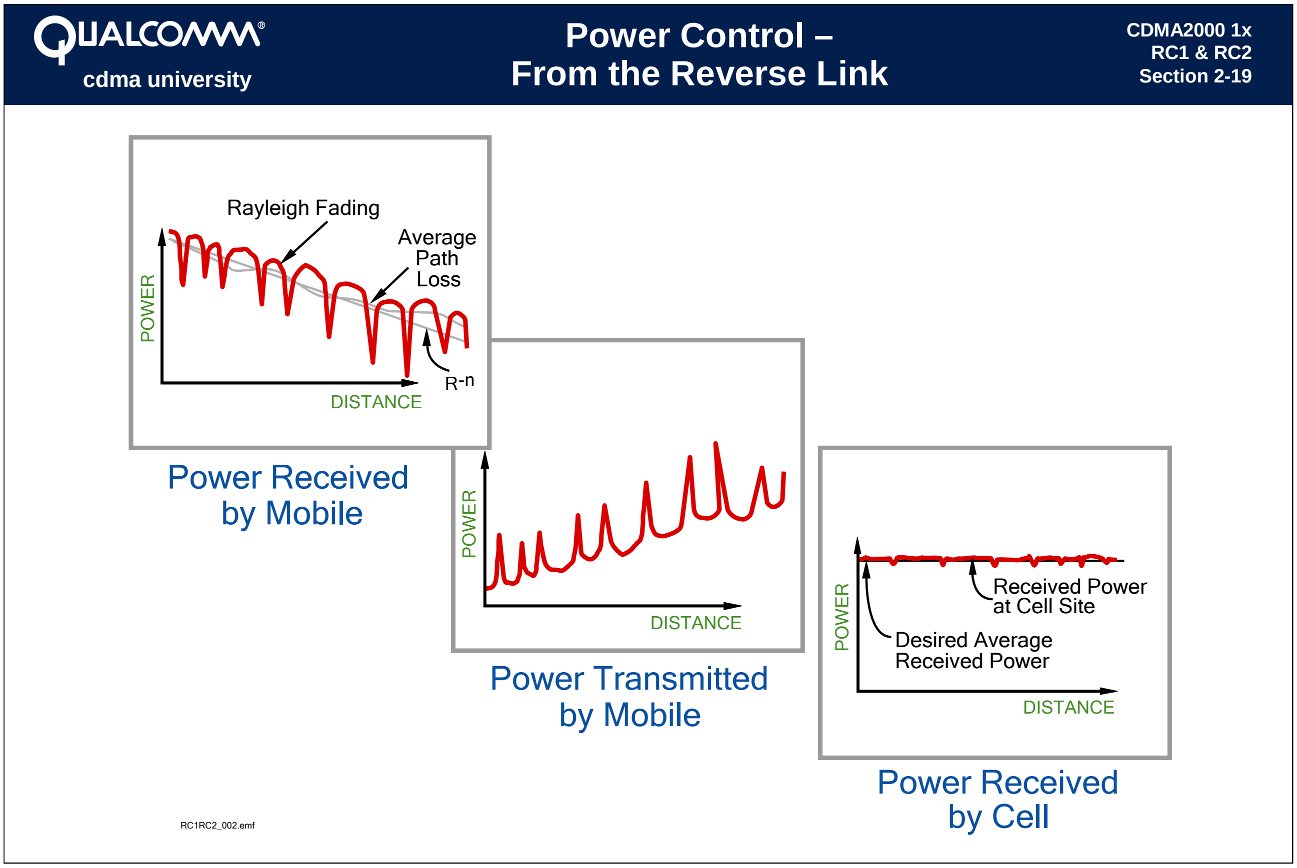
Large changes in path loss can occur over very small distances or very short time intervals. This effect is called *fast fading*. Fast fading is a function of the strength and delay of the multipath waves and the bandwidth of the transmitted signal.

In the mobile environment, signals are reflected and scattered by obstacles in their path. These obstacles can be buildings, hillsides, trees, and vehicles. The result is multiple copies of the same signal arriving at the receive antenna. These multiple copies, however, took different paths and so arrive at the receive antenna offset in time. This offset can cause the signals to add in a destructive way at one moment and reinforce each other in the next. This is *fast fading*.

Such fading in narrowband systems causes fluctuations in received signal by 20-30 dB while the mobile travels a distance of only 1 meter. The use of a wideband CDMA signal can significantly reduce the impact of fast fading.

Forward and Reverse Channels are Not Correlated

An additional complication results from the frequency separation between the Forward and Reverse links (45 MHz for cellular systems; 80 MHz for PCS systems). This amount of separation is usually great enough to decouple any dependency between fast fading in the two directions. Fast fading in the Forward direction, then, is often different than the fading seen in the Reverse direction.



From the Reverse Link

The Power received by the mobile is a function of the path loss and the fast fading.

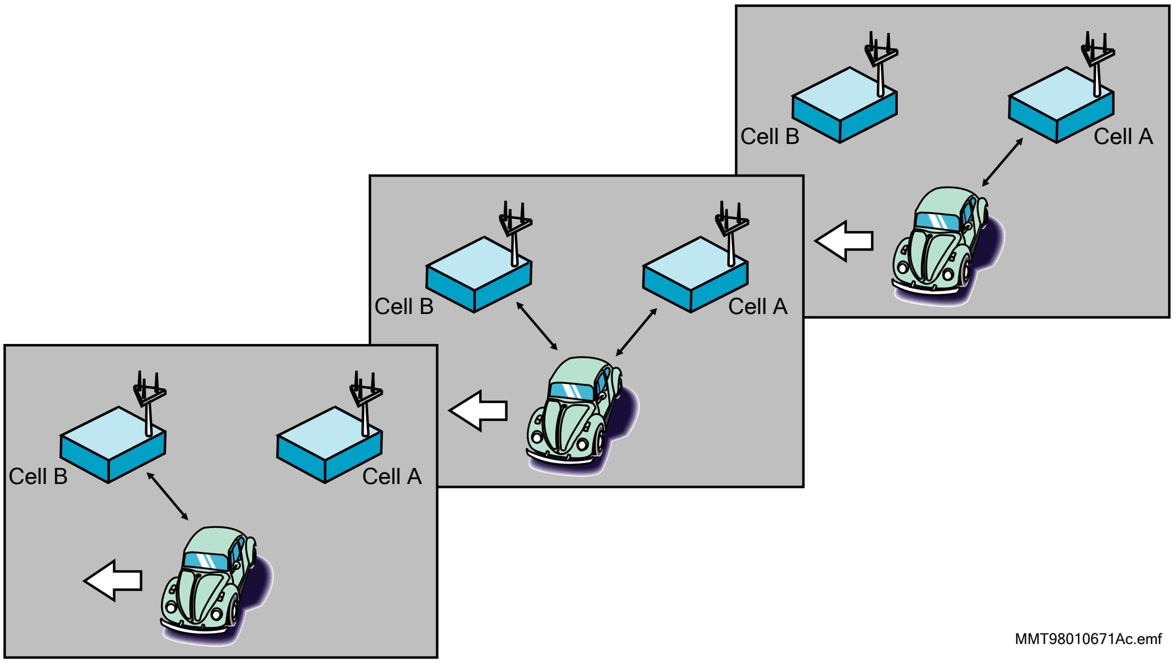
The power transmitted by the mobile is also a function of the path loss and the fast fading.

The power received at the Base Station is nearly constant, only limited by the rate at which Closed Loop power control can correct the fast fading.

QUALCOMM cdma university

Soft Handoffs

CDMA2000 1x RC1 & RC2 Section 2-20



Soft Handoffs

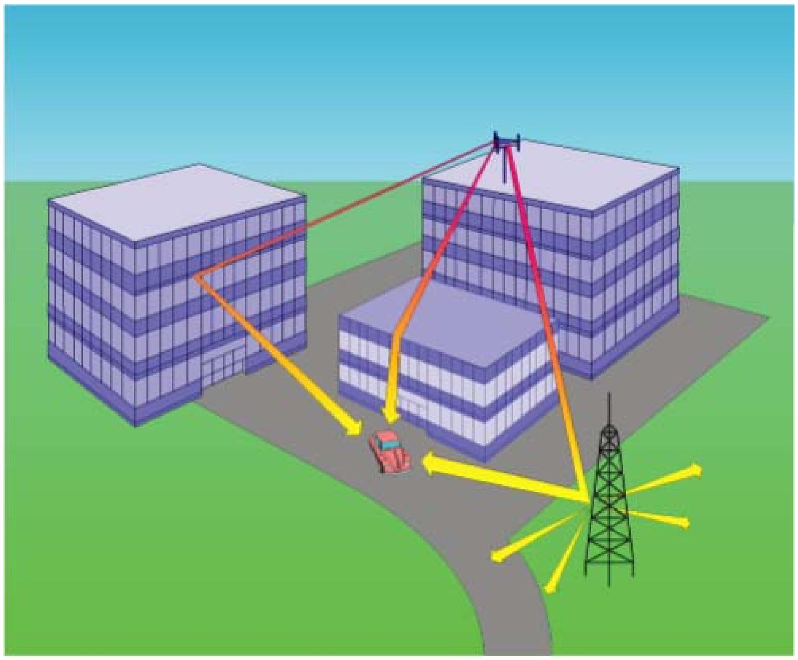
Soft handoff refers to the state where the mobile is in communication with multiple Base Stations at the same time. Soft handoff is a *make-before-break* type of handoff, whereby a mobile acquires a target code channel before breaking an existing one.

Soft handoff is a special attribute of CDMA and is enabled by universal frequency reuse.

Soft handoff has several advantages:

- Fewer dropped calls.
- Soft handoffs in general require less mobile transmit power.
- Increases capacity.
- Improved call quality.

Multipaths



Multipaths

Propagation in relatively small congested cells is dominated by diffraction, scattering, and reflection caused by the structures and objects surrounding both the cell site and the mobile antennas. The multipaths formed by the scatterers and reflectors add up at the receive antenna to produce the received signal.

Diffraction occurs when the radio path is blocked by an object that has sharp irregularities.

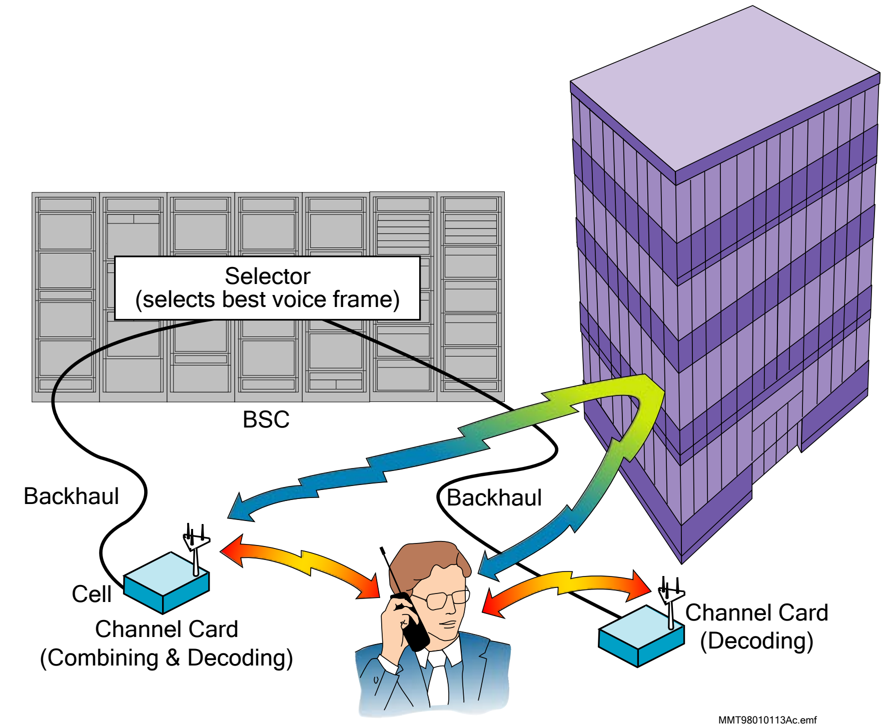
Scattering occurs when the wave strikes objects that are small compared to a wavelength. Foliage, lampposts, and street signs produce scattering.

Reflection occurs when a propagating electromagnetic wave impinges upon an object that has very large dimensions when compared to the wavelength of the propagating wave (Rappaport, page 78).

cdma university

Multipaths (continued)

CDMA2000 1x
RC1 & RC2
Section 2-22



Better Use of Multipath

One of the main advantages of CDMA systems is the capability of using signals that arrive in the receivers with different time delays. This phenomenon is called *multipath*.

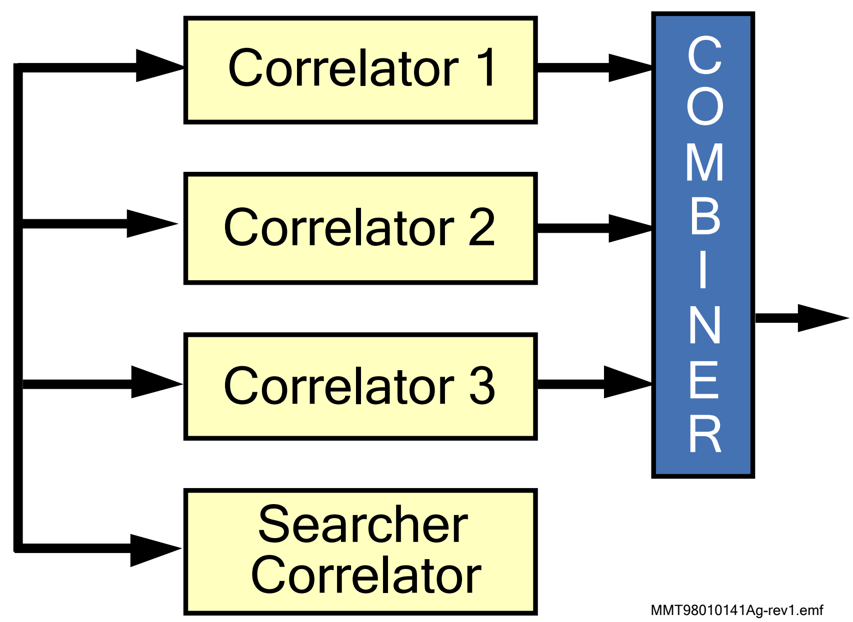
FDMA (analog cellular) and TDMA, which are narrowband systems, cannot discriminate between the multipath arrivals, and resort to equalization to mitigate the negative effects of multipath.

Due to its wide bandwidth and rake receivers, CDMA uses the multipath signals and combines them to make an even stronger signal at the receivers.

cdma university

Multipaths – Mobile Rake Receiver

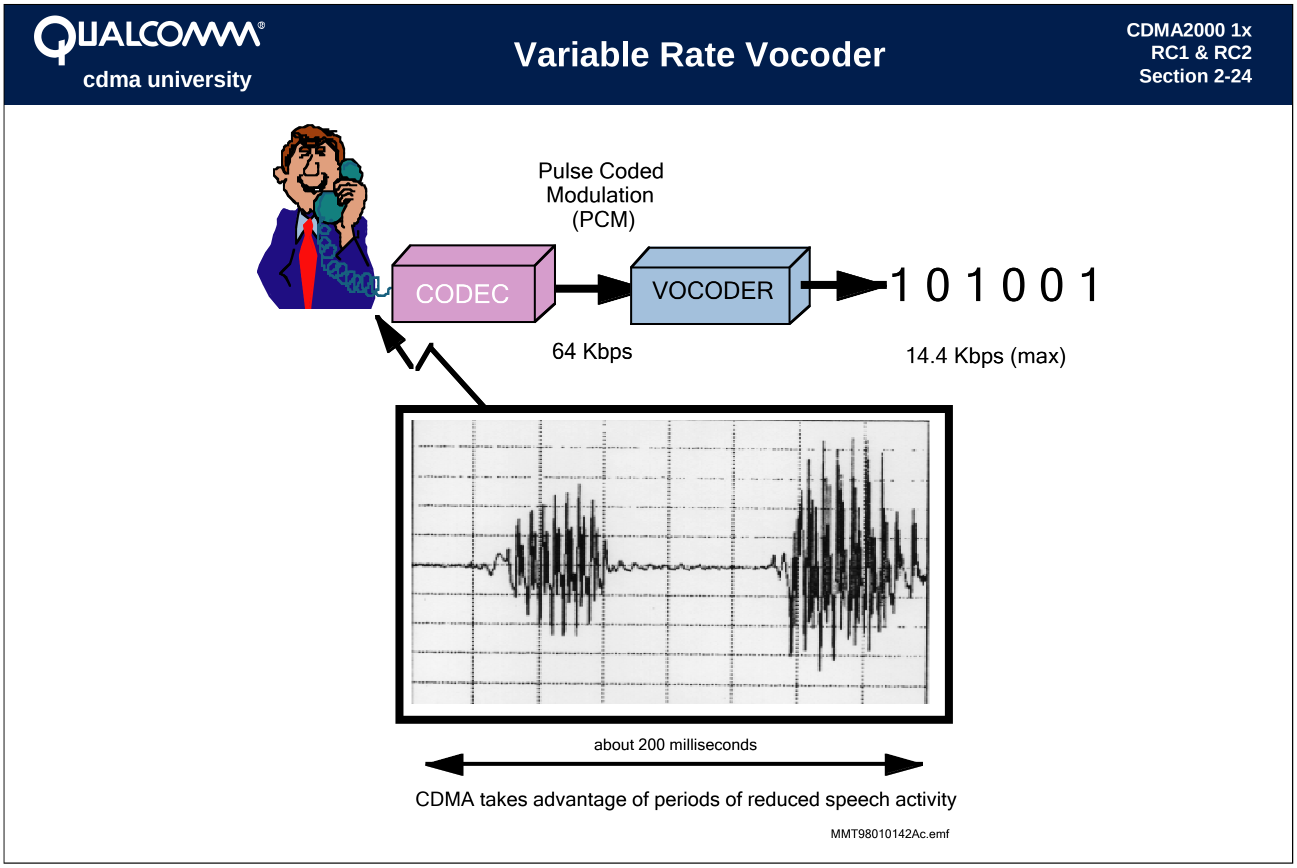
CDMA2000 1x
RC1 & RC2
Section 2-23



Rake Receivers

CDMA mobiles use *rake receivers*. The rake receiver is essentially a set of four or more receivers (or *fingers*).

One of the receivers constantly searches for different multipaths and helps to direct the other three fingers to lock onto strong multipath signals. Each finger then demodulates the signal corresponding to a strong multipath. The results are combined to make the signal stronger.



Codec

A *codec* is an analog-to-digital and digital-to-analog converter.

The figure depicts the codec as an analog-to-digital converter whose output is a wideband PCM signal (bit rate = 64 kbps).

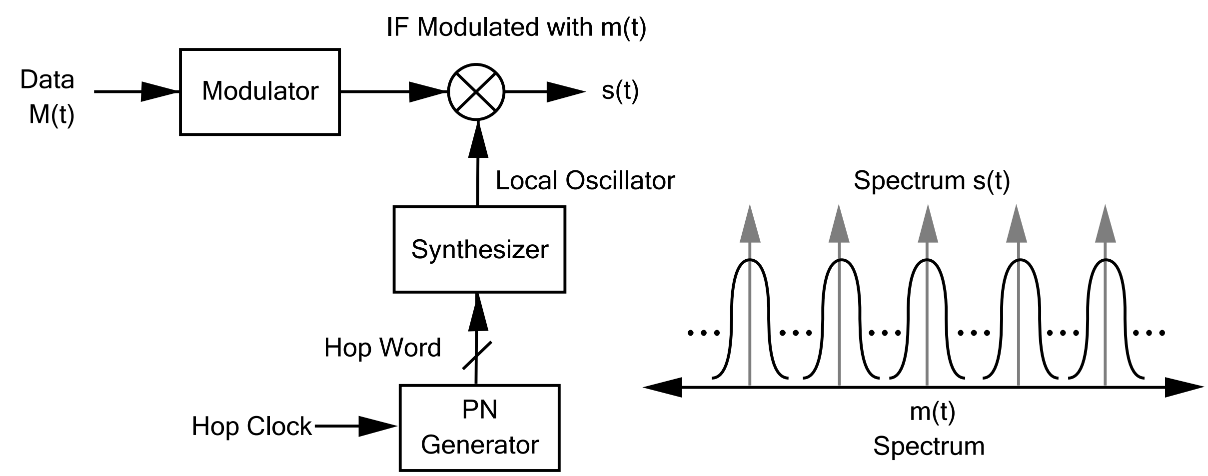
Variable Rate Vocoder

The vocoder compresses the output of the codec to a lower bit rate to reduce bandwidth. The *variable rate vocoder* takes advantage of low speech activity and transmits at lower rates, thus reducing the average transmission to about 4 kbps. The vocoder outputs frames at full, half, quarter, and eighth rates.

cdma university

Spread Spectrum Techniques – Frequency Hopped Spread Spectrum

CDMA2000 1x
RC1 & RC2
Section 2-25



MMT98010185Ag.emf

Frequency Hopped Spread Spectrum

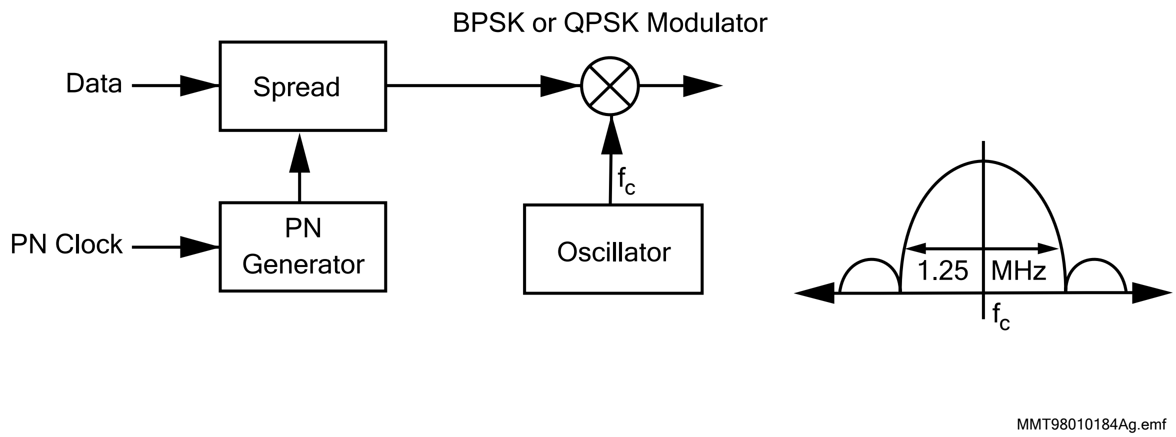
Spreading can also be achieved by hopping the narrowband information signal over a set of frequencies. This type of spreading can be classified as Fast or Slow depending on the rate of hopping to the rate of information:

- Fast hopping — the hopping rate is larger than the bit rate.
- Slow hopping — more than one bit is hopped from one frequency to another.

QUALCOMM cdma university

Spread Spectrum Techniques – Direct Sequence Spread Spectrum

CDMA2000 1x RC1 & RC2 Section 2-26



Direct Sequence Spread Spectrum

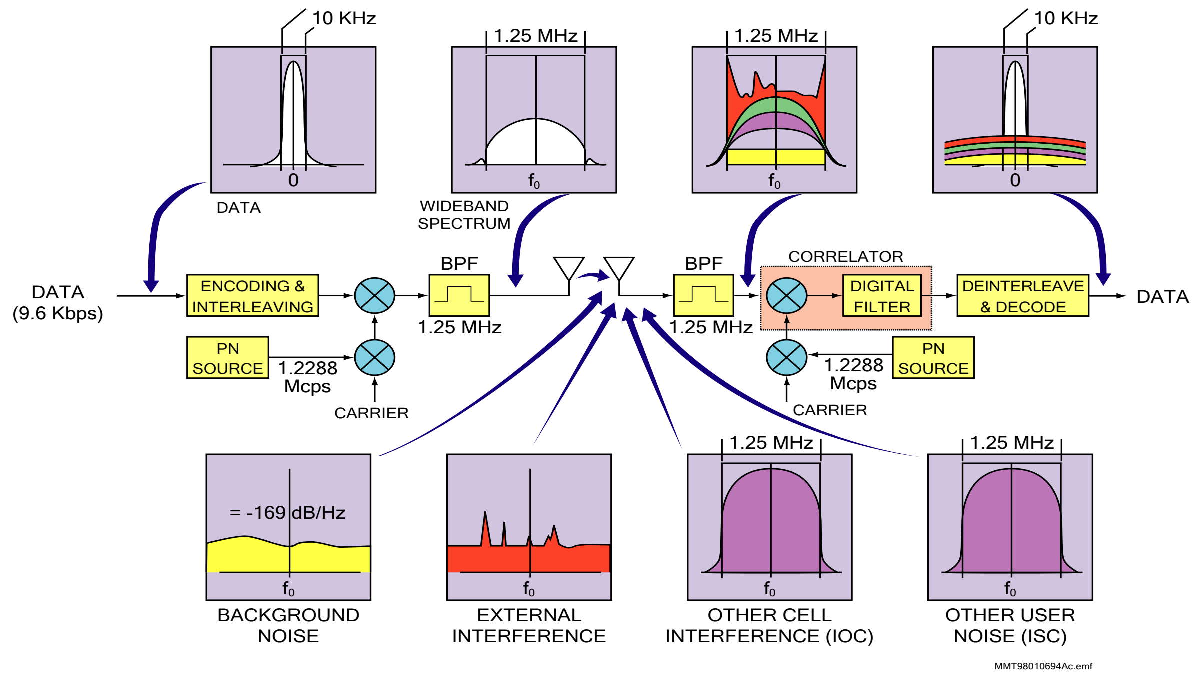
The information signal is inherently narrowband, on the order of less than 10 KHz. The energy from this narrowband signal is spread over a much larger bandwidth by multiplying the information signal by a wideband spreading code.

Direct sequence spread spectrum is the technique used in the IS-95 CDMA cellular system. The details on how this spreading is accomplished are discussed in Section 4, CDMA Physical Layer.

cdma university

Spread Spectrum Techniques – View of the CDMA Concept

CDMA2000 1x
RC1 & RC2
Section 2-27



View of the CDMA Concept

This view shows the narrowband data, spreading of the data, the receiver gathering the transmitted signal plus the various forms of interference, the despreading of the data, and how the modulator rejects the wideband interference and passes the narrowband information.

The data to be transmitted is much smaller than the spreading bandwidth. In this case, the data occupies a 10 Khz bandwidth.

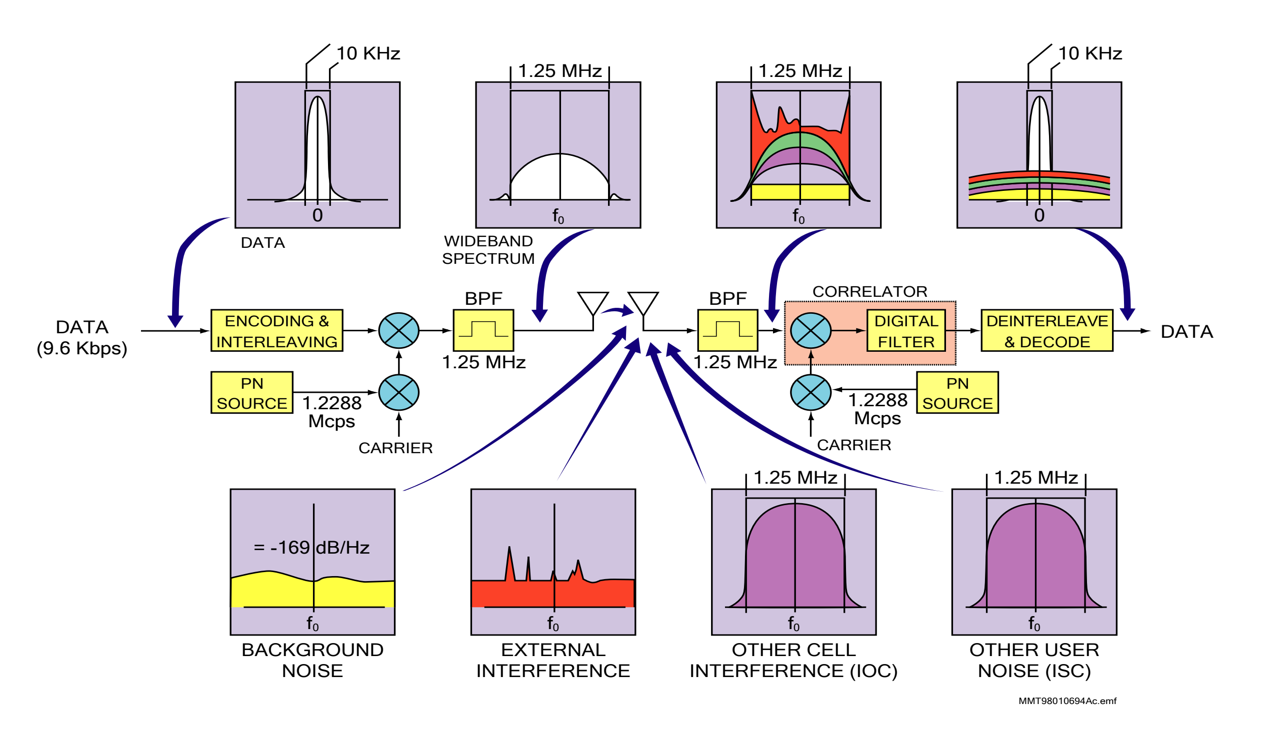
The RF carrier frequency is multiplied by the PN code with a chip rate (bit rate) of 1.2288 Mcps which results in a RF signal that is wideband.

This wideband RF/PN signal is then used to multiply the data signal, which results in a wideband signal. This wideband signal is then transmitted over-the-air to the receiver.

QUALCOMM cdma university

Spread Spectrum Techniques – View of the CDMA Concept (continued)

CDMA2000 1x
RC1 & RC2
Section 2-28



The Receiver

The receiver antenna receives the transmitted signal, thermal noise, and other interference.

To generate a wideband spreading signal that is identical to the transmit spreading signal, the receiver uses two components:

- An RF carrier of exactly the same frequency as the transmitter.
- A PN generator that generates the same PN and is exactly synchronized to the transmit PN (including the propagation delay from transmitter to receiver and the delay through the radio circuits).

When the received signal is multiplied by the receiver carrier/PN, the wideband signal is exactly un-modulated back to the original narrowband signal. The thermal noise (and other interference) is also multiplied by this carrier/PN signal and, since these signals are not correlated, their product is a wideband signal.

The demodulator then uses a narrowband filter to pass the data signal to the demodulator and reject most of the energy of the wideband interference signals. This ratio of the data bandwidth to the interference bandwidth is the Processing Gain of the spread spectrum receiver.

QUALCOMM cdma university

Capacity – Reverse Capacity Estimate

CDMA2000 1x RC1 & RC2 Section 2-29

$$\#\ \text{of users} \approx \frac{\left(\frac{W}{R}\right) G_A\, G_V}{\left(\frac{E_b}{I_o}\right)(1+f)}$$

MMT98010186Ag-rev1.emf

A Reverse Capacity Estimate

The equation in the figure is an estimate of Reverse Traffic Channel capacity. It is based on the following assumptions:

1. Each user's transmitted power is controlled so that all are received at the Base Station at equal power levels. If the received signal power of each user is S watts, and the background noise is negligible, the total interference power, I, presented to each user's demodulator is: $I = [N_{users} - 1]S$.

2. The digital demodulator for each user can operate against Gaussian noise at a bit energy-to-noise density level of E_b/I_0. This parameter is the figure of merit of the digital modem and varies typically between 3 dB and 9 dB depending on its implementation, use of error-correcting coding, channel impairments such as fading, and, of course, error rate requirements.

(continued on next page)

QUALCOMM cdma university

Capacity – Reverse Capacity Estimate (continued)

CDMA2000 1x RC1 & RC2 Section 2-30

$$\# \text{ of users} \approx \frac{\left(\frac{W}{R}\right) G_A \, G_V}{\left(\frac{E_b}{I_o}\right)(1+f)}$$

MMT98010186Ag-rev1.emf

3. Suppose further that two additional processing features are added to the spread spectrum multiple access system to diminish interference. The first is to stop transmission, or at least reduce its rate and power, when voice (or data) activity is absent or reduced. Since for a uniform population this reduces the average signal power of all users and consequently the interference received by each user, the capacity is increased proportional to this overall rate reduction, provided the user population is large enough that the weak law of large numbers guarantees that the interference is nearly at its average value most of the time. We denote this factor as the voice activity gain, G_V. By numerous measurements on two-way telephone conversations, it has been established that voice is active only about 2/5 of the time so that $G_V = 2.5$.
4. Similarly, if we assume that the population of users is uniformly distributed in area over the single isolated cell, employing a sectored antenna reduces the interference and hence increases capacity by the antenna gain factor, G_A. Note that if the users are uniformly distributed in area, this is the classical definition of (two-dimensional) antenna gain, which is the received energy in the direction of the transmitter divided by the mean received energy, averaged over the circle. For a three sectored antenna, this gain factor is less than three. If we take the loss from ideal gain to be 1 dB, $G_A = 2.4$.
5. Finally, since all users in all cells employ the common spectral allocation of W Hz, it is necessary to evaluate the interference introduced into each user's demodulator in the given cell by all users in all other cells.

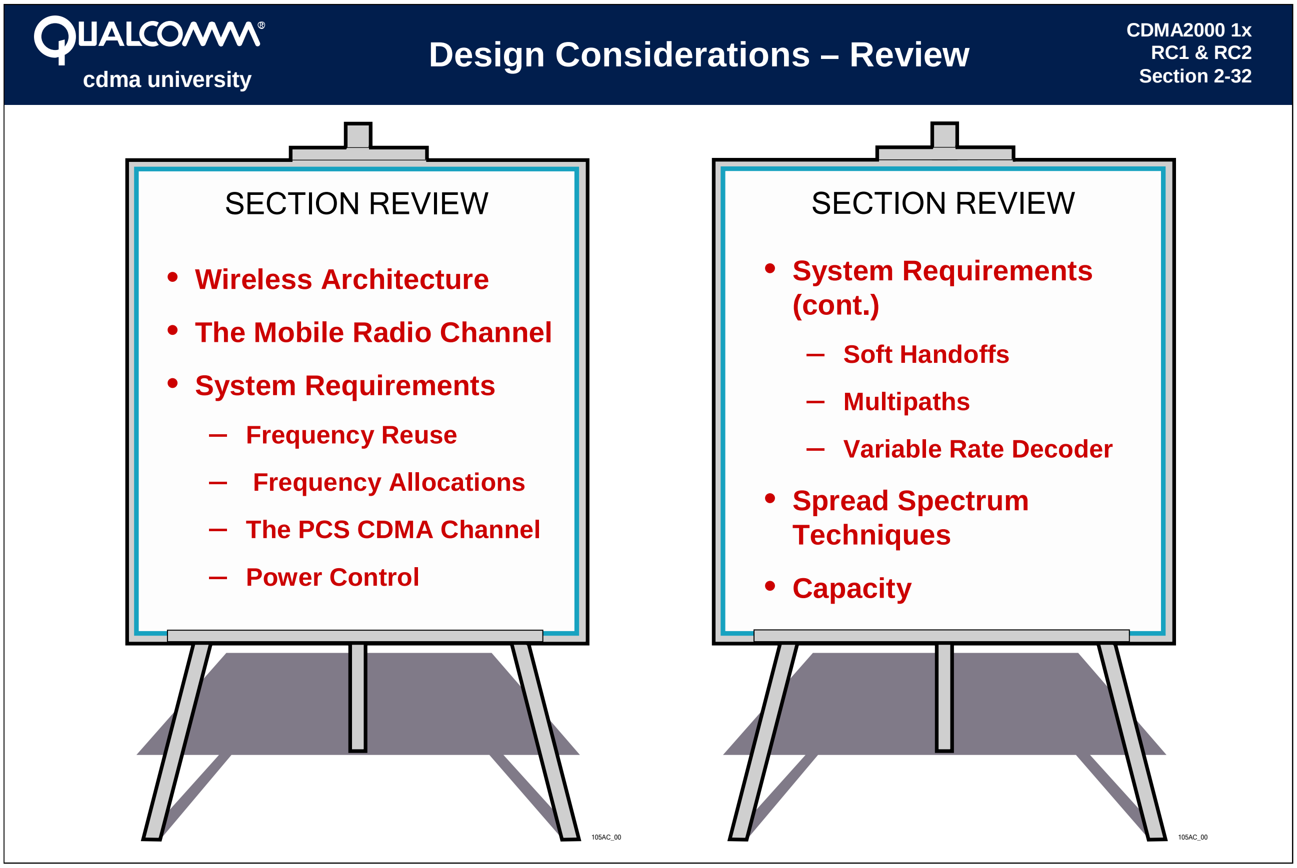
QUALCOMM cdma university

What We Learned in This Section

CDMA2000 1x RC1 & RC2 Section 2-31

- ✓ The elements of a wireless architecture.
- ✓ The characteristics of the mobile radio channel.
- ✓ The mobile subscribers' requirements.
- ✓ The limitations of conventional approaches to mobile communications.
- ✓ The basic principles of spread spectrum communications.

Notes



Review

This section addressed several factors that influenced the design of the IS-95 system.

QUALCOMM cdma university

Section 3: Codes in CDMA

SECTION 3

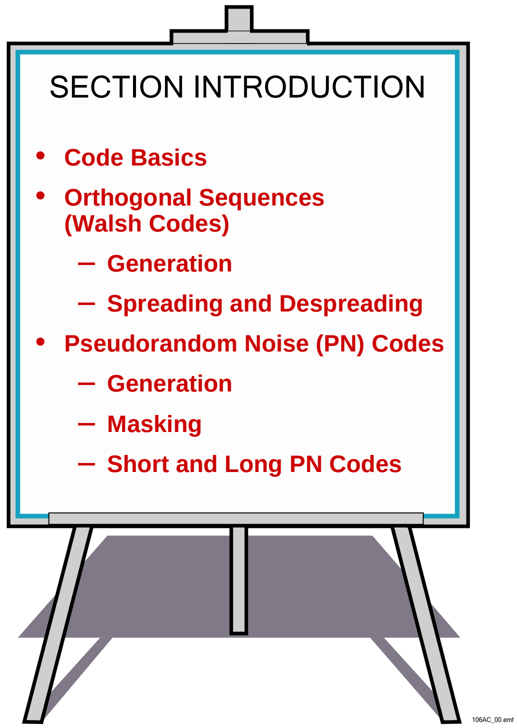
Codes in CDMA

Notes

QUALCOMM cdma university

Section Introduction

CDMA2000 1x
RC1 & RC2
Section 3-2



Section Introduction

CDMA2000 systems use two types of code sequences:

- Orthogonal sequences (Walsh codes).
- Pseudorandom noise (PN) sequences.

This section examines the basic properties of both codes.

QUALCOMM cdma university

Section Learning Objectives

CDMA2000 1x
RC1 & RC2
Section 3-3

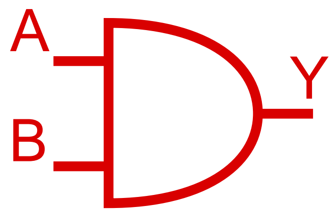
- List the two types of code sequences used in CDMA2000 systems.
- List and describe the properties of orthogonal and PN codes.
- Describe how these two code sequences are generated.
- Describe the process of spreading and despreading using these two codes.
- Describe the process of time-shifting a PN code sequence.

Notes

QUALCOMM cdma university

Code Basics – AND Function

CDMA2000 1x RC1 & RC2 Section 3-4



A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

MMT98010155Ag.emf

AND Function

The figure depicts a two-input AND gate and its corresponding truth table. A and B denote the inputs to the gate, while Y denotes its output. The AND operation (or function) is simply defined by the equation:

$$Y = \mathrm{A} \bullet \mathrm{B}$$

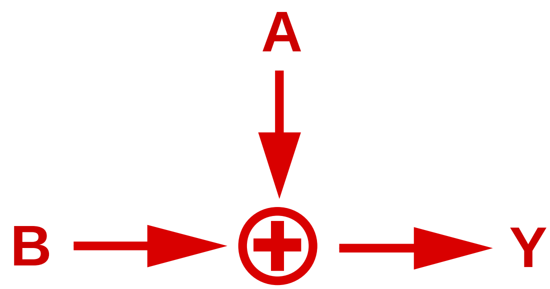
The AND gate outputs a logic “1” only when both inputs A and B are logic “1” as well. The output of the AND gate is zero if any of its inputs assumes the logic “0” state.

Understanding AND gate operation will prove useful in the discussion that follows.

cdma university

Code Basics – XOR Function

CDMA2000 1x
RC1 & RC2
Section 3-5



A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

MMT98010156Ag.emf

XOR Function

The figure depicts a two-input XOR gate and its corresponding truth table. A and B denote the inputs, while Y denotes its output. The XOR operation (or function) is simply defined by the equation:

$$Y = \mathrm{A} \oplus \mathrm{B} = \overline{\mathrm{A}} \bullet \mathrm{B} + \mathrm{A} \bullet \overline{\mathrm{B}}$$

The XOR gate produces a one when the two inputs are at opposite levels. When the total number of ones at the inputs is odd, the result of XORing them is “1”.

This operation is also needed for the upcoming discussion of codes.

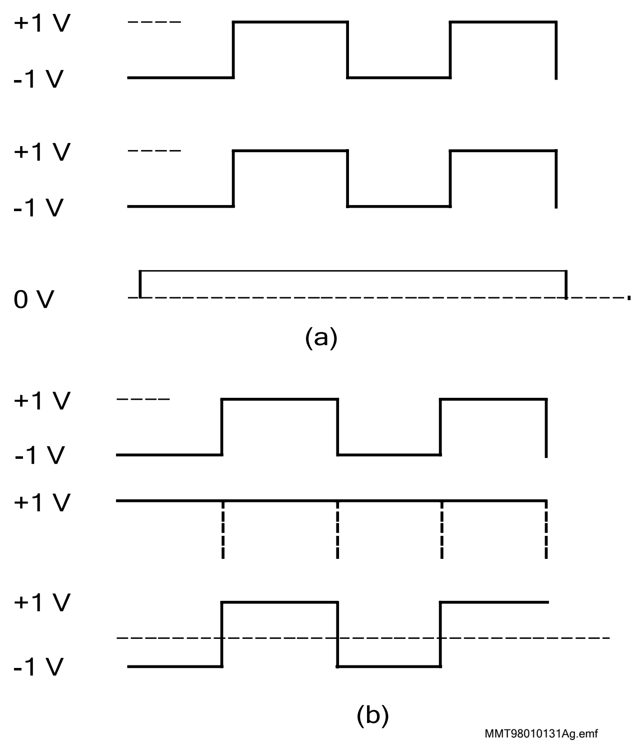
QUALCOMM cdma university

Code Basics – Correlation

CDMA2000 1x
RC1 & RC2
Section 3-6

(a)
Complete Correlation

(b)
No Correlation



Correlation

Correlation is a measure of similarity between any two arbitrary signals. It is computed by multiplying the two signals and then summing (integration) the result over a defined time window. For example:

- Figure (a) — the two signals are identical and therefore their correlation is 1 or 100%.
- Figure (b) — the two signals are uncorrelated and therefore knowing one of them does not provide any information on the other.

QUALCOMM cdma university

Orthogonal Sequences – Orthogonal Functions

CDMA2000 1x RC1 & RC2 Section 3-7

Orthogonal functions have ZERO CORRELATION. Two binary sequences are orthogonal if the process of "XORing" them results in an equal number of 1's and 0's:

EXAMPLE:

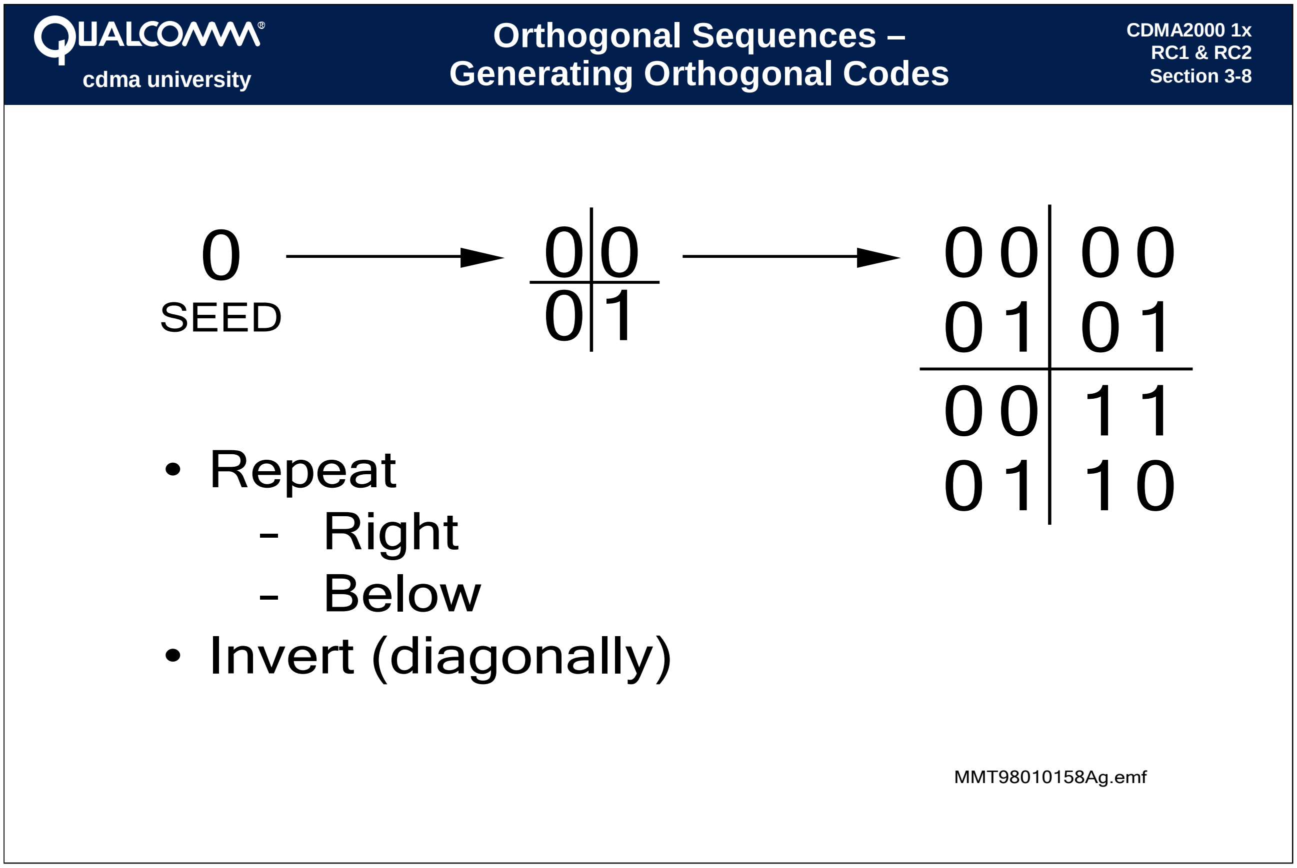
```
 0000
 0101
------
 0101
```

MMT98010157Ag.emf

Orthogonal Functions

Orthogonal functions (that is, signals or sequences) have zero cross-correlation. Zero correlation is obtained if the product of two signals, summed over a period of time, is zero.

For the special case of binary sequences, the values 0 and 1 may be viewed as having opposite polarity. Thus when the product (XORing in this case) of two binary sequences results in an equal number of 1's and 0's, the cross-correlation is zero.



Generating Orthogonal Codes

Orthogonal codes are easily generated by starting with a seed of 0, repeating the 0 horizontally and vertically, and then complementing the 0 diagonally. This process is continued with the newly-generated block until the desired codes with the proper length are generated.

Sequences created in this way are referred to as *Walsh codes*.

	0123	4567	1 8901	1111 2345	1111 6789	2222 0123	2222 4567	2233 8901	3333 2345	3333 6789	4444 0123	4444 4567	4455 8901	5555 2345	5555 6789	6666 0123
0	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
1	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101
2	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011
3	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110
4	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111
5	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010
6	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100
7	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001
8	0000	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111
9	0101	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010
10	0011	0011	1100	1100	0011	0011	1100	1100	0011	0011	1100	1100	0011	0011	1100	1100
11	0110	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001
12	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111	0000
13	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010	0101
14	0011	1100	1100	0011	0011	1100	1100	0011	0011	1100	1100	0011	0011	1100	1100	0011
15	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001	0110
16	0000	0000	0000	0000	1111	1111	1111	1111	0000	0000	0000	0000	1111	1111	1111	1111
17	0101	0101	0101	0101	1010	1010	1010	1010	0101	0101	0101	0101	1010	1010	1010	1010
18	0011	0011	0011	0011	1100	1100	1100	1100	0011	0011	0011	0011	1100	1100	1100	1100
19	0110	0110	0110	0110	1001	1001	1001	1001	0110	0110	0110	0110	1001	1001	1001	1001
20	0000	1111	0000	1111	1111	0000	1111	0000	0000	1111	0000	1111	1111	0000	1111	0000
21	0101	1010	0101	1010	1010	0101	1010	0101	0101	1010	0101	1010	1010	0101	1010	0101
22	0011	1100	0011	1100	1100	0011	1100	0011	0011	1100	0011	1100	1100	0011	1100	0011
23	0110	1001	0110	1001	1001	0110	1001	0110	0110	1001	0110	1001	1001	0110	1001	0110
24	0000	0000	1111	1111	1111	1111	0000	0000	0000	0000	1111	1111	1111	1111	0000	0000
25	0101	0101	1010	1010	1010	1010	0101	0101	0101	0101	1010	1010	1010	1010	0101	0101
26	0011	0011	1100	1100	1100	1100	0011	0011	0011	0011	1100	1100	1100	1100	0011	0011
27	0110	0110	1001	1001	1001	1001	0110	0110	0110	0110	1001	1001	1001	1001	0110	0110
28	0000	1111	1111	0000	1111	0000	0000	1111	0000	1111	1111	0000	1111	0000	0000	1111
29	0101	1010	1010	0101	1010	0101	0101	1010	0101	1010	1010	0101	1010	0101	0101	1010
30	0011	1100	1100	0011	1100	0011	0011	1100	0011	1100	1100	0011	1100	0011	0011	1100
31	0110	1001	1001	0110	1001	0110	0110	1001	0110	1001	1001	0110	1001	0110	0110	1001
32	0000	0000	0000	0000	0000	0000	0000	0000	1111	1111	1111	1111	1111	1111	1111	1111
33	0101	0101	0101	0101	0101	0101	0101	0101	1010	1010	1010	1010	1010	1010	1010	1010
34	0011	0011	0011	0011	0011	0011	0011	0011	1100	1100	1100	1100	1100	1100	1100	1100
35	0110	0110	0110	0110	0110	0110	0110	0110	1001	1001	1001	1001	1001	1001	1001	1001
36	0000	1111	0000	1111	0000	1111	0000	1111	1111	0000	1111	0000	1111	0000	1111	0000
37	0101	1010	0101	1010	0101	1010	0101	1010	1010	0101	1010	0101	1010	0101	1010	0101
38	0011	1100	0011	1100	0011	1100	0011	1100	1100	0011	1100	0011	1100	0011	1100	0011
39	0110	1001	0110	1001	0110	1001	0110	1001	1001	0110	1001	0110	1001	0110	1001	0110
40	0000	0000	1111	1111	0000	0000	1111	1111	1111	1111	0000	0000	1111	1111	0000	0000
41	0101	0101	1010	1010	0101	0101	1010	1010	1010	1010	0101	0101	1010	1010	0101	0101
42	0011	0011	1100	1100	0011	0011	1100	1100	1100	1100	0011	0011	1100	1100	0011	0011
43	0110	0110	1001	1001	0110	0110	1001	1001	1001	1001	0110	0110	1001	1001	0110	0110
44	0000	1111	1111	0000	0000	1111	1111	0000	1111	0000	0000	1111	1111	0000	0000	1111
45	0101	1010	1010	0101	0101	1010	1010	0101	1010	0101	0101	1010	1010	0101	0101	1010
46	0011	1100	1100	0011	0011	1100	1100	0011	1100	0011	0011	1100	1100	0011	0011	1100
47	0110	1001	1001	0110	0110	1001	1001	0110	1001	0110	0110	1001	1001	0110	0110	1001
48	0000	0000	0000	0000	1111	1111	1111	1111	1111	1111	1111	1111	0000	0000	0000	0000
49	0101	0101	0101	0101	1010	1010	1010	1010	1010	1010	1010	1010	0101	0101	0101	0101
50	0011	0011	0011	0011	1100	1100	1100	1100	1100	1100	1100	1100	0011	0011	0011	0011
51	0110	0110	0110	0110	1001	1001	1001	1001	1001	1001	1001	1001	0110	0110	0110	0110
52	0000	1111	0000	1111	1111	0000	1111	0000	1111	0000	1111	0000	0000	1111	0000	1111
53	0101	1010	0101	1010	1010	0101	1010	0101	1010	0101	1010	0101	0101	1010	0101	1010
54	0011	1100	0011	1100	1100	0011	1100	0011	1100	0011	1100	0011	0011	1100	0011	1100
55	0110	1001	0110	1001	1001	0110	1001	0110	1001	0110	1001	0110	0110	1001	0110	1001
56	0000	0000	1111	1111	1111	1111	0000	0000	1111	1111	0000	0000	0000	0000	1111	1111
57	0101	0101	1010	1010	1010	1010	0101	0101	1010	1010	0101	0101	0101	0101	1010	1010
58	0011	0011	1100	1100	1100	1100	0011	0011	1100	1100	0011	0011	0011	0011	1100	1100
59	0110	0110	1001	1001	1001	1001	0110	0110	1001	1001	0110	0110	0110	0110	1001	1001
60	0000	1111	1111	0000	1111	0000	0000	1111	1111	0000	0000	1111	0000	1111	1111	0000
61	0101	1010	1010	0101	1010	0101	0101	1010	1010	0101	0101	1010	0101	1010	1010	0101
62	0011	1100	1100	0011	1100	0011	0011	1100	1100	0011	0011	1100	0011	1100	1100	0011
63	0110	1001	1001	0110	1001	0110	0110	1001	1001	0110	0110	1001	0110	1001	1001	0110

MMT98010159Ag.eps

Generating Orthogonal Codes (continued)

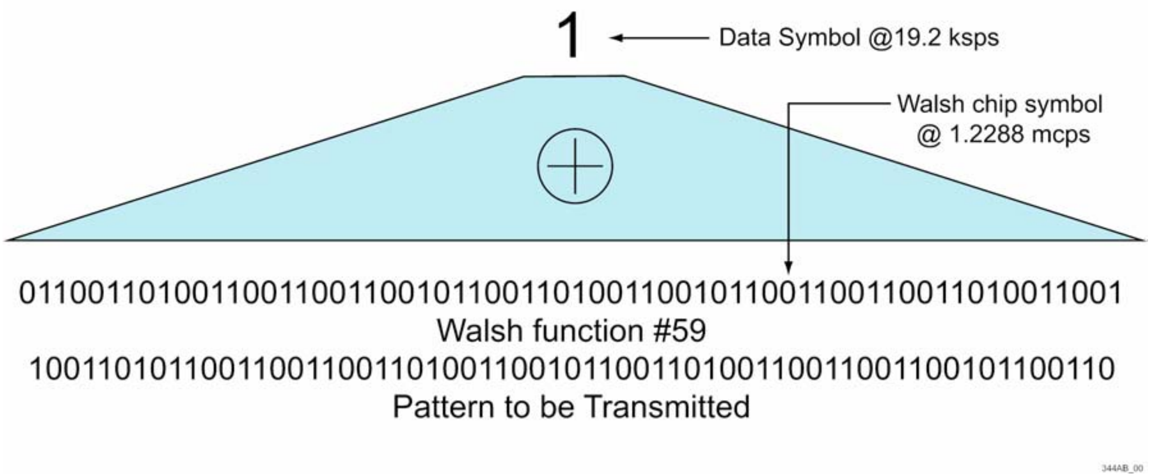
The orthogonal sequences currently used in terrestrial CDMA2000 systems are Walsh codes of length 64.

- In the Forward CDMA link, Walsh codes are used to separate users. In any given sector, each Forward Channel is assigned a distinct Walsh code.
- In the Reverse CDMA link, the 64 Walsh sequences are used as a signaling set by the Baseband Orthogonal Modulator.

QUALCOMM cdma university

Orthogonal Sequences – Orthogonal Spreading

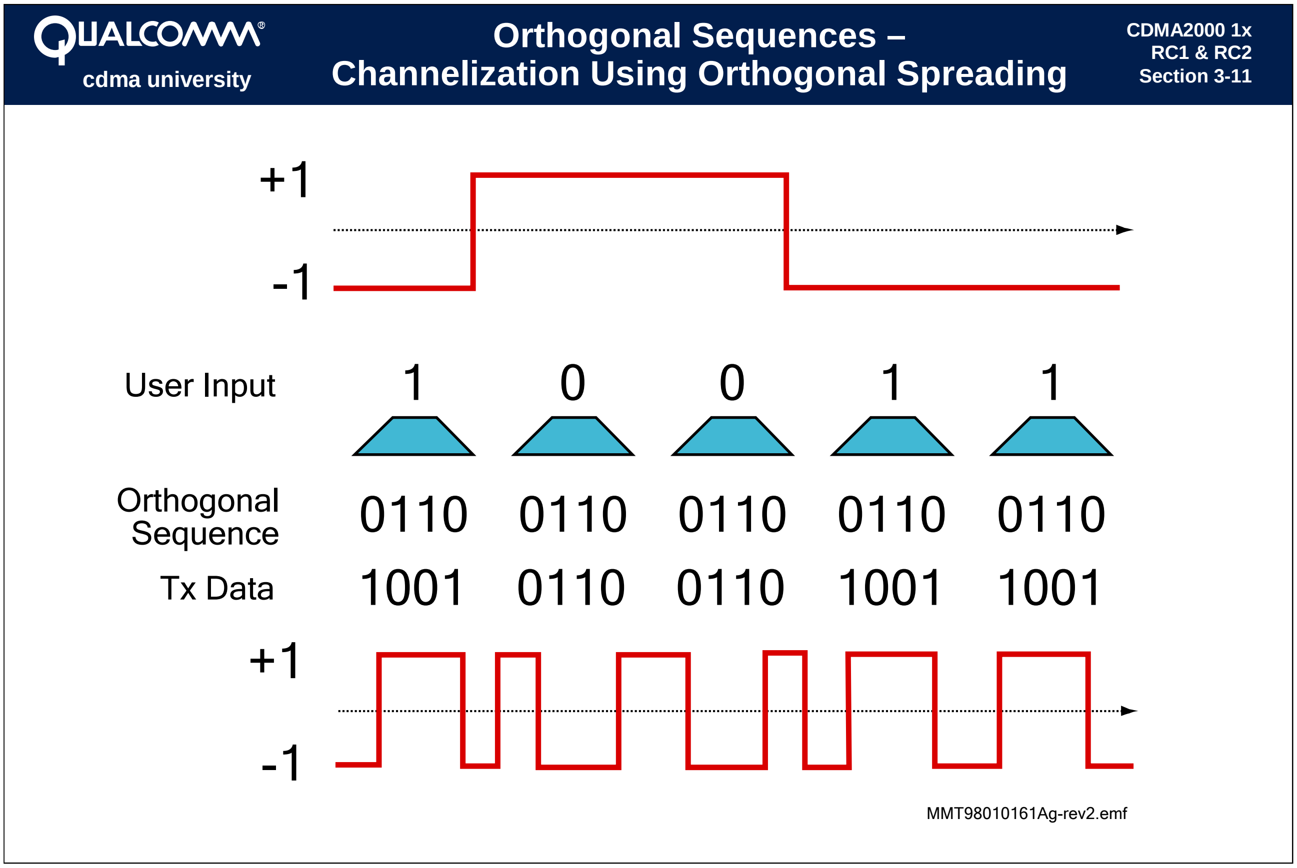
CDMA2000 1x RC1 & RC2 Section 3-10



Orthogonal Spreading

The principle behind spreading and despreading is that when a symbol is XORed with a known pattern and the result is again XORed with the same pattern, the original symbol is recovered. In other words, the effect of an XOR operation if performed twice using the same code is null.

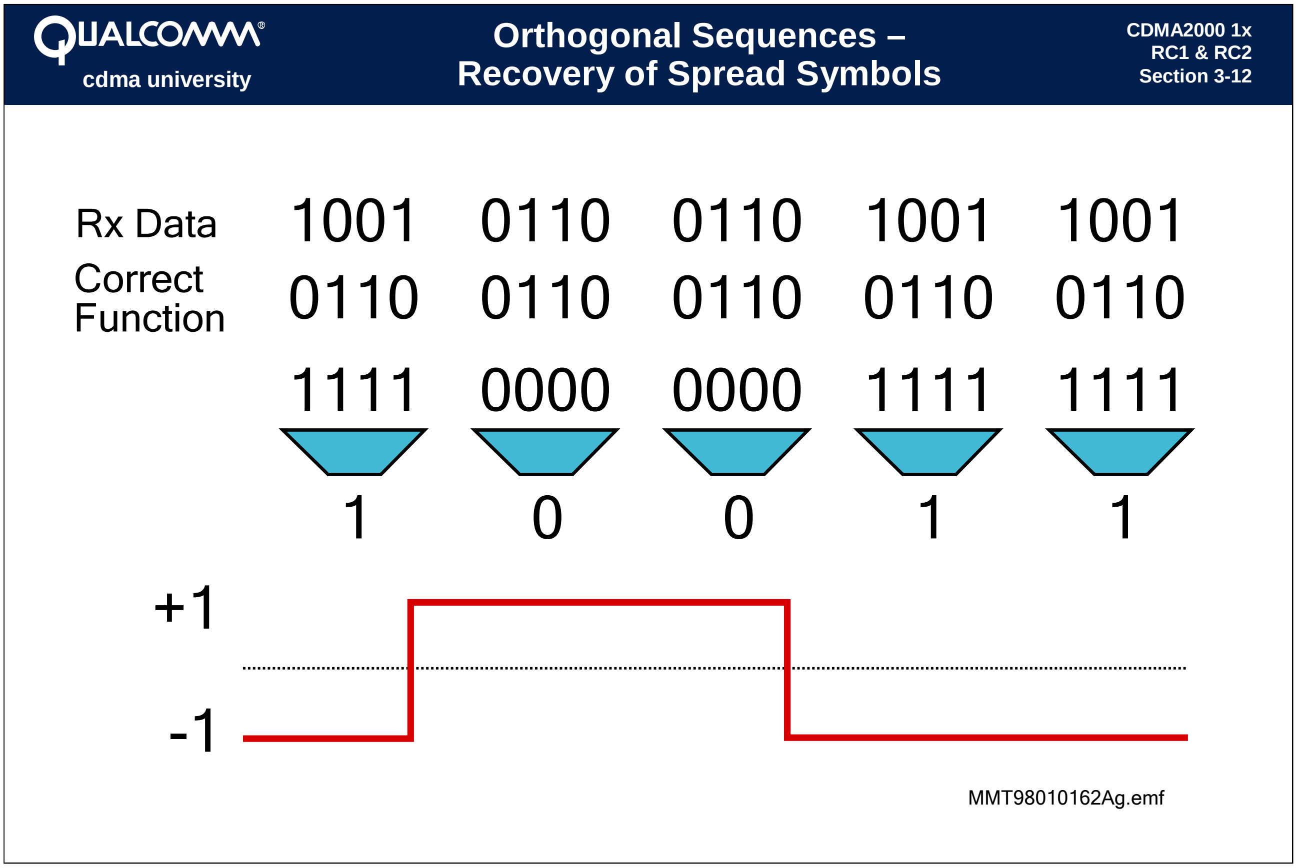
In orthogonal spreading, each encoded symbol is XORed with all 64 chips of the Walsh code. For example, in the figure a symbol of value “1” is orthogonally spread with Walsh code 59, thus yielding a 64-chip representation of the symbol.



Example of Channelization Using Orthogonal Spreading

By spreading, each symbol is XORed with all the chips in the orthogonal sequence (Walsh sequence) assigned to the user. The resulting sequence is processed and is then transmitted over the Physical Channel along with other spread symbols.

In this figure, a 4-digit code is used. The product of the user symbols and the spreading code is a sequence of digits that must be transmitted at 4 times the rate of the original encoded binary signal.



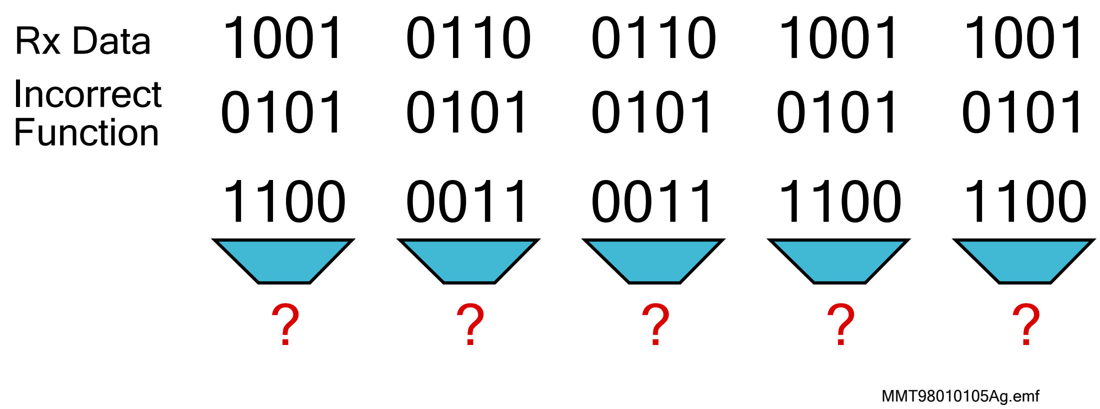
Recovery of Spread Symbols

The receiver despreads the chips by using the same Walsh code used at the transmitter. Notice that under no-noise conditions, the symbols or digits are completely recovered without any error. In reality, the channel is not noise-free, but CDMA2000 systems employ Forward Error Correction (FEC) techniques to combat the effects of noise and enhance the performance of the system.

QUALCOMM cdma university

Orthogonal Sequences – Recovery of Spread Symbols using Wrong Function

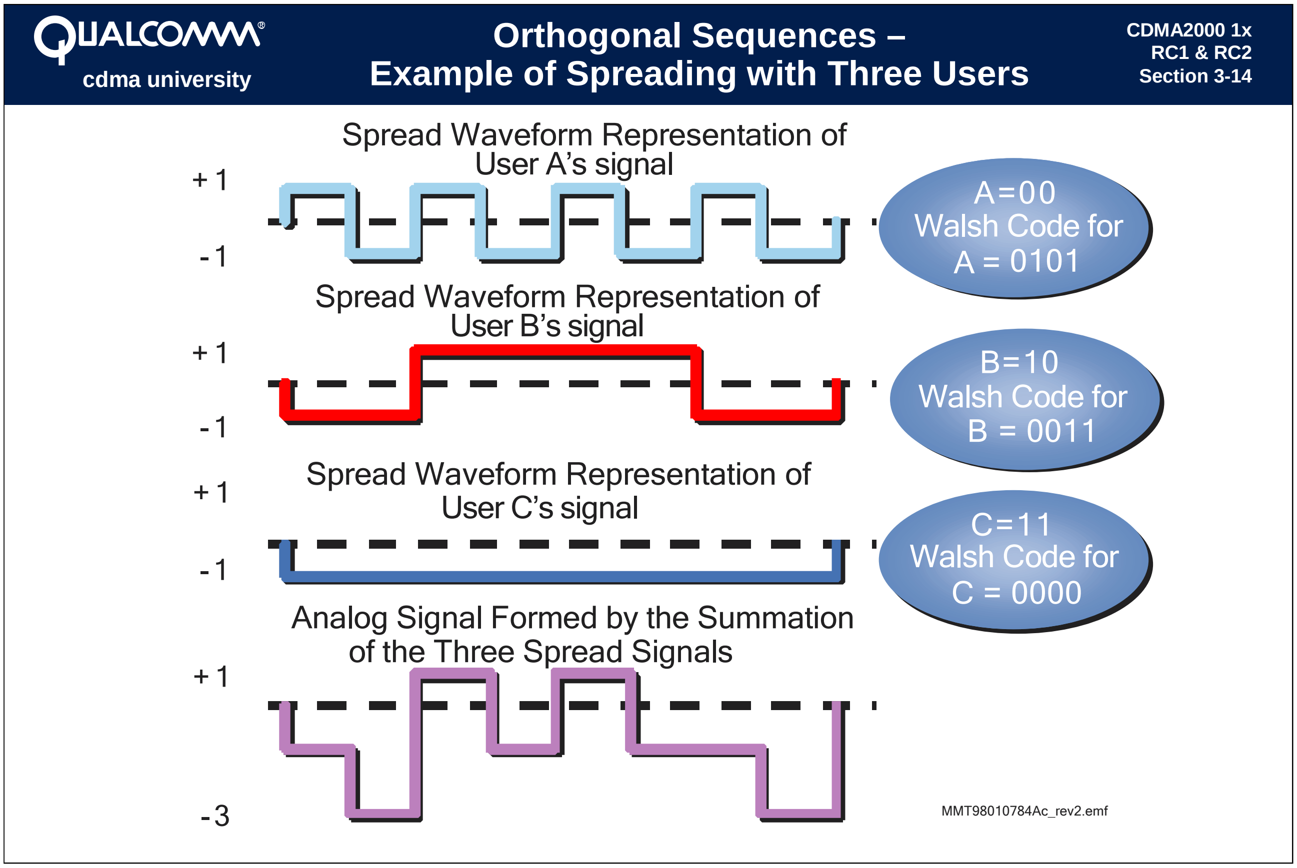
CDMA2000 1x RC1 & RC2 Section 3-13



Recovery of Spread Symbols using Wrong Function

When the wrong Walsh sequence is used for despreading, the resulting correlation yields an average of zero. This clearly demonstrates the advantage of the orthogonality property of the Walsh codes.

Whether the wrong code is mistakenly used by the target user or by other users attempting to decode the received signal, the resulting correlation is always zero because of the orthogonality property of the Walsh sequences.



An Example of Spreading with Three Subscribers

In this example, three users, A, B, and C are assigned three orthogonal codes for spreading purposes:

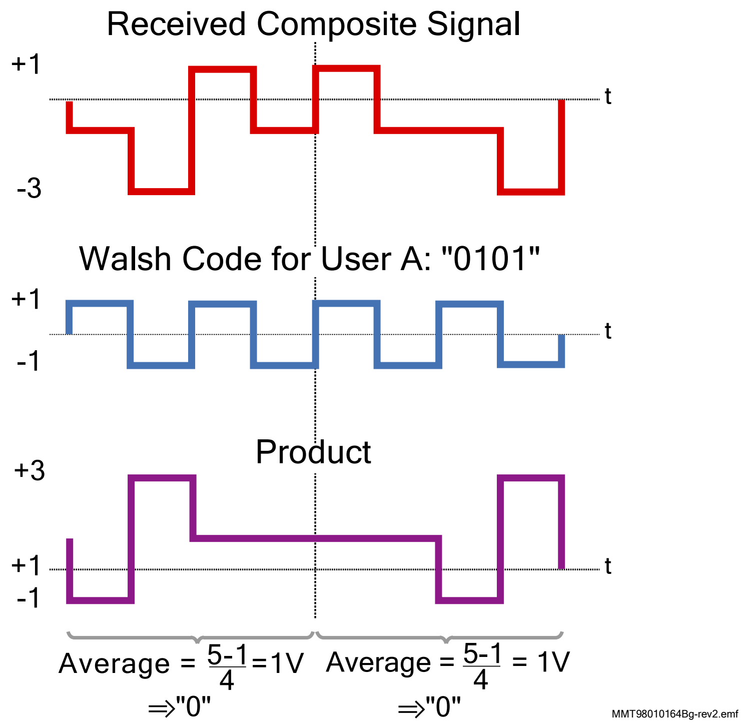
- User A signal = 00, Spreading Code = 0101
- User B signal = 10, Spreading Code = 0011
- User C signal = 11, Spreading Code = 0000

The analog signal shown on the bottom of the figure is the composite signal when all of the spread symbols are summed together.

QUALCOMM cdma university

Orthogonal Sequences – Despreading Example

CDMA2000 1x RC1 & RC2 Section 3-15



Despreading Example

At the receiver of user A, the composite analog signal is multiplied by the Walsh code corresponding to user A and the result is then averaged over the symbol time. This process is called correlation. Note that the average voltage value over one symbol time is equal to 1. Therefore, the original bit transmitted by A was “0”.

You may try to decode the symbols for users B or C in the same manner. This process occurs in the CDMA mobile for recovering the signals.

QUALCOMM cdma university

Orthogonal Sequences – Walsh Usage

CDMA2000 1x RC1 & RC2 Section 3-16

- RC1 and RC2 use Walsh 64.
- RC3 through RC9 use variable length Walsh functions.
  - 1x typically uses 64 and 128 length.
- Length is a function of data rate.
- For 1x the Walsh chip rate is always 1.2288 Mcps.

Walsh Usage

Since RC1 and RC2 are the TIA/EIA-95 mode, only Walsh 64 is used.

RC3 through RC9 use variable length Walsh functions to handle different data rates. For RC3, voice calls use Walsh 64, while for RC4 voice calls use Walsh 128.

The higher the data rate, the shorter the Walsh function used. This is because the chip rate for the Walsh function is constant (1.2288 Mcps for 1x), and the full length of the Walsh function must be employed for each data bit.

QUALCOMM cdma university

Orthogonal Sequences – Walsh Space

CDMA2000 1x RC1 & RC2 Section 3-17

Capacity of new Traffic Channels (RC3 and up) can exceed Walsh 64 space.

- Use RC4 with Walsh 128 space.
- Use QOF (Quasi Orthogonal Functions).
- With variable data rates and higher capacity Walsh space planning is more difficult for RC3 and up.
- Release A has many new physical channels; each requires a unique Walsh code.

Walsh Space

With the increased capacity of CDMA2000, environments exist where the capacity may exceed 64 channels. In this case RC4 could be employed since it uses Walsh 128, or the QOF functions could be employed to augment the smaller Walsh 64 space. Quasi Orthogonal Functions are not perfectly orthogonal, so they do create some interference in the Forward link signal.

The use of the higher data rates requires shorter Walsh functions, and these shorter functions are the seed function for longer functions. Thus when a high data rate channel is employed using a short Walsh function, this precludes using Walsh functions of longer length that have the short function as seed.

QUALCOMM cdma university

PN Codes

CDMA2000 1x RC1 & RC2 Section 3-18

PN Codes:

Maximum Length Pseudorandom Binary Sequences

Properties:

- Balance
- Run-Length
- Shift and Add
- Autocorrelation

Pseudorandom Noise (PN) Codes

Maximum Length Pseudorandom Binary Sequences

- **Pseudorandom:** Of, relating to, or being random numbers generated by a *deterministic* process.
- **Binary:** Takes on one of two values.
- **Maximum Length:** Maximum achievable period of a generated sequence – not arbitrary.

Properties

- **Balance property:** The output sequence will have an almost equal number of zeros and ones (2^{r-1} ones and $2^{r-1} - 1$ zeros).
- **Run-length property:** In any period, half of the runs of consecutive zeros or ones are of length one, one-fourth are of length two, one-eighth are of length three, etc.
- **Shift and add property:** The chip-by-chip sum of the output sequence C_k and any shift of itself C_{k+t}, τ ¼ 0 is a time-shifted version of the same sequence.
- **Autocorrelation property:** This property will be discussed in a later slide in this section.

PN Balance

Maximal Length PN codes have one more one than zeros. Not all PN codes have this good behavior.

This balance of ones and zeros gives the PN code good noise-like properties that are important to CDMA2000.

QUALCOMM cdma university

PN Codes – One-Zero Distribution

CDMA2000 1x RC1 & RC2 Section 3-20

The number of runs of each length is a decreasing power of 2 as the run length increases.

Distribution of Runs for a $2^7 - 1$ Bit *m*-Sequence

Run Length (bits)	Number of Runs: Ones	Number of Runs: Zeros	Number of Bits Included
1	16	16	32
2	8	8	32
3	4	4	24
4	2	2	16
5	1	1	10
6	0	1	6
7	1	0	7
			127 total

Adapted from R.C. Dixon, *Spread Spectrum Systems*

One-Zero Distribution

With the Run Length distribution as shown in the above slide, the power spectral density of the PN code is flat with frequency (or “white”) which means that when it is used for spreading, the energy of the spread waveform is evenly spread across the wideband signal.

PN Codes – Code Isolation

Each Base Station is assigned a unique PN code offset that is modulated on top of the Walsh code.

- Each sector of a Base Station is unique.
- Necessary because each Base Station uses the same Walsh code set.

Code Isolation

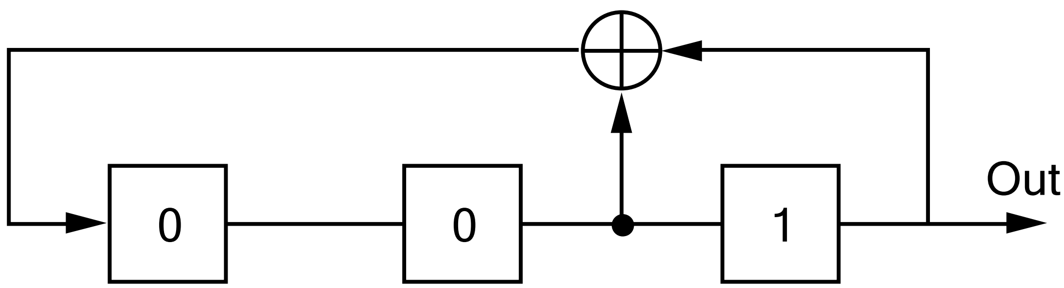
The Short PN is used as the final step in the spread spectrum modulation, and this makes the Forward link from each sector a unique waveform, since every sector has a different Short PN offset.

The entire set of Walsh functions is reused in each sector.

QUALCOMM cdma university

PN Codes – Generation

CDMA2000 1x
RC1 & RC2
Section 3-22



- Seed Register with 001
- Output will be a 7-digit sequence that repeats continually: 1001011

MMT98010166Ag.emf

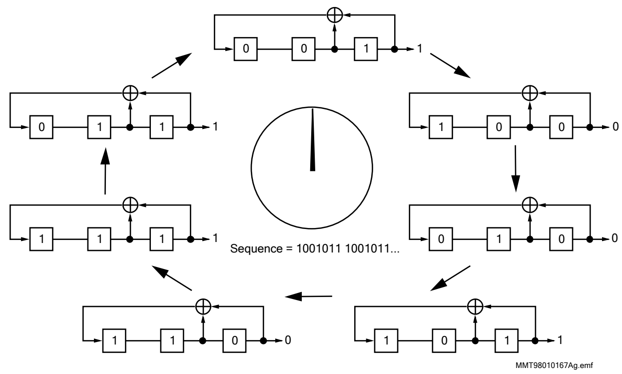
PN Code Generation

PN codes are generated from prime polynomials using modulo 2 arithmetic. The state machines generating these codes are very simple and consist of shift registers and XOR gates.

QUALCOMM cdma university

PN Codes – Generation (continued)

CDMA2000 1x
RC1 & RC2
Section 3-23



Clock Pulse	D3	D2	D1
0	0	0	1
1	1	0	0
2	0	1	0
3	1	0	1
4	1	1	0
5	1	1	1
6	0	1	1
7	0	0	1

MMT98010168Ag.emf

Shift Registers

PN codes are maximum length. In general, if there are N shift registers (N = number of shift registers), the length of the PN code is equal to 2^N-1.

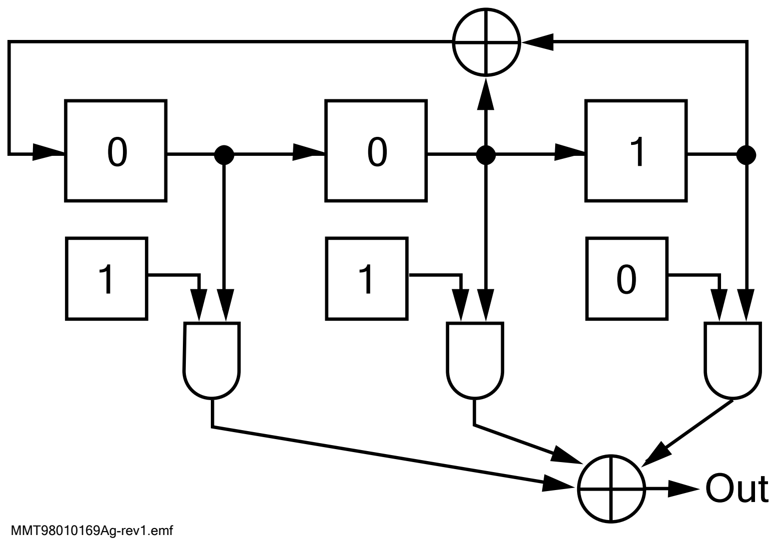
In this example, the number of distinct states in the shift registers is 2^3-1=7.

QUALCOMM cdma university

PN Codes – Masking

CDMA2000 1x
RC1 & RC2
Section 3-24

Masking will cause the generator to produce the same sequence, but offset in time.



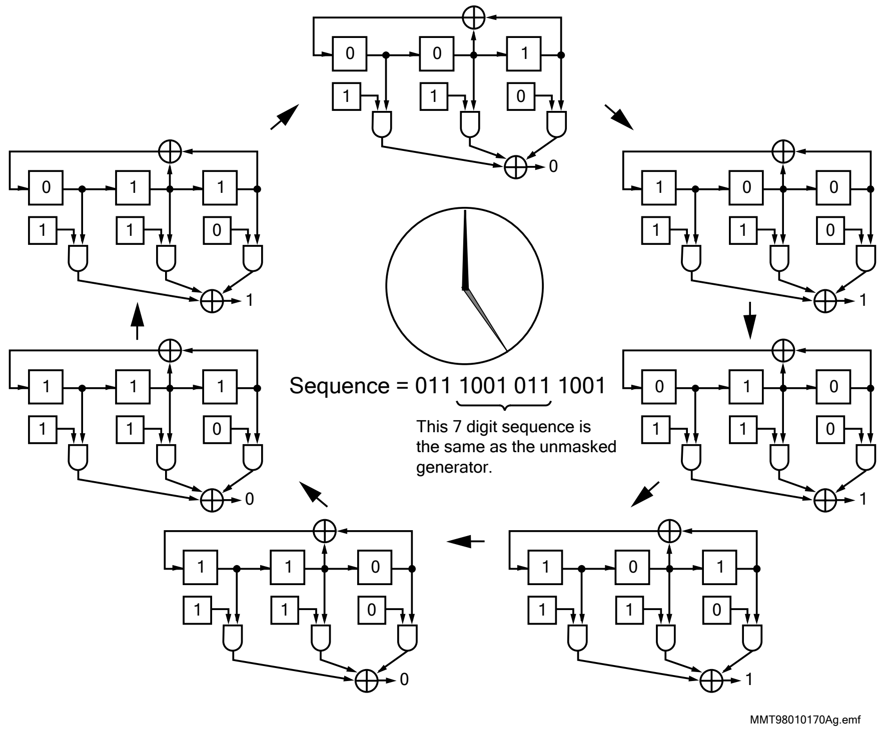
PN Offset (Masking)

Masking provides the shift in time for PN codes. Different masks correspond to different time shifts. In CDMA2000 systems, Electronic Serial Numbers (ESN) are used as masks for users on the Traffic Channels.

QUALCOMM cdma university

PN Codes – Masking (continued)

CDMA2000 1x RC1 & RC2 Section 3-25



Sequence Produced by a Masked Generator

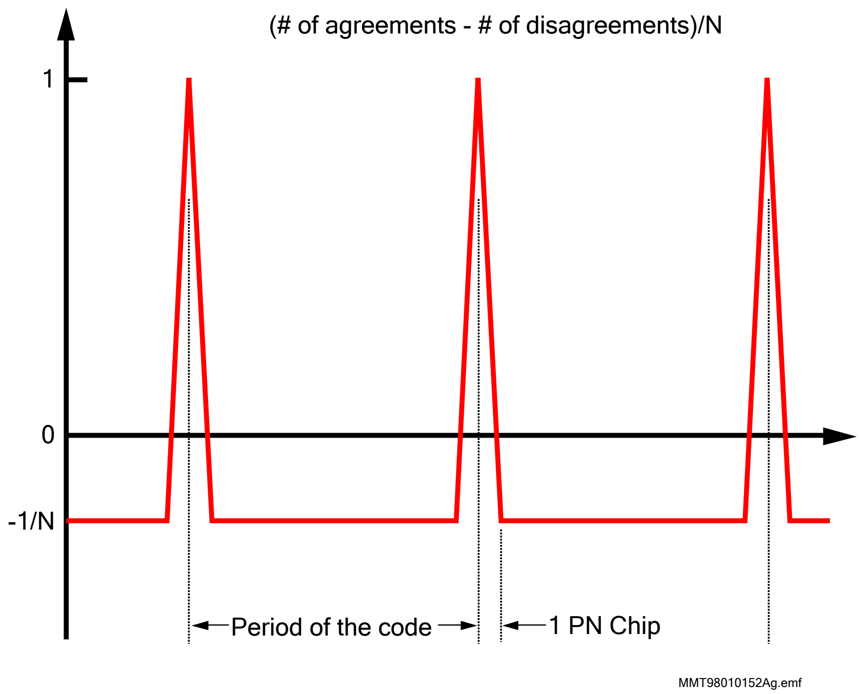
This example illustrates how a mask produces the same original sequence shifted in time.

The content of the 3-digit mask determines the offset of the sequence. Masking is used to produce offsets in both the short codes and the long code. The offsets of the short PN codes are used to uniquely identify the Forward channels of individual sectors or cells. The offsets of the Long PN code are used to separate code channels in the Reverse direction.

QUALCOMM cdma university

PN Codes – Autocorrelation of a PN Code

CDMA2000 1x RC1 & RC2 Section 3-26



Autocorrelation of a Pseudorandom Noise Code

PN sequences have an important property: time-shifted versions of the same PN sequence have very little correlation with each other.

Autocorrelation is the measure of correlation between a PN code and a time-shifted version of the same code. The figure shows the autocorrelation function, and it is clear that it is a two-valued function. As long as the time shift is greater than the chip time, correlation is very small.

The channelization of users in the Reverse link is accomplished by assigning them different time-shifted versions of the long code, thus making them uncorrelated with each other. This property is then exploited to separate subscribers' signals in the BTS receivers.

QUALCOMM cdma university

PN Codes – Short and Long

CDMA2000 1x RC1 & RC2 Section 3-27

- Two Short Codes (2^{15} = 32,768)
  - Termed "I" and "Q" codes (different taps)
  - Used for Quadrature Spreading
  - Unique offsets serve as identifiers for a Cell or a Sector
  - Repeat every 26.67 msec (at a clock rate of 1.2288 Mcps)
- One Long Code (2^{42} - 1 = 4400 Billion)
  - Used for spreading and scrambling
  - Repeats every 41 days (at a clock rate of 1.2288 Mcps)

MMT98010165Ag-rev1.emf

Short and Long PN Codes

The two short codes and one long code used in CDMA systems are time-synchronized to midnight, January 6, 1980 (GPS time). In CDMA2000 systems, all Base Stations and all mobiles use the same three PN sequences.

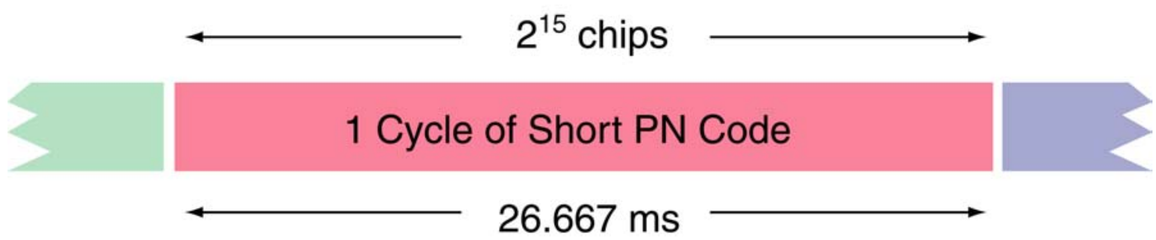
The two short codes are the same length, but are different codes. The codes are different patterns of ones and zeros because the feedback used to make the PN generator is tapped at different shift register outputs

A true Maximal Length PN code has a length of 2^N –1 bits. The short codes used in CDMA2000 have been modified by adding an extra zero to increase the length to an even number of bits. This makes the system design and hardware design easier to implement.

QUALCOMM cdma university

PN Codes – Short PN

CDMA2000 1x RC1 & RC2 Section 3-28



Short PN Code

The short PN code repeats every 26.667 ms, with length 2^{15} chips. Each sector of a Base Station uses the same short code phase to spread all the signals from that sector. Each sector uses a unique time offset.

The mobile can discern these unique offsets and thus identify the different sectors of the cellular system. It is desirable to have many unique offsets to make system planning easy.

With 512, or 2^9, unique offsets, then offsets occur every 64 chips, or 2^6.

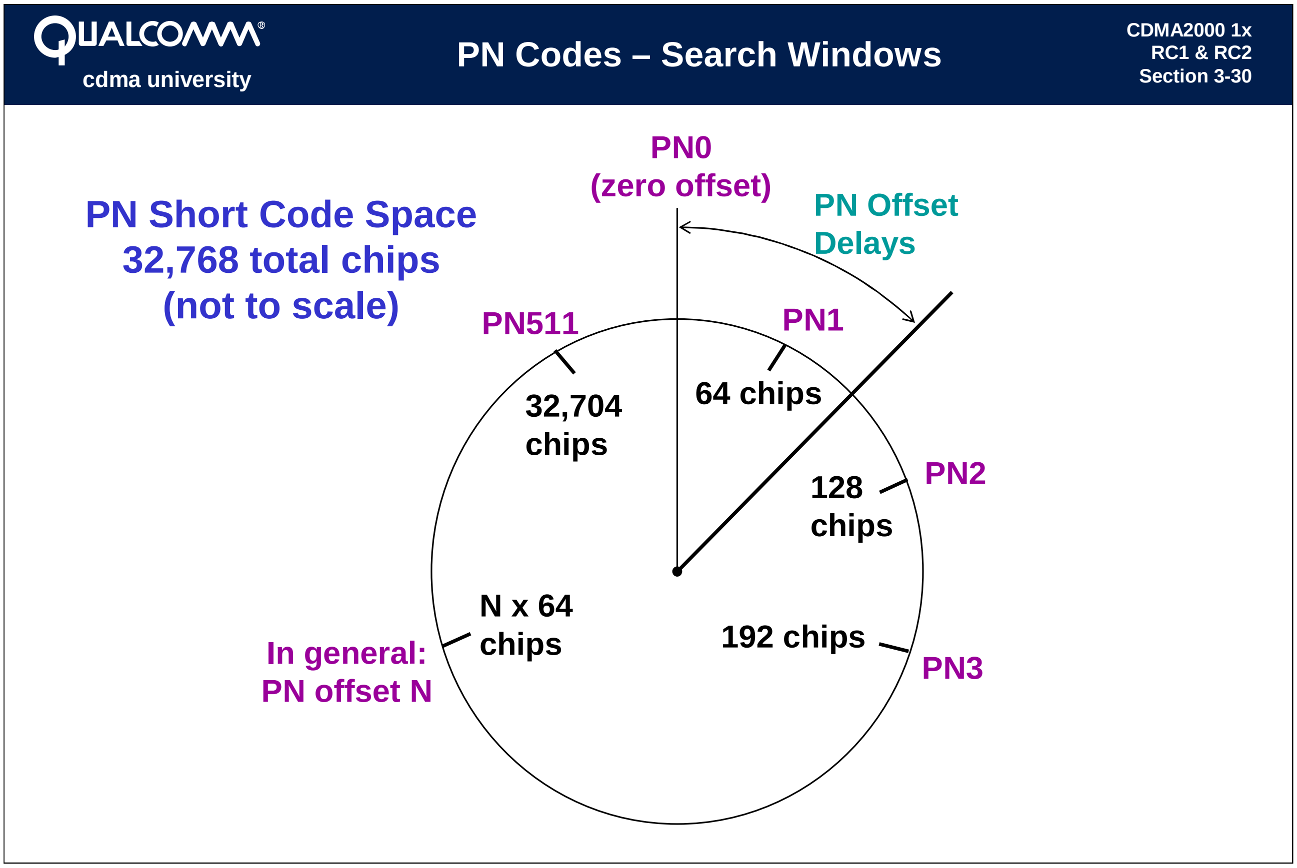
PN Codes – Chips vs. Distance

With the speed of light at 3E8 m/sec, and 1 chip of PN at 814nS:

- In one chip time the speed of light (or the speed of the radio wave) moves 244 m.
- Or about 4 chips per Km, 6 chips per mile.

Chips vs. Distance

The Base Stations radiate the Short PN code at the correct time, and due to the speed of radio waves, these signals arrive at the mobile at a later time. The mobile does not know the distance to the Base Station, so the mobile timing is offset from the true system time by the one-way path delay.



Search Windows

The Short PN is offset in groups of 64 bits because the delay ambiguity of the mobile can be many chips in a real system due to the speed of light.

Most commercial networks use a PN increment of 4, resulting in an offset between sectors of 256 chips.

What We Learned in This Section

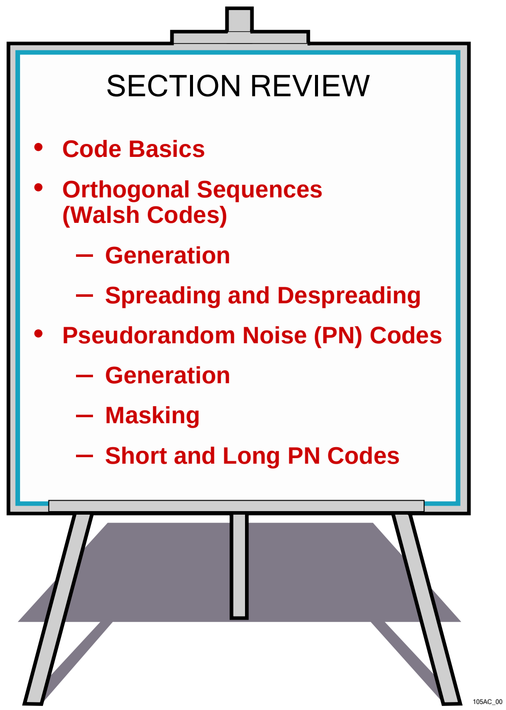
- ✓ The two types of code sequences used in CDMA2000 systems.
- ✓ The properties of orthogonal and PN codes.
- ✓ How these two code sequences are generated.
- ✓ The process of spreading and despreading using these two codes.
- ✓ The process of time-shifting a PN code sequence.

Notes

QUALCOMM cdma university

Codes in CDMA – Review

CDMA2000 1x RC1 & RC2 Section 3-32



Notes

QUALCOMM cdma university

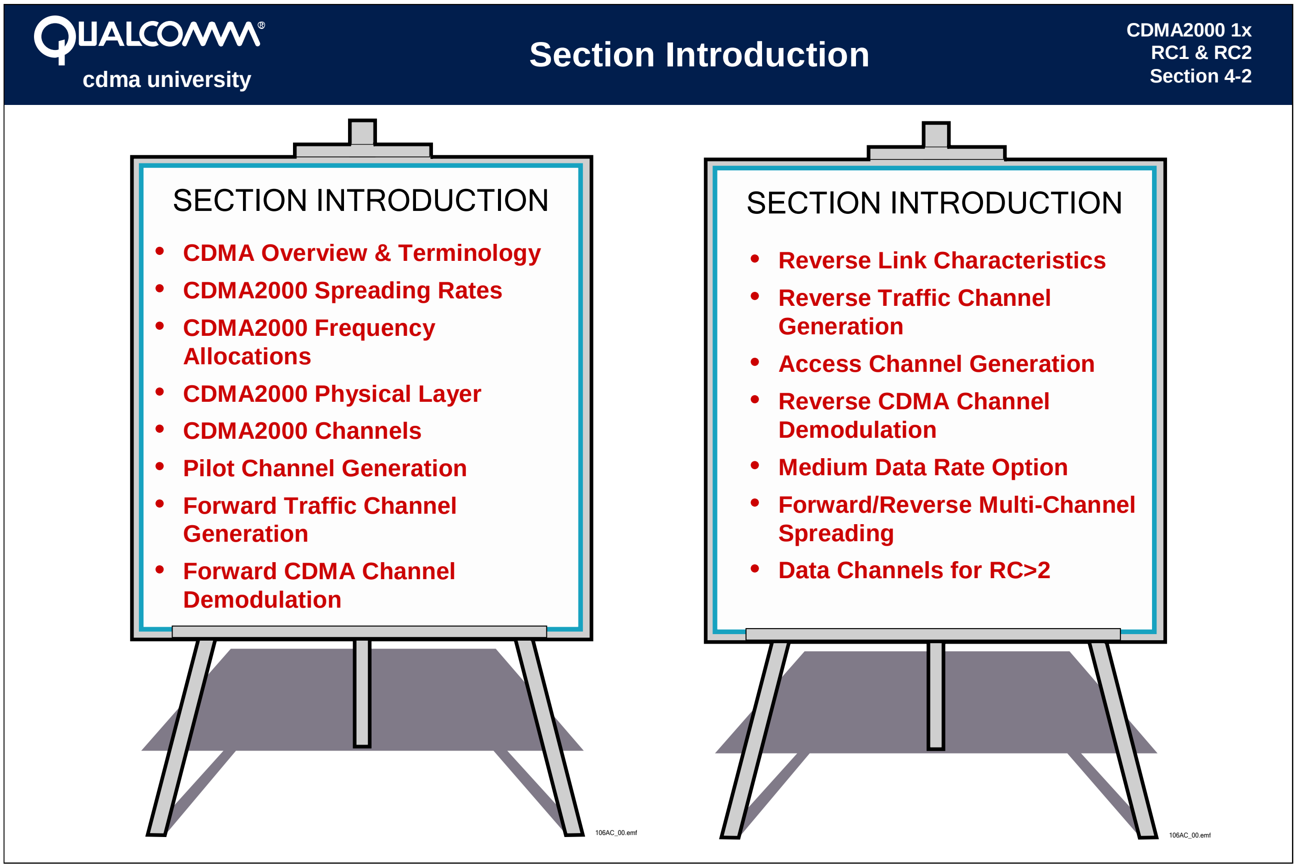
Section 4: CDMA Physical Layer

CDMA2000 1x
RC1 & RC2
Section 4-1

SECTION
4

CDMA Physical Layer

Notes



Section Introduction

TIA/EIA-95 and CDMA2000 provide a detailed specification for the generation of spread spectrum signals. This section carefully discusses these details, along with the rationale for many of the design decisions.

The standard, however, contains no details on demodulation. Consequently, this section provides only a brief overview of the structure and processes performed in the demodulators.

QUALCOMM cdma university

Section Learning Objectives

CDMA2000 1x RC1 & RC2 Section 4-3

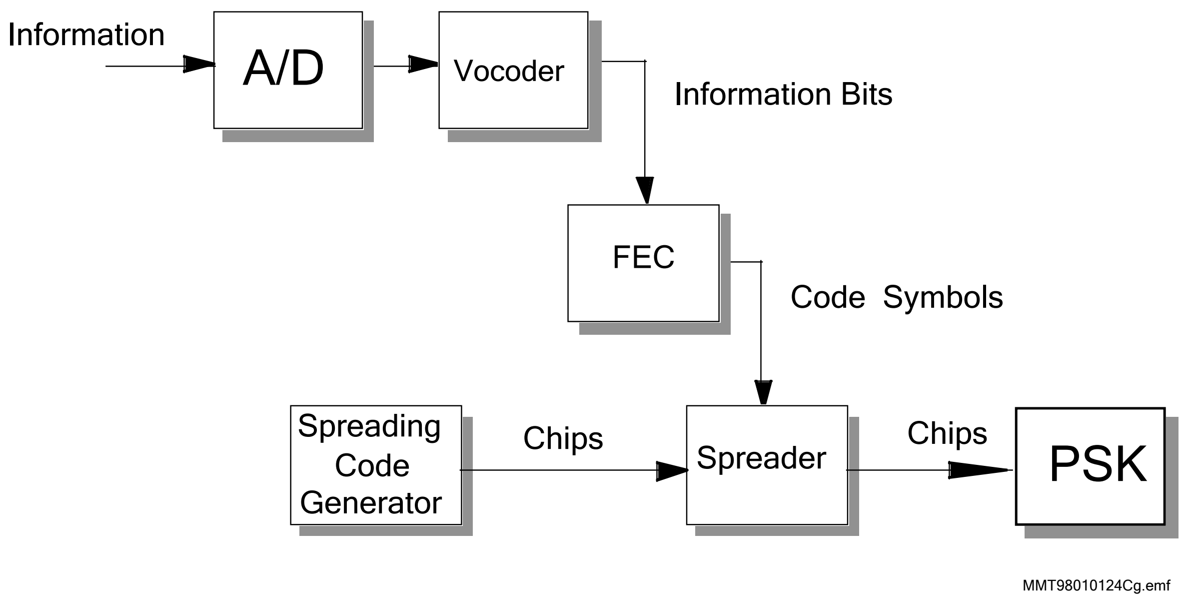
- Describe the generation of the CDMA waveforms in both the Forward and Reverse directions.
- List the CDMA code channels.
- List the steps in the generation of each code channel.
- Explain the rationale for each step.
- Describe the demodulation of the Forward and Reverse CDMA channels.

Notes

QUALCOMM cdma university

CDMA Overview & Terminology – Bits, Symbols, and Chips

CDMA2000 1x RC1 & RC2 Section 4-4



An Overview of CDMA2000 Modulation

CDMA2000 systems convert the analog voice signal into a digital signal for transmission. There are several steps in the digital transmission process. Many of these steps are common to digital wireless schemes. After each step in digital processing, the signal conveys a different meaning and several terms are used to refer to the signal at different stages in the process.

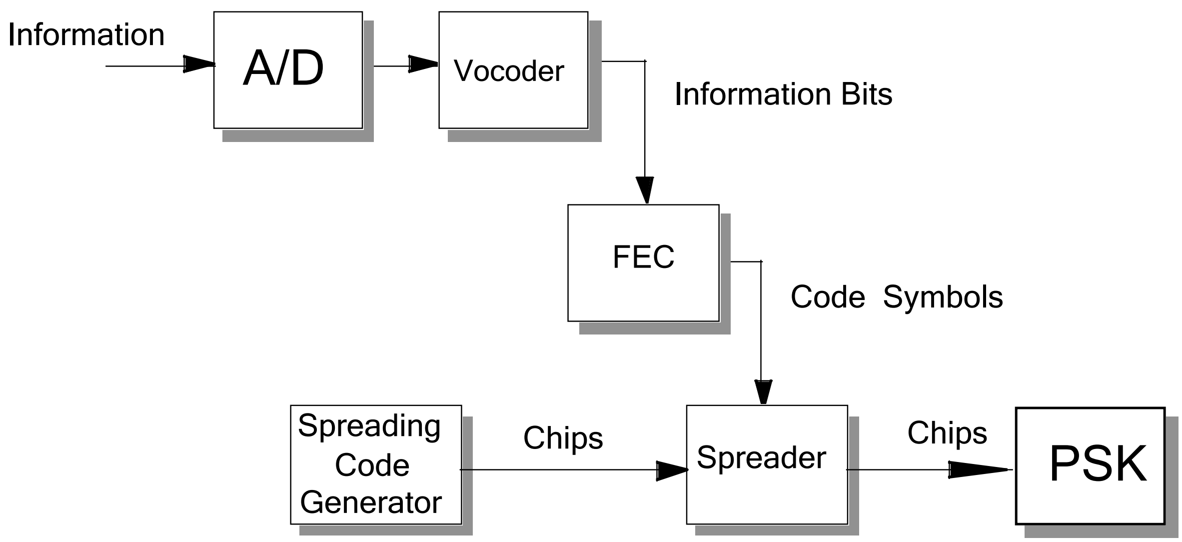
The Bit

A *bit* is the fundamental unit of information: a single binary digit. Analog information is encoded into a sequence of binary digits (A/D conversion). Both user data and error detection code digits are considered bits. The *bit rate* (bits per second) is a measure of the volume of information being transmitted.

cdma university

CDMA Overview & Terminology – Bits, Symbols, and Chips (continued)

CDMA2000 1x
RC1 & RC2
Section 4-5



MMT98010124Cg.emf

The Code Symbol

In CDMA2000 systems, a *code symbol* is the output of the coding process (Forward Error Correction [FEC]). Each bit produces several code symbols. The symbol rate is a measure of the redundancy introduced by the FEC scheme. Each symbol is also a single binary digit.

The Chip

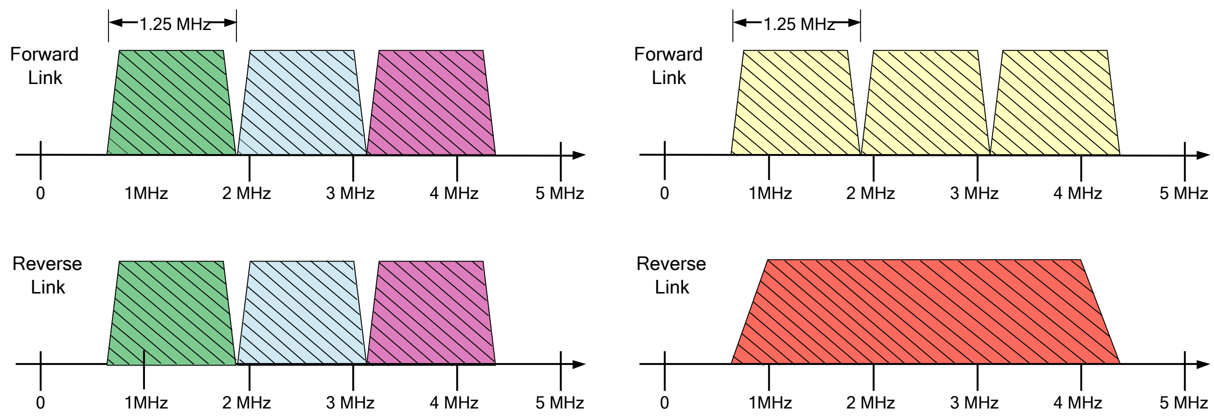
The output digits of a spreading code generator are commonly termed *chips*. A chip is also a single binary digit. Several chips are used to spread a single code symbol. The *chip rate* is a measure of the amount of spreading performed.

Bits, symbols, and chips all look the same: a single binary digit. What distinguishes one from another is their relationship to the information signal.

QUALCOMM cdma university

CDMA2000 Spreading Rate 1 and Spreading Rate 3

CDMA2000 1x RC1 & RC2 Section 4-6



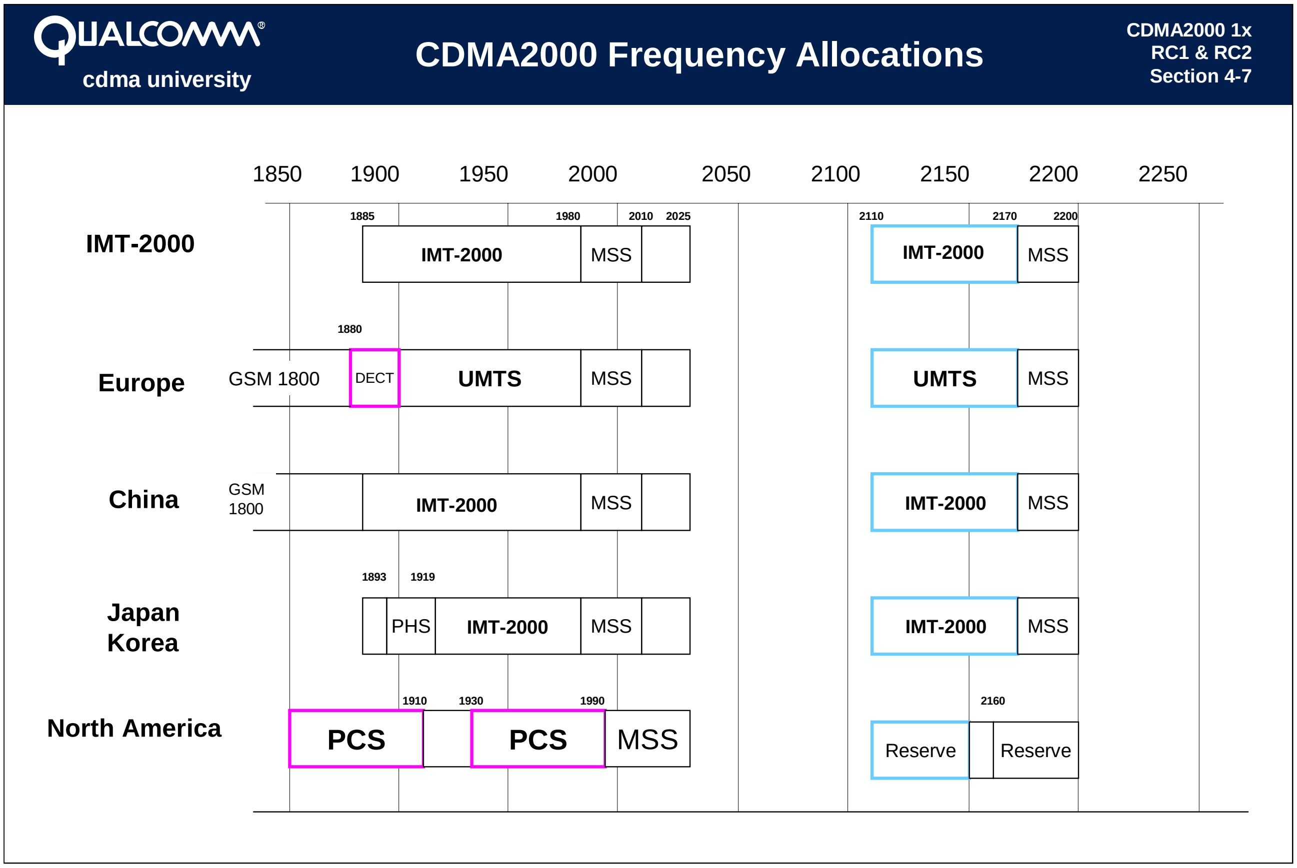
Spreading Rate 1 Spreading Rate 3

085AC_00-rev1.emf

Spreading Rates

CDMA2000 supports two different spreading rates:

- **Spreading Rate 1 —** also called "1x"
  - Both Forward and Reverse Channels use a single direct-sequence spread carrier with a chip rate of 1.2288 Mcps.
- **Spreading Rate 3 —** also called "3x" or MC (Multi-Carrier)
  - Forward Channels use three direct-sequence spread carriers each with a chip rate of 1.2288 Mcps.
  - Reverse Channels use a single direct-sequence spread carrier with a chip rate of 3.6864 Mcps.



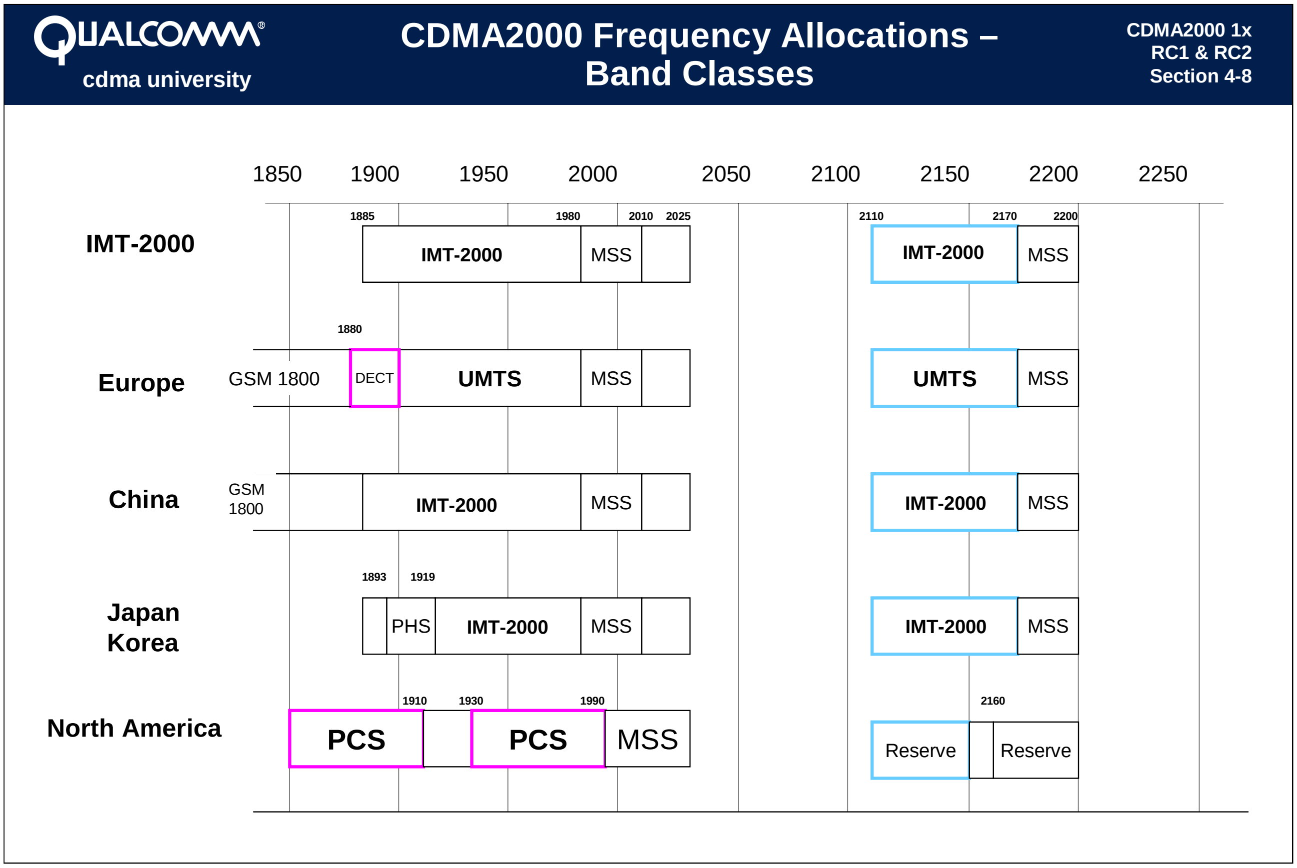
CDMA2000 Frequency Allocations

It would be desirable to have a universal frequency allocation for all CDMA2000 systems. Unfortunately, spectrum allocations are controlled by individual regulatory agencies, and no universally clear spectrum was available. The chart above shows the desired spectrum allocations for CDMA2000 (called International Mobile Telecommunications [IMT]-2000).

In China, the entire spectrum is available.

In Europe, Japan, and Korea, portions of it are available (Europe calls it Universal Mobile Telecommunications System [UMTS]).

In North America, CDMA2000 systems are supported in the the Personal Communications System (PCS) and cellular bands.



CDMA2000 Band Classes

CDMA2000 defines the following band classes:

- Band Class 0 – North American Cellular Band (“800”). Also in Korea, Australia, Hong Kong, China, Taiwan, and others.
- Band Class 1 – North American PCS Band (“1900”)
- Band Class 2 – Total Access Communications System (TACS) Band (“900”)
- Band Class 3 – JTACS Band (Japanese “800 reversed”)
- Band Class 4 – Korean PCS Band (“1800”)
- Band Class 5 – Nordic Mobile Telephone (NMT) - 450 Band
- Band Class 6 – IMT-2000 Band (1900 - 2100)
- Band Class 7 – North American Cellular Band (“700”)
- Band Class 8 – European 1800
- Band Class 9 – European 900
- Band Class 10 – Specialized Mobile Radio (SMR) – 900 Band

QUALCOMM cdma university

CDMA2000 Frequency Allocations – Band Class 0 and Spreading Rate 1

CDMA2000 1x RC1 & RC2 Section 4-9

			Transmit Frequency Band (MHz)	
System Designator	CDMA Channel Validity	CDMA Channel Number	Mobile Station	Base Station
A" (1 MHz)	Not Valid Valid	991–1012 1013–1023	824.040–824.670 824.700–825.000	869.040–869.670 869.700–870.000
A (10 MHz)	Valid Not Valid	1–311 312–333	825.030–834.330 834.360–834.990	870.030–879.330 879.360–879.990
B (10 MHz)	Not Valid Valid Not Valid	334–355 356–644 645–666	835.020–835.650 835.680–844.320 844.350–844.980	880.020–880.650 880.680–889.320 889.350–889.980
A' (1.5 MHz)	Not Valid Valid Not Valid	667–688 689–694 695–716	845.010–845.640 845.670–845.820 845.850–846.480	890.010–890.640 890.670–890.820 890.850–891.480
B' (2.5 MHz)	Not Valid Valid Not Valid	717–738 739–777 778–799	846.510–847.140 847.170–848.310 848.340–848.970	891.510–892.140 892.170–893.310 893.340–893.970

Band Class 0, Spreading Rate 1

Band Class 0 is the North American Cellular Band. The bandwidth of each CDMA channel in Band Class 0 is 1.23 MHz. If a CDMA2000 1x system is deployed in this band, the channel number assignment for Spreading Rate 1 will be the same as that of TIA/EIA-95A/B.

No guard band is required between adjacent CDMA channels if those channels belong to the same system operator. However, a guard band is required between a CDMA system and any other system.

QUALCOMM cdma university

CDMA2000 Frequency Allocations – Band Class 0 and Spreading Rate 3

CDMA2000 1x RC1 & RC2 Section 4-10

			Transmit Frequency Band (MHz)	
System Designator	CDMA Channel Validity	CDMA Channel Number	Mobile Station	Base Station
A" (1 MHz)	Not Valid	991–1023	824.040–825.000	869.040–870.000
A (10 MHz)	Not Valid Valid Not Valid	1–36 37–262 263–333	825.030–86.080 826.110–832.860 832.890–834.990	870.030–871.080 871.110–877.860 877.890–879.990
B (10 MHz)	Not Valid Valid Not Valid	334–404 405–595 596–666	835.020–837.120 837.150–842.850 842.880–844.980	880.020–882.120 882.150–887.850 887.880–889.980
A' (1.5 MHz)	Not Valid	667-716	845.010–846.480	890.010–891.480
B' (2.5 MHz)	Not Valid	717–799	846.510–848.970	891.510–893.970

Band Class 0, Spreading Rate 3

If a CDMA2000 3x system is deployed in Band Class 0, the system designators A', A", and B' are not valid to be used as the center frequency of the CDMA carriers.

If the mobile uses Spreading Rate 3 for the Forward Traffic Channel and uses Spreading Rate 1 for the Reverse Traffic Channel, then any of the three carriers may be used as the center frequency of the Reverse Traffic Channel. The mobile would be told which carrier to use by the 1xRL_FREQ_OFFSET parameter of the Extended Channel Assignment Message.

QUALCOMM cdma university

CDMA2000 Frequency Allocations – Band Class 0 Preferred Channels

CDMA2000 1x RC1 & RC2 Section 4-11

CDMA preferred set of frequency assignment:

System Designator	Spreading Rate	Preferred Set Channel Numbers
A	1	283 (Primary) and 691 (Secondary)
	3	37, 78, 119, 160, 201, 242
B	1	384 (Primary) and 777 (Secondary)
	3	425, 466, 507, 548, 589

Sync Channel preferred set of frequency assignment for SR3:

System Designator	Preferred Set of Channel Numbers
A	37, 160, 283
B	384, 507, 630

Preferred Channels in Band Class 0

Preferred channels are specified for each system operator of the cellular band (A and B systems) to assist the mobile system acquisition process.

- For Spreading Rate 1 systems, these preferred channels are the same as for CDMAOne systems.
- For Spreading Rate 3 systems, the mobile must first acquire the Sync Channel, which is transmitted as a Spreading Rate 1 channel. The preferred Sync Channel numbers are 37, 160, and 283 for the A carrier, and 384, 507, and 630 for the B carrier.

The preferred Sync Channel numbers for Spreading Rate 3 were chosen so that a 3x MC system may be overlaid with a 1x system in such a way that one of the carriers is a preferred 1x channel. For example, if channel 242 is the center carrier for a 3x system, then channel 283 will be the right carrier, and 283 is a preferred channel for a 1x system.

QUALCOMM cdma university

CDMA2000 Frequency Allocations – Band Class 1 and Spreading Rate 1

CDMA2000 1x RC1 & RC2 Section 4-12

Block Designator	CDMA Channel Validity	CDMA Channel Number	Transmit Frequency Band (MHz)	
			Mobile Station	Base Station
A (15 MHz)	Not Valid Valid Cond. Valid	0–24 25–275 276–299	1850.000–1851.200 1851.250–1863.750 1863.800–1864.950	1930.000–1931.200 1931.250–1943.750 1943.800–1944.950
D (5 MHz)	Cond. Valid Valid Cond. Valid	300–324 325–375 376–399	1865.000–1866.200 1866.250–1868.750 1868.800–1869.950	1945.000–1946.200 1946.250–1948.750 1948.800–1949.950
B (15 MHz)	Cond. Valid Valid Cond. Valid	400–424 425–675 676–699	1870.000–1871.200 1871.250–1883.750 1883.800–1884.950	1950.000–1951.200 1951.250–1963.750 1963.800–1964.950
E (5 MHz)	Cond. Valid Valid Cond. Valid	700–724 725–775 776–799	1885.000–1886.200 1886.250–1888.750 1888.800–1889.950	1965.000–1966.200 1966.250–1968.750 1968.800–1969.950
F (5 MHz)	Cond. Valid Valid Cond. Valid	800–824 825–875 876–899	1890.000–1891.200 1891.250–1893.750 1893.800–1894.950	1970.000–1971.200 1971.250–1973.750 1973.800–1974.950
C (15 MHz)	Cond. Valid Valid Not Valid	900–924 925–1175 1176–1199	1895.000–1896.200 1896.250–1908.750 1908.800–1909.950	1975.000–1976.200 1976.250–1988.750 1988.800–1989.950

Band Class 1, Spreading Rate 1

Band Class 1 is the North American PCS Band.

The bandwidth of each CDMA channel in Band Class 1 is 1.25 MHz. If a CDMA2000 1x system is deployed in this band, the channel number assignment for Spreading Rate 1 will be the same as that of TIA/EIA-95A/B.

QUALCOMM cdma university

CDMA2000 Frequency Allocations – Band Class 1 and Spreading Rate 3

CDMA2000 1x RC1 & RC2 Section 4-13

Block Designator	CDMA Channel Validity	CDMA Channel Number	Transmit Frequency Band (MHz)	
			Mobile Station	Base Station
A (15 MHz)	Not Valid Valid Cond. Valid	0–49 50–250 251–299	1850.000–1852.450 1852.500–1862.500 1862.550–1864.950	1930.000–1932.450 1932.500–1942.500 1942.550–1944.950
D (5 MHz)	Cond. Valid Valid Cond. Valid	300–349 350 351–399	1865.000–1867.450 1867.500 1867.550–1869.950	1945.000–1947.450 1947.500 1947.550–1949.950
B (15 MHz)	Cond. Valid Valid Cond. Valid	400–449 450–650 651–699	1870.000–1872.450 1872.500–1882.500 1882.550–1884.950	1950.000–1952.450 1952.500–1962.500 1962.550–1964.950
E (5 MHz)	Cond. Valid Valid Cond. Valid	700–749 750 751–799	1885.000–1887.450 1887.500 1887.550–1889.950	1965.000–1967.450 1967.500 1967.550–1969.950
F (5 MHz)	Cond. Valid Valid Cond. Valid	800–849 850 851–899	1890.000–1892.450 1892.500 1892.550–1894.950	1970.000–1972.450 1972.500 1972.550–1974.950
C (15 MHz)	Cond. Valid Valid Not Valid	900–949 950–1150 1151–1199	1895.000–1897.450 1897.500–1907.500 1907.550–1909.950	1975.000–1977.450 1977.500–1987.500 1987.550–1989.950

Band Class 1, Spreading Rate 3

If a CDMA2000 3x system is deployed in Band Class 1, only one CDMA channel is allowed for D, E, and F carriers.

Conditionally valid channel numbers are permissible only if the adjacent block is allocated to the same licensee or if other valid authorization has been obtained.

As for Band Class 0, CDMA2000 defines a set of preferred channel numbers for Spreading Rate 1 and 3, and preferred Sync Channel numbers for Spreading Rate 3, for mobiles operating in Band Class 1.

New concepts in the CDMA2000 Physical Layer (RC3 or greater):

- Spreading Rate 1 (1x) and Spreading Rate 3 (3x)
- Logical channels
- Radio configurations
- Many new Physical Channels
- Transmit Diversity Pilot Channels
- Enhanced Access Channel procedures
- Reverse Link Pilot Channel

CDMA2000 Physical Layer

The increased performance available from CDMA2000 is at the expense of complexity.

Currently 1x spreading rates are being deployed in Release 0. The 3x rates are now completely defined (both Physical Layer and Signaling Layers) in Release A.

Many Radio Configurations are required to define the spreading rates, Forward Error Correction rates, and Data rates.

New Physical Channels have been added for better signaling efficiency and higher data rates.

Transmit Diversity has been added to improve the performance in difficult environments.

The Reverse link now contains a Pilot signal to improve the capacity of the Reverse link.

CDMA2000 Physical Layer – RC1 and RC2

- 1x (1.2288 MHz) spreading rate.
- Two Radio Configuration with fixed data rates:
  - 9.6 kbps for RC1
  - 14.4 kbps for RC2
- Data is BPSK modulated on Forward link.
- Forward link uses coherent modulation.
- Reverse link uses non-coherent modulation.
- Fixed 20 ms frames.

RC1 and RC2

Radio Configurations 1 and 2 are the TIA/EIA-95 backward-compatible modes of operation. These two modes are simpler than the CDMA2000 modes.

The Spreading rate is fixed at the 1x rate.

There are only two data rate sets available: 9.6 kbps and 14.4 kbps. These are the maximum channel rates, with ½ , ¼ and 1/8 of these channels rates also being available for variable rate voice services.

The data is modulated in a BPSK format onto the radio frequency carrier wave, where in CDMA2000 the modulation is QPSK.

Since the Forward link also contains a Pilot signal, the Mobile is able to demodulate coherently.

The Reverse link does not contain a Pilot in RC1 and RC2, so demodulation in the Base Station is non-coherent.

All frame times are fixed at 20 ms. This gives reasonable delays that are acceptable for voice services, and reasonable interleaver gains.

QUALCOMM cdma university

CDMA2000 Channels –
Logical Channel Naming

CDMA2000 1x
RC1 & RC2
Section 4-16

Convention for Logical Channel Naming

1ST LETTER	2ND LETTER	3RD LETTER
f = Forward **r** = Reverse	**d** = Dedicated **c** = Common	**t** = Traffic **s** = Signaling

Examples: f-csch = Forward Common Signaling Channel
r-dtch = Reverse Dedicated Traffic Channel

CDMA2000 Logical Channel Naming

A Logical Channel name consists of three lowercase letters followed by "ch" (channel).
A hyphen is used after the first letter.

Logical Channel names are differentiated by:

- Direction (Forward or Reverse)
- Whether the information is shared by all users (common) or specific to an individual user (dedicated)
- Whether the information is control information (signaling) or user information (traffic).

QUALCOMM cdma university

CDMA2000 Channels – Physical Channel Naming

CDMA2000 1x RC1 & RC2 Section 4-17

Channel Name	Physical Channel
F/R-PICH	Forward/Reverse Pilot Channel
F-APICH	Dedicated Auxiliary Pilot Channel
F-TDPICH	Transmit Diversity Pilot Channel
F-ATDPICH	Auxiliary Transmit Diversity Pilot Channel
F-SYNCH	Sync Channel
F-PCH	Paging Channel
F-QPCH	Quick Paging Channel
F-BCCH	Broadcast Control Channel
F-CACH	Common Assignment Channel
F-CPCCH	Common Power Control Channel
F/R-CCCH	Forward/Reverse Common Control Channel
R-ACH	Access Channel
R-EACH	Enhanced Access Channel
F/R-FCH	Forward/Reverse Fundamental Channel
F/R-DCCH	Forward/Reverse Dedicated Control Channel
F/R-SCH	Forward/Reverse Supplemental Channel
F/R-SCCH	Forward/Reverse Supplemental Code Channel

CDMA2000 Physical Channel Naming

A Physical Channel name is represented by an uppercase abbreviation. As in the case of Logical Channel names, the first letters in the name of the channel indicates the direction of the channel. The rest of the name is usually an acronym based on the full name of the channel.

Note that there are some channels for which the literature is inconsistent. For example, the Sync Channel is sometimes named F-SYNC and other times F-SYNCH. The Broadcast Control Channel may be named F-BCCH or F-BCH. Sometimes the F and R direction indicators are dropped if the rest of the channel name is unique.

Not all Channels are available in the early releases of CDMA2000.

- For RC1 and RC2 (IS-95) , the available Physical channels are F-PICH, F-SYNCH, F-PCH, F/R-FCH (traffic channels), R-ACH, F/R-SCCH
- Release 0 adds the R-PICH, F-QPCH, F/R-DCCH, and the F/R-SCH
- All channels are available in Release A.

QUALCOMM cdma university

CDMA2000 Channels – Logical-to-Physical Channel Mapping

CDMA2000 1x RC1 & RC2 Section 4-18

Physical Channel	Logical Channel	Information
F/R-FCH	f/r-dsch	Layer 3 signaling messages
	f/r-dtch	User Data (voice, data services)
F/R-SCH	f/r-dtch	User Data (data services)
F/R-DCCH	f/r-dsch	Layer 3 signaling message
	f/r-dtch	User Data (voice, data services)
F-SYNC	f-csch	Sync Channel Message
F-CCCH	f-csch	Mobile Directed Messages
F-BCCH	f-csch	Broadcast Messages
F-PCH	f-csch	TIA/EIA-95 Compatible Paging Channel Messages
R-EACH	r-csch	Mobile Access Messages
R-ACH	r-csch	Mobile Access Messages (TIA/EIA-95 compatible)

CDMA2000 Logical-to-Physical Channel Mapping

The table in the slide shows a typical mapping of logical channels to physical channels.

For common signaling channels, the mappings shown assume that all common signaling Physical Channels are supported (F-BCCH, F-CCCH, F-PCH, R-EACH, and R-ACH). If the Base Station is configured to support only the TIA/EIA-95 compatible common channels, then the F-BCCH, F-CCCH, and R-EACH channels are not present in the mapping.

For dedicated channels, the mapping is established for each call, as a function of what services are in use (voice, circuit-switched data, packet data).

QUALCOMM cdma university

CDMA2000 Channels – FL Physical Layer Changes for RC>2

CDMA2000 1x RC1 & RC2 Section 4-19

- Channels are orthogonalized by Walsh functions.
- QPSK data modulation.
- Forward Error Correction:
  - Convolutional codes (K=9) are used for voice and data.
  - Turbo codes are used for high data rates on Supplemental Channels.
- Supports Quasi-orthogonal Forward link channelization:
  - Used when running out of orthogonal space (insufficient number of Walsh codes).

FL Physical Channel Changes for RC>2

The Forward link continues to be channelized by Walsh functions, but with QPSK data modulation the Walsh space available is bigger. In the extreme case of Smart Antennas, or 3x MC operation, there may not be sufficient Walsh functions and deployments may use Quasi-orthogonal Walsh functions.

Fast Forward power control is available in 1x to increase the capacity and quality of the Forward link. Longer frame lengths are available for data transmissions to increase the interleaver gain.

CDMA2000 Channels – FL Physical Layer Changes for RC>2 (cont.)

QUALCOMM cdma university

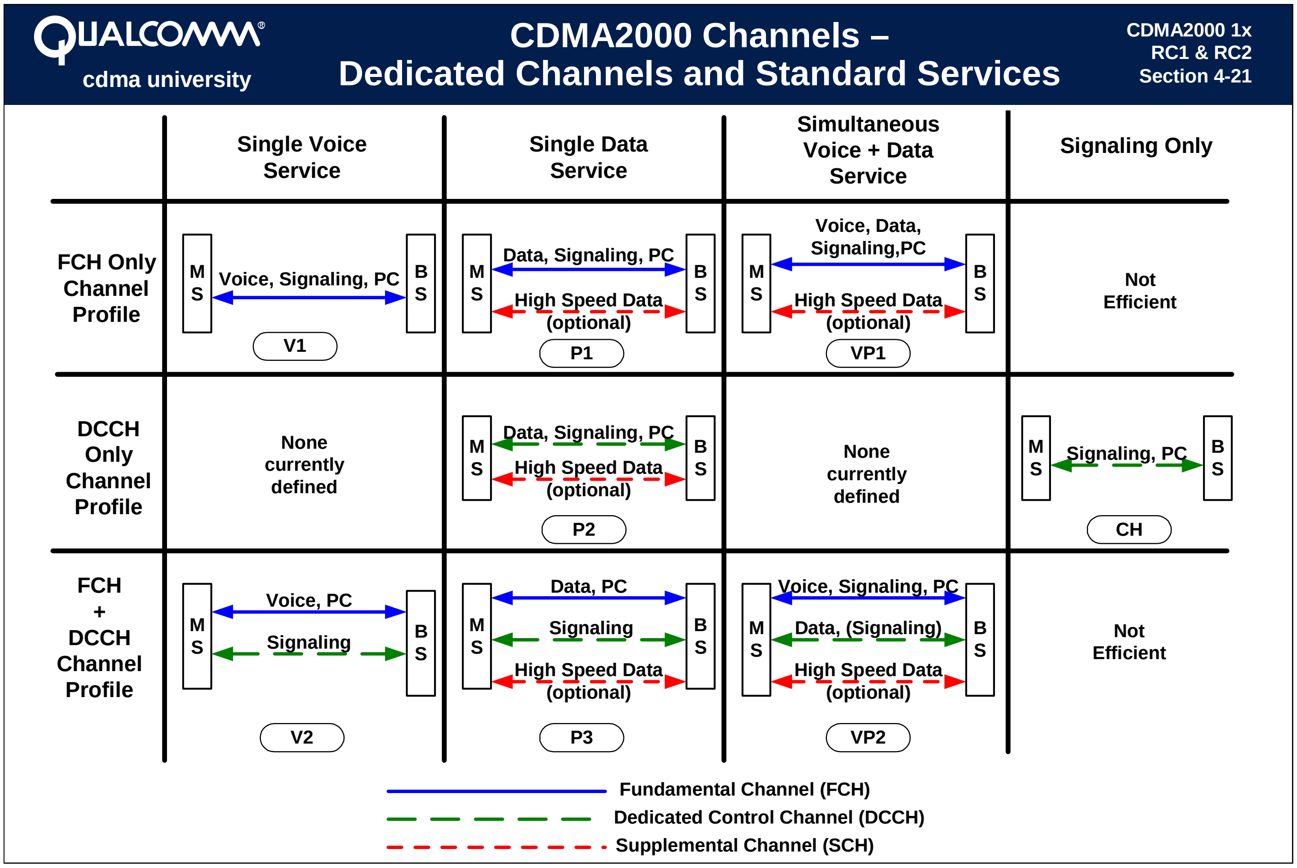
CDMA2000 1x RC1 & RC2 Section 4-20

- Synchronous Forward link
- Forward link transmit diversity
- Fast Forward power control:
  - 800 Hz update rate
- Supplemental Channel Active Set subset of Fundamental Channel Active Set
- Frame lengths:
  - 5 ms, 20 ms, 40 ms, and 80 ms frames are used for signaling, control information, and user information.

FL Physical Channel Changes for RC>2

TIA/EIA-95 are RC1 and RC2.

RC>2 are CDMA2000 modes.



Dedicated Channels and Standard Services

Although not specified in the CDMA2000 standard, the following services have become de facto standards in the industry:

- V1 Voice and signaling on FCH
- P1 Data and signaling on FCH, optional Data on SCH
- VP1 Voice, Data, and signaling on FCH, optional Data on SCH
- P2 Data on DCCH, optional Data on SCH
- V2 Voice on FCH, signaling on DCCH
- P3 Data on FCH, signaling on DCCH, optional Data on SCH
- VP2 Voice and signaling on FCH, Data on DCCH , optional Data on SCH

Note that Power Control (PC) is always carried on FCH if it is present; otherwise it is carried on DCCH.

In any of the services that support data, high speed data may optionally be carried on SCH, to achieve data rates up to 2 Mbps.

CH is the Control Hold mode. In the Control Hold mode, only the reserve Pilot is transmitted, and it may be operating in gated mode to conserve power.

Note that only V1 and P1 service is available in RC1 and RC2.

QUALCOMM cdma university

CDMA2000 Channels – Radio Configurations

CDMA2000 1x RC1 & RC2 Section 4-22

Radio Configuration:

- A set of Forward Traffic Channel and Reverse Traffic Channel transmission formats that are characterized by Physical Layer parameters such as transmission rates, modulation characteristics, and spreading rate

CDMA2000 Radio Configurations:

- RC1 through RC9 on the Forward link
- RC1 through RC6 on the Reverse link

Radio Configurations

A radio configuration defines Forward or Reverse Traffic Channel characteristics as:

- Rate set
- Spreading rate
- Channel coding (Turbo or convolutional)
- Channel coding rate
- Modulation (Quadrature Phase Shift Key [QPSK] or Binary Phase Shift Key [BPSK])
- Orthogonal Transmit Diversity (OTD) allowed

QUALCOMM cdma university

CDMA2000 Channels – Forward Link Radio Configurations

Radio Configuration	Spreading Rate	Max Data Rate* (kbps)	Effective FEC Code Rate	OTD Allowed	FEC Encoding	Modulation
1	1	9.6	1/2	No	Conv	BPSK
2	1	14.4	3/4	No	Conv	BPSK
3	1	153.6	1/4	Yes	Conv and Turbo	QPSK
4	1	307.2	1/2	Yes	Conv and Turbo	QPSK
5	1	230.4	3/8	Yes	Conv and Turbo	QPSK
6	3	307.2	1/6	Yes	Conv and Turbo	QPSK
7	3	614.4	1/3	Yes	Conv and Turbo	QPSK
8	3	460.8	1/4 or 1/3	Yes	Conv and Turbo	QPSK
9	3	1036.8	1/2or 1/3	Yes	Conv and Turbo	QPSK

* Maximum data rate for a single Supplemental Channel

RC1 and RC2 correspond to TIA/EIA-95.

Forward Link Radio Configurations

Radio Configurations 1 and 2 correspond to TIA/EIA-95B Rate Set 1 and Rate Set 2, respectively. These are backward compatible Radio Configurations.

Radio Configurations 3, 4, and 5 use Spreading Rate 1, and Radio Configurations 6, 7, 8, and 9 use Spreading Rate 3. Turbo coding or convolutional coding may be used.

Max Data Rate refers to the maximum data rate for a single Supplemental Channel. Since up to two Supplemental Channels may be used for a single traffic channel, the total maximum data rate is twice the value shown in the table.

QUALCOMM cdma university

CDMA2000 Channels – Reverse Link Radio Configurations

Radio Configuration	Spreading Rate	Max Data Rate* (kbps)	Effective FEC Code Rate	FEC Encoding	Modulation
1	1	9.6	1/3	Conv	64-ary ortho
2	1	14.4	1/2	Conv	64-ary ortho
3	1	153.6 (307.2)	1/4 (1/2)	Conv or Turbo	QPSK
4	1	230.4	3/8	Conv or Turbo	QPSK
5	3	153.6 (614.4)	1/4 (1/3)	Conv or Turbo	QPSK
6	3	460.8 (1036.8)	1/4 (1/2)	Conv or Turbo	QPSK

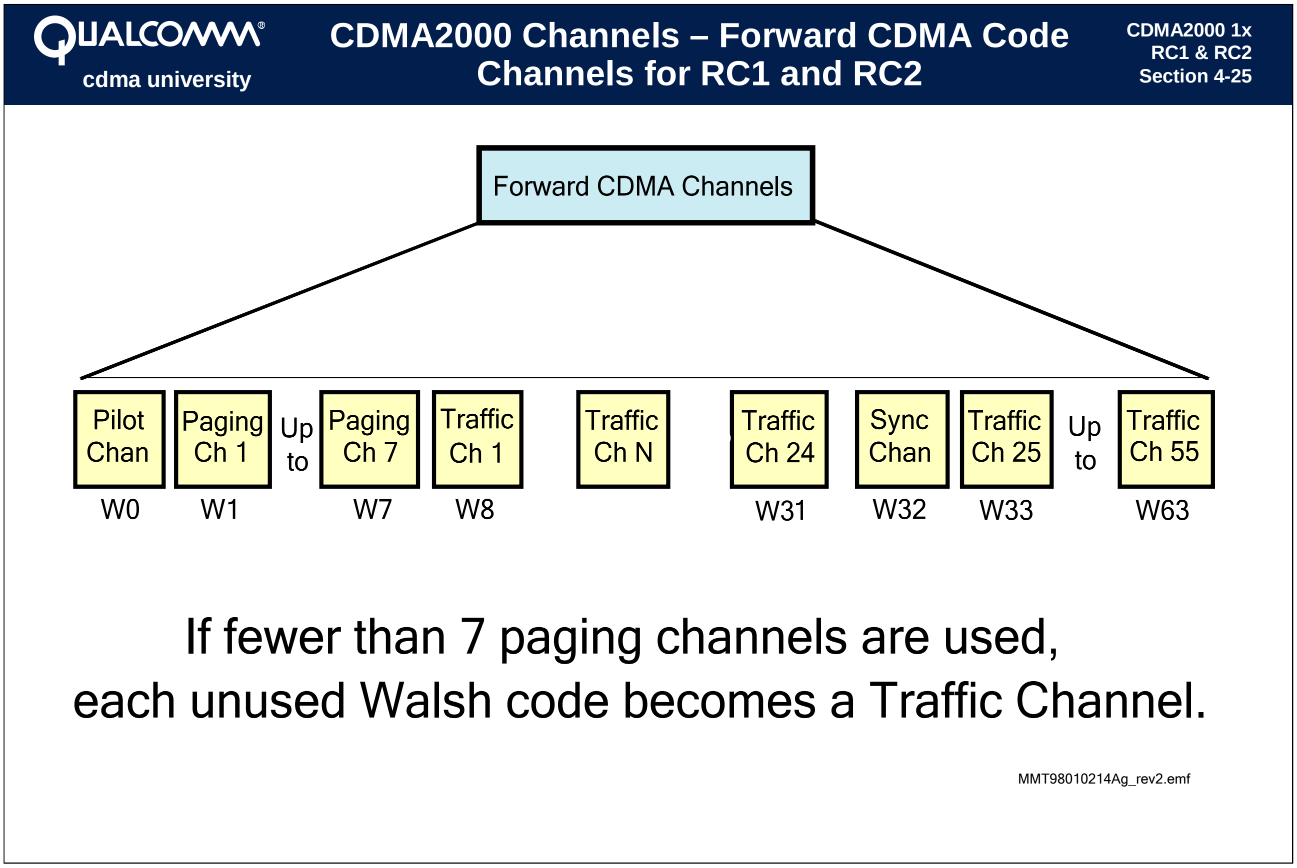
* Maximum data rate for a single Supplemental Channel

RC1 and RC2 correspond to TIA/EIA-95.

Reverse Link Radio Configurations

Radio Configurations 1 and 2 correspond to TIA/EIA-95B Rate Set 1 and Rate Set 2, respectively. These are backward-compatible Radio Configurations.

Radio Configurations 3 and 4 use Spreading Rate 1, and Radio Configurations 5 and 6 use Spreading Rate 3. Turbo or convolutional coding may be used.



Forward CDMA Code Channels

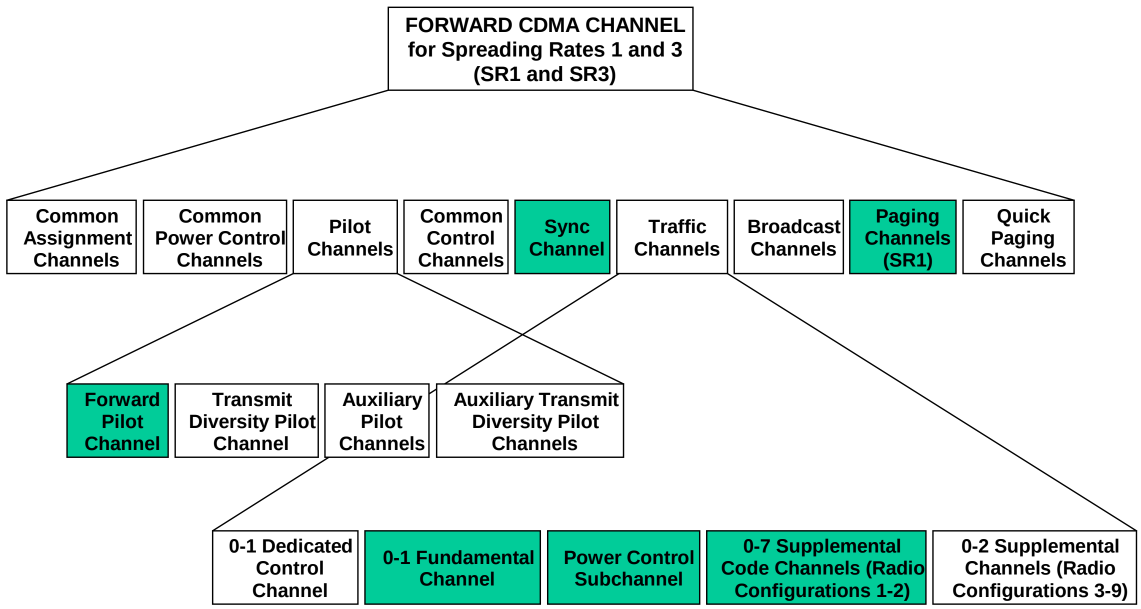
Overhead channels have fixed Walsh code assignments:

- The Pilot Channel is always Walsh code 0.
- The Sync Channel is always Walsh code 32.
- The Paging Channels use Walsh codes 1-7.

cdma university

CDMA2000 Channels – Backward Compatible Forward Link Code Channels

CDMA2000 1x RC1 & RC2 Section 4-26



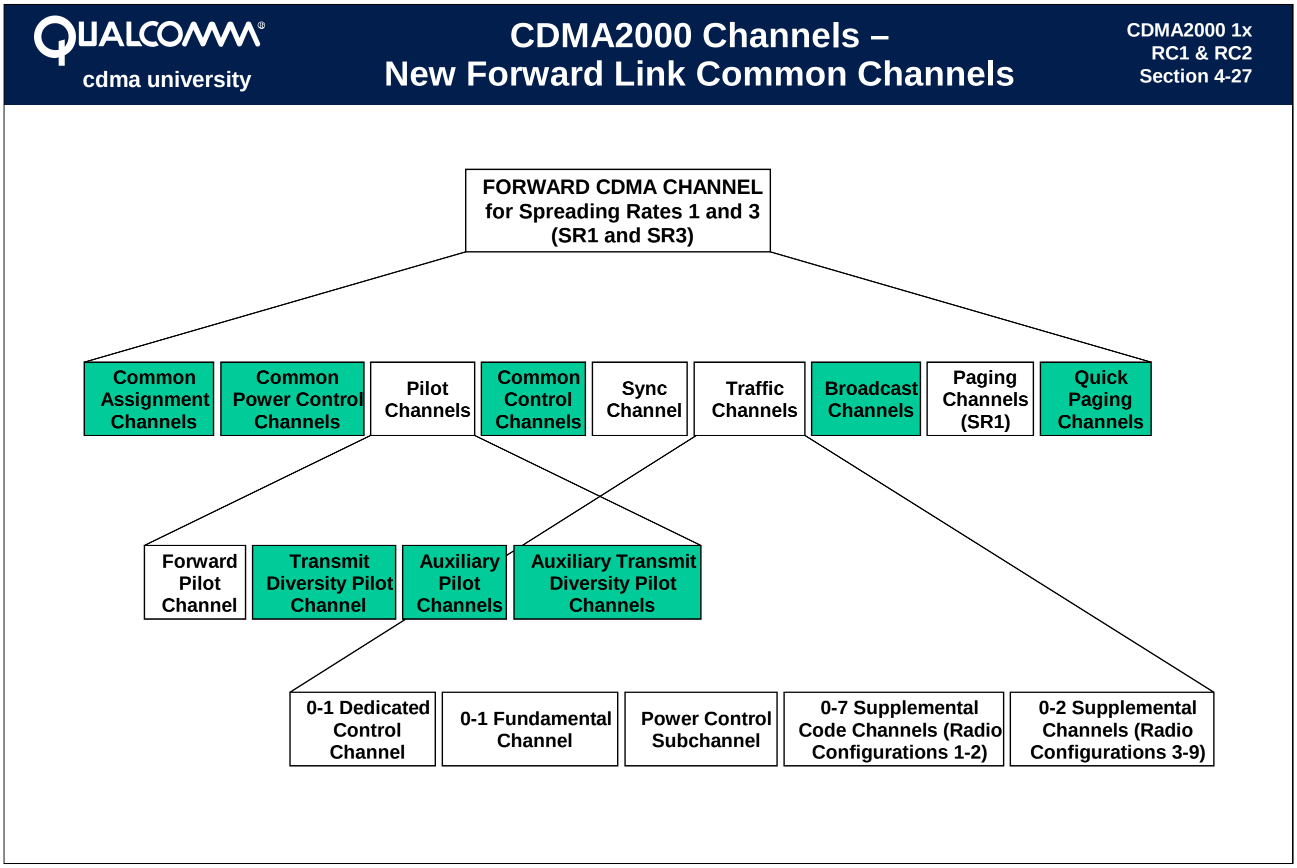
TIA/EIA-95 A/B Backward-Compatible Forward Link Code Channels

The Forward Pilot, Sync, and Paging Channels are compatible with TIA/EIA-95B. In Radio Configurations 1 and 2, the Fundamental and Supplemental Code Channels are backward-compatible. In these configurations, the maximum number of Supplemental Code Channels is seven, which allows the transmission rate to reach up to 115.2 kbps.

As in TIA/EIA-95B, the Power Control Subchannel is associated with the Fundamental Channel for Radio Configurations 1 and 2.

The Forward link code channels are assigned as follows:

- W_0^{64} reserved for forward Pilot Channel
- W_{32}^{64} reserved for Sync Channel
- W_1^{64} through W_7^{64} reserved for Paging Channels
- W_n^{64} may be used for Radio Configurations 1 and 2 Fundamental and Supplemental Code Channels, for $0 < n < 64$, except for those Code Channels used for Sync and Paging Channels.

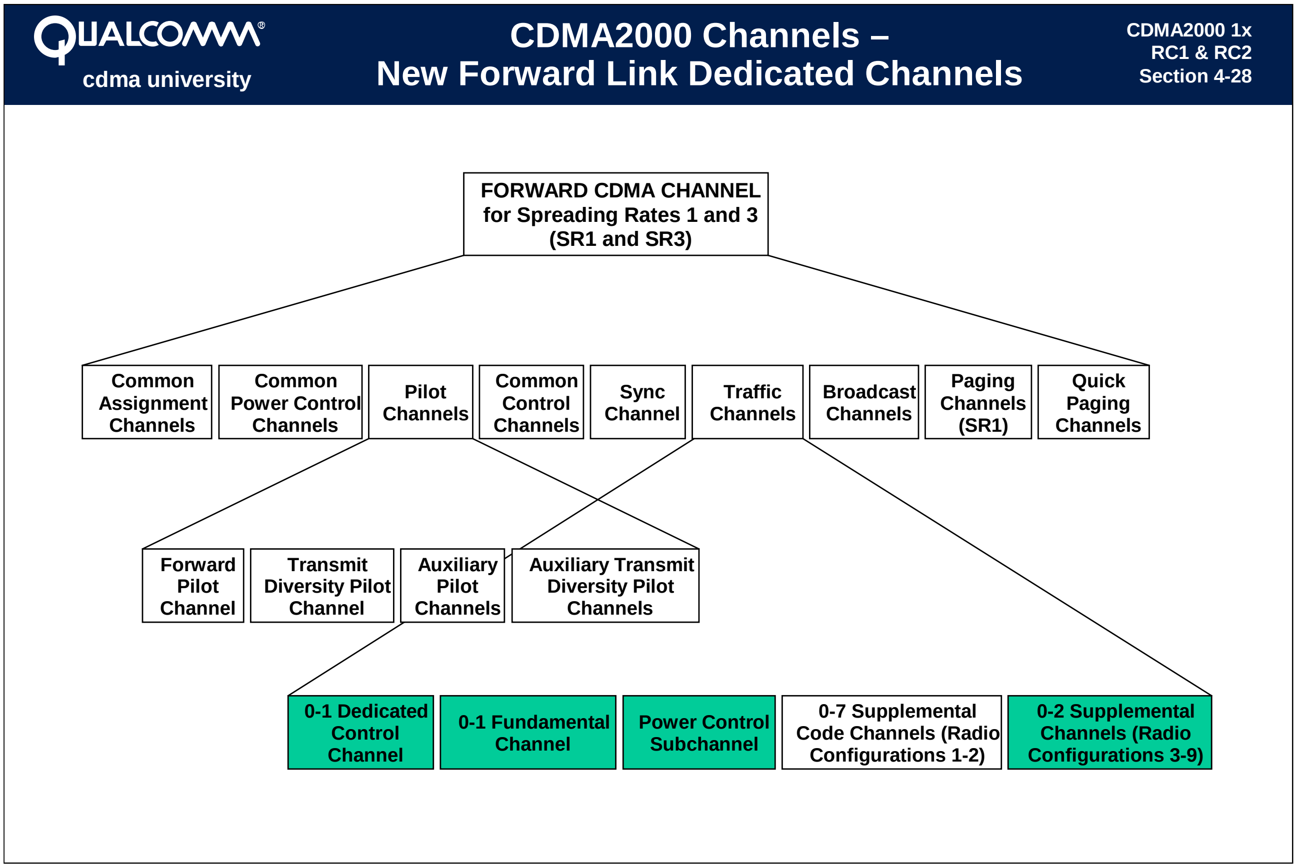


New Forward Link Common Channels

CDMA2000 introduces several new Forward link common channels:

- **Pilot Channels** – If transmit diversity is supported, one or more Pilots may be used. The auxiliary Pilot Channels may be used for smart antenna applications.
- **Quick Paging Channel** – Provides for improved slotted mode operation and improved battery life for mobile. Walsh Codes W_{80}^{128} , W_{48}^{128} , W_{112}^{128} are reserved for Quick Paging Channels, if the Base Station supports Quick Paging Channels.
- **Common Control Channel** – Carries mobile-directed messages for CDMA2000-compatible mobiles.
- **Broadcast Channel** – Carries broadcast messages for CDMA2000-compatible mobiles, including overhead messages and broadcast Short Message Service (SMS) messages.
- **Common Power Control Channel** – Used with Enhanced Access Channel Procedures (Reservation Mode) to send power control bits to the mobile so that Access Channel messages maybe sent under power control.
- **Common Assignment Channel** – Used with Enhanced Access Channel Procedures (Reservation Mode) to assign the Reverse Common Control Channel (R-CCCH) and Common Power Control Subchannel.

Release A adds several new physical channels.



New Forward Link Dedicated Channels

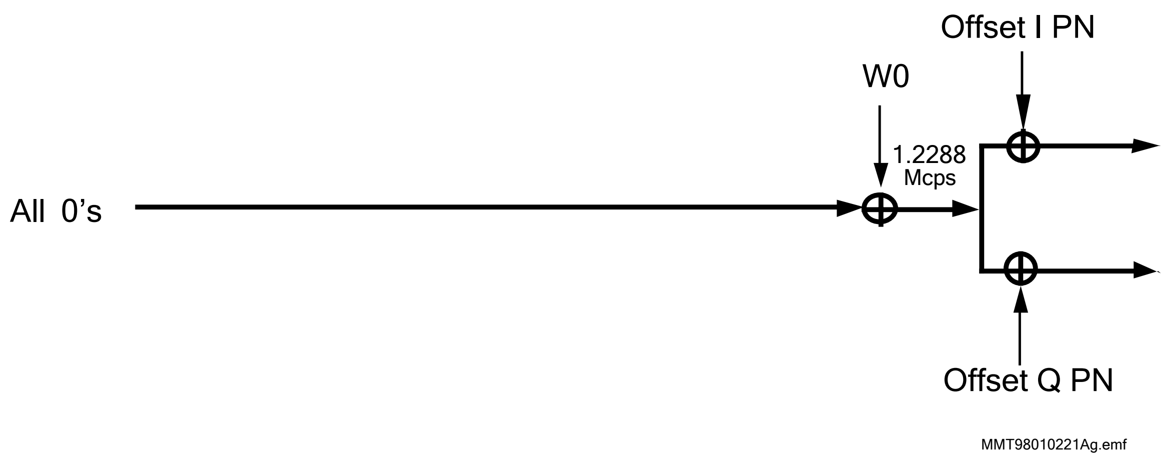
CDMA2000 Release 0 introduces several new Forward link dedicated channels:

- **Forward Fundamental Channel –** Used for the transmission of user and signaling information to a specific mobile during a call. Each Forward Traffic Channel may contain one Forward Fundamental Channel.
- **Forward Dedicated Control Channel –** Used for transmission of user and signaling information to a specific mobile during a call. Each Forward Traffic Channel may contain one Forward Dedicated Control Channel.
- **Forward Supplemental Channel** (valid for Radio Configurations 3 through 9) – Used for the transmission of user information to a specific mobile during a call. This is typically used for high speed data applications. Each Forward Traffic Channel may contain up to two Supplemental Channels.
- **Power Control Subchannel –** Typically associated with the Fundamental Channel, but if the F-FCH is not used for a given call, then associated with the Dedicated Control Channel (F-DCCH).

cdma university

Pilot Channel Generation

CDMA2000 1x
RC1 & RC2
Section 4-29



Pilot Channel Generation

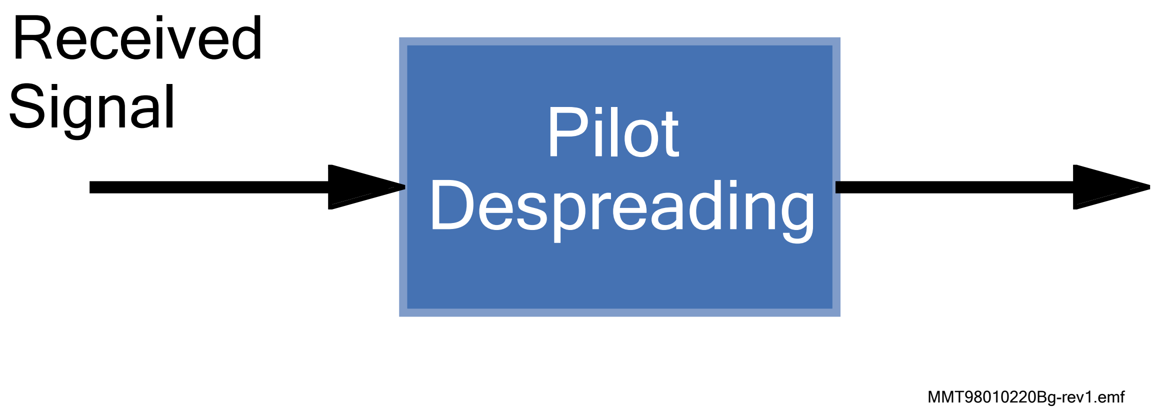
The Pilot Channel has no information on it; no message, no data.

The Pilot Channel is simply all zeros spread by Walsh code zero and by the short PN codes.

QUALCOMM cdma university

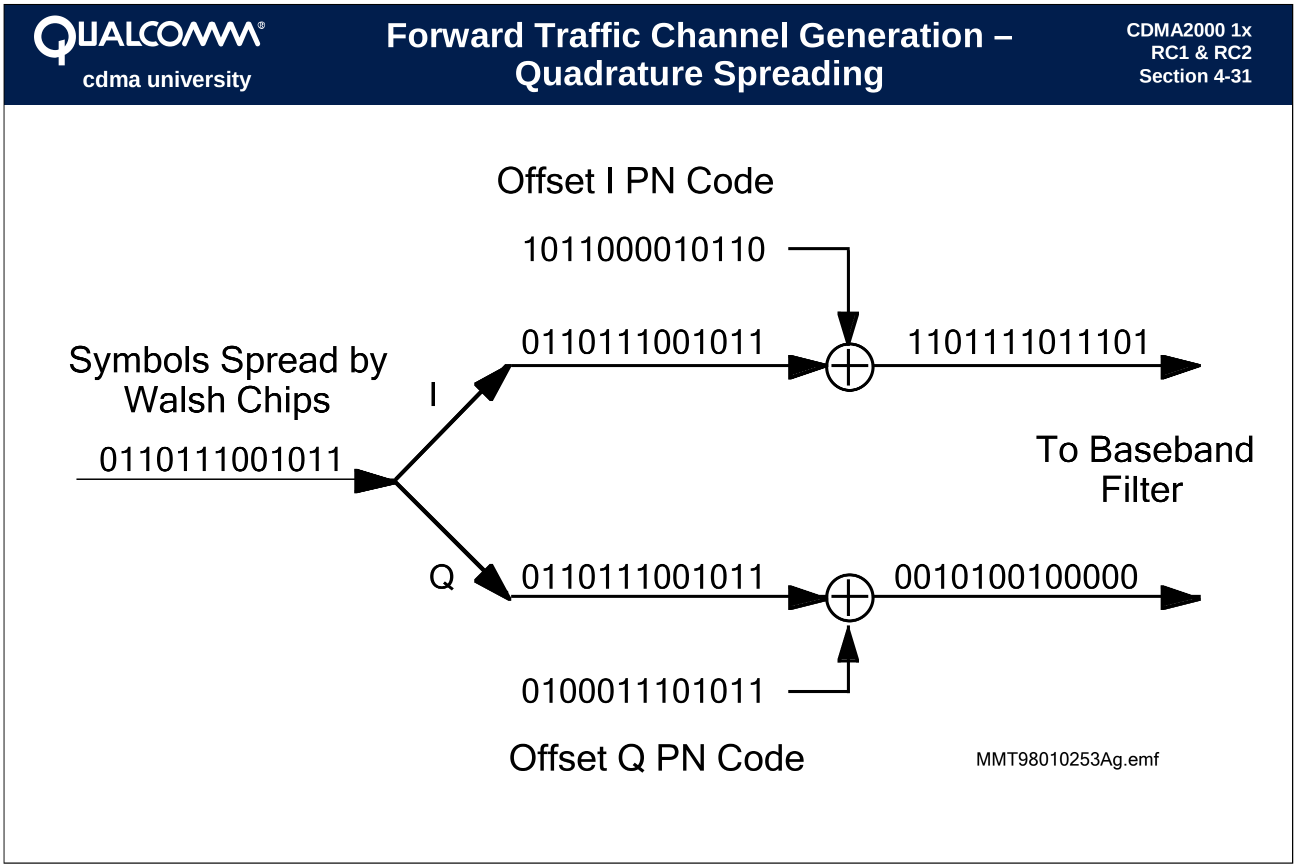
Pilot Channel Generation – Pilot Demodulation

CDMA2000 1x RC1 & RC2 Section 4-30



Pilot Demodulation

Demodulation of the Pilot provides the mobile with a reference for time, carrier phase, and signal strength. The phase reference allows the mobile to demodulate coherently.



Quadrature Spreading

After spreading by the Walsh code sequence, the Forward Traffic Channel is spread in quadrature. All of the information is sent into both I and Q, making the data modulation BPSK.

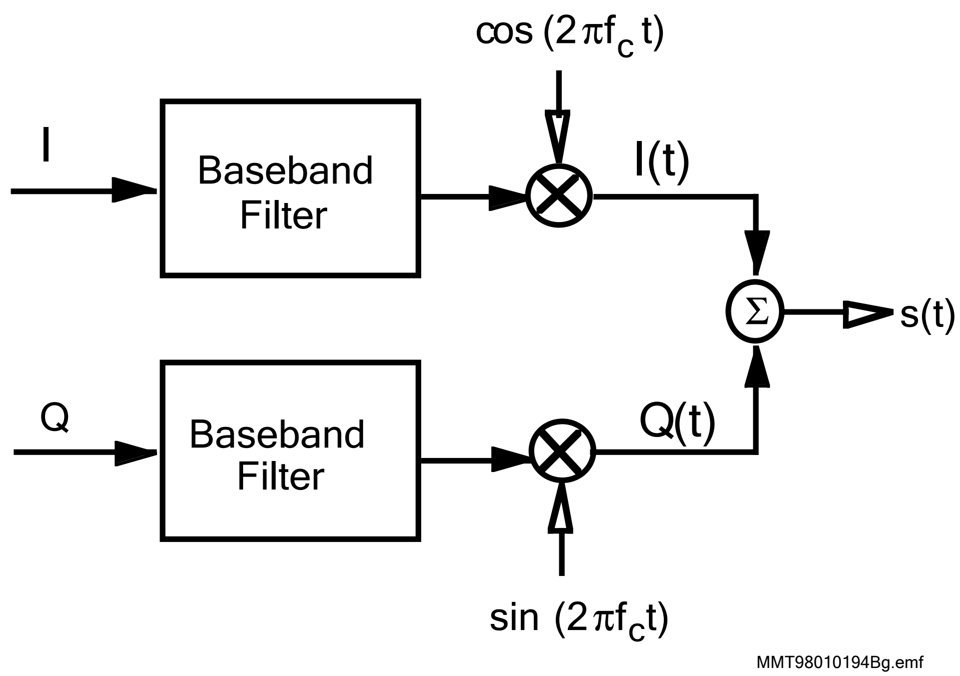
Each arm is spread using a Pseudorandom Noise code. These short PN codes are a second layer of coding that isolates one sector from another. This enables the re-use of the Walsh codes in every sector.

The I and Q codes are offset by the same amount. The I and Q codes are both 2^{15} bits in length, but are different codes.

cdma university

Forward Traffic Channel Generation – Filtering and Up Conversion

CDMA2000 1x
RC1 & RC2
Section 4-32



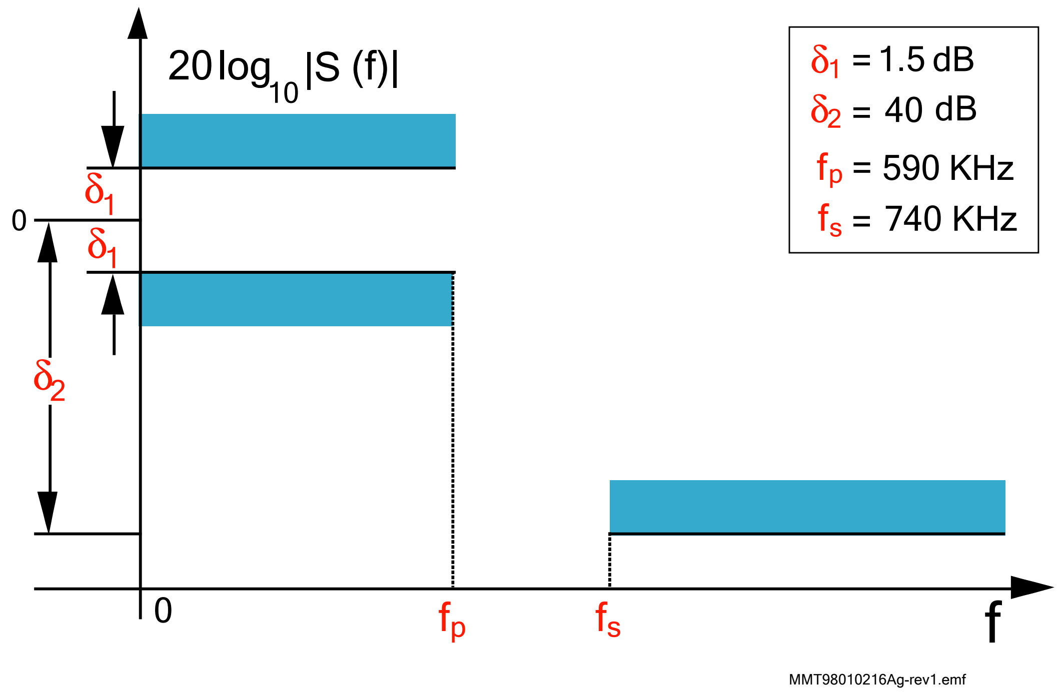
Filtering and Up Conversion

This simple illustration indicates that the IS-95 Forward Traffic Channel employs QPSK spreading. Up-conversion to the Radio Frequency is shown using the Sin and Cos frequencies of f_c .

QUALCOMM cdma university

Forward Traffic Channel Generation – 1x Filter Mask

CDMA2000 1x RC1 & RC2 Section 4-33



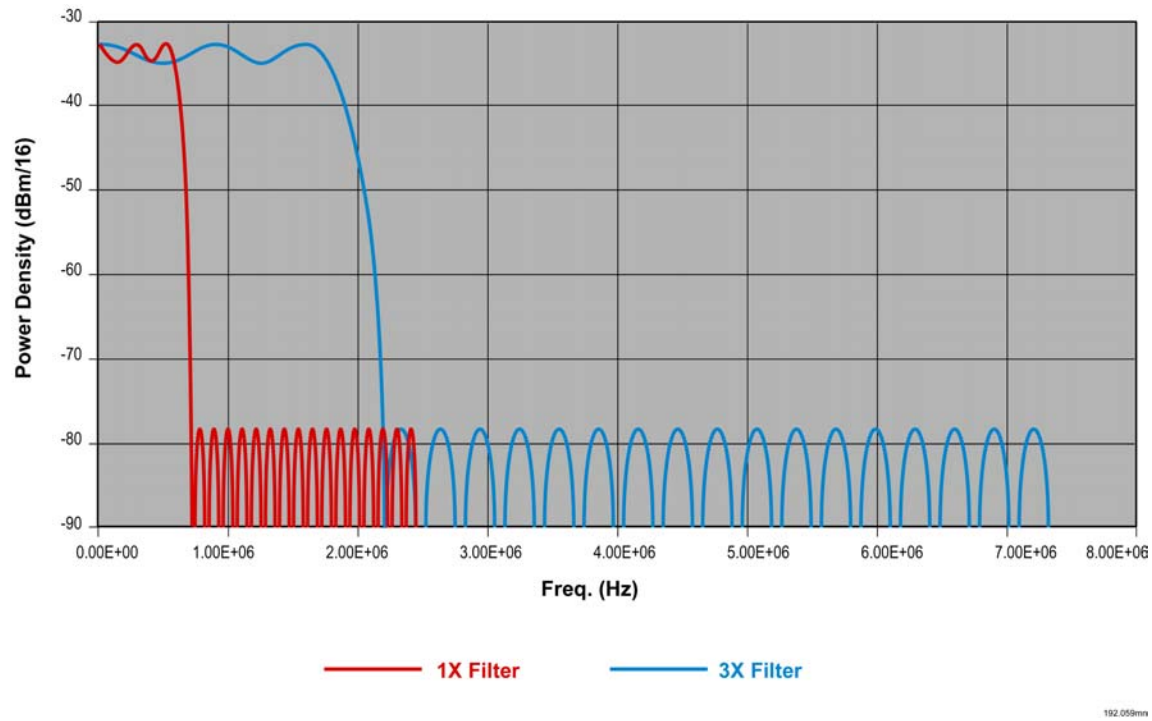
1x Filter Mask

The spread waveform must be restricted to the authorized bandwidth. A low pass filter mask is specified. At 3 dB down from the passband, the filter bandwidth is 615 KHz.

QUALCOMM cdma university

Forward Traffic Channel Generation – Transmitter Filter

CDMA2000 1x
RC1 & RC2
Section 4-34



Transmitter Filter

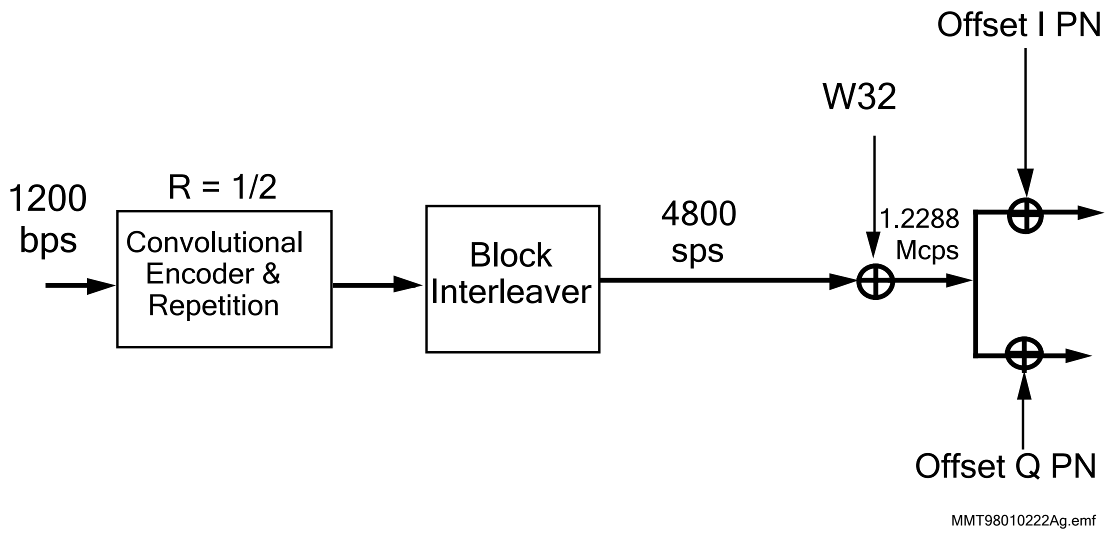
The baseband filtering is a combination of digital and analog techniques. This figure shows the frequency response of the 1x and 3x digital filters. The digital filters are a 48 tap FIR (finite duration impulse response filter) for 1x, and a 108 tap filter for 3x.

The analog filtering requirements are determined by the adjacent channels and out-of-band emissions requirements and the overall linearity and fidelity of the transmit electronics.

QUALCOMM cdma university

Forward Traffic Channel Generation – Sync Channel Generation

CDMA2000 1x RC1 & RC2 Section 4-35



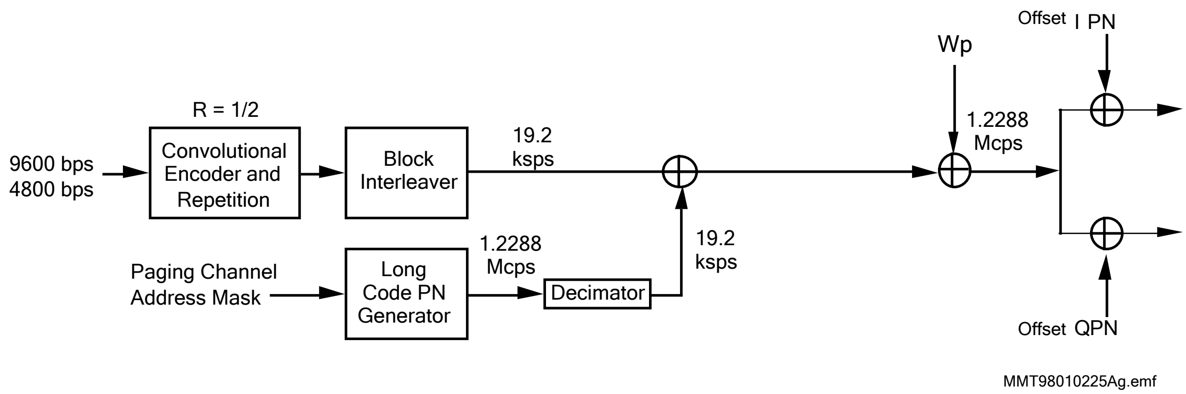
Sync Channel Block Diagram

Unlike the Pilot Channel, the Sync Channel transmits a message. Channel coding is used to protect the bits in this message. The same rate ½ coding is used followed by block interleaving. The Sync Channel is spread by Walsh code 32.

QUALCOMM cdma university

Forward Traffic Channel Generation – Paging Channel Generation

CDMA2000 1x
RC1 & RC2
Section 4-36



Paging Channel Block Diagram

Generation of the Paging Channel for RC1, RC2 and Release 0 is very similar to generation of the Forward Traffic Channel. A key difference is that the Paging Channel is not punctured with power control information.

cdma university

Forward Traffic Channel Generation – Paging Channel Long Code Mask

41 … 29	28 … 24	23 … 21	20 … 9	8 … 0
1100011001101	00000	PCN	000000000000	PILOT_PN

PCN = Paging Channel Number

PILOT_PN = PN offset for the Forward CDMA Channel

MMT98010226Ag.emf

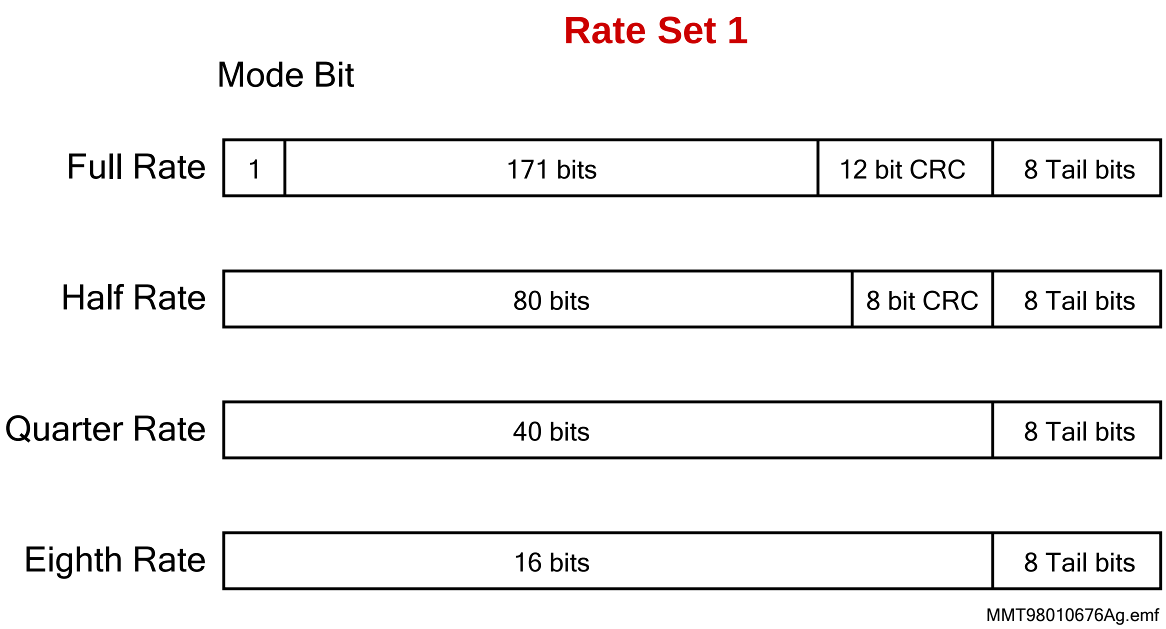
Paging Channel Long Code Mask

The Paging Channel is scrambled using the Long PN Code. The code generator is masked with a 42 bit mask as shown in the figure.

cdma university

Forward Traffic Channel Generation – Rate Set 1 Vocoder Frame Format

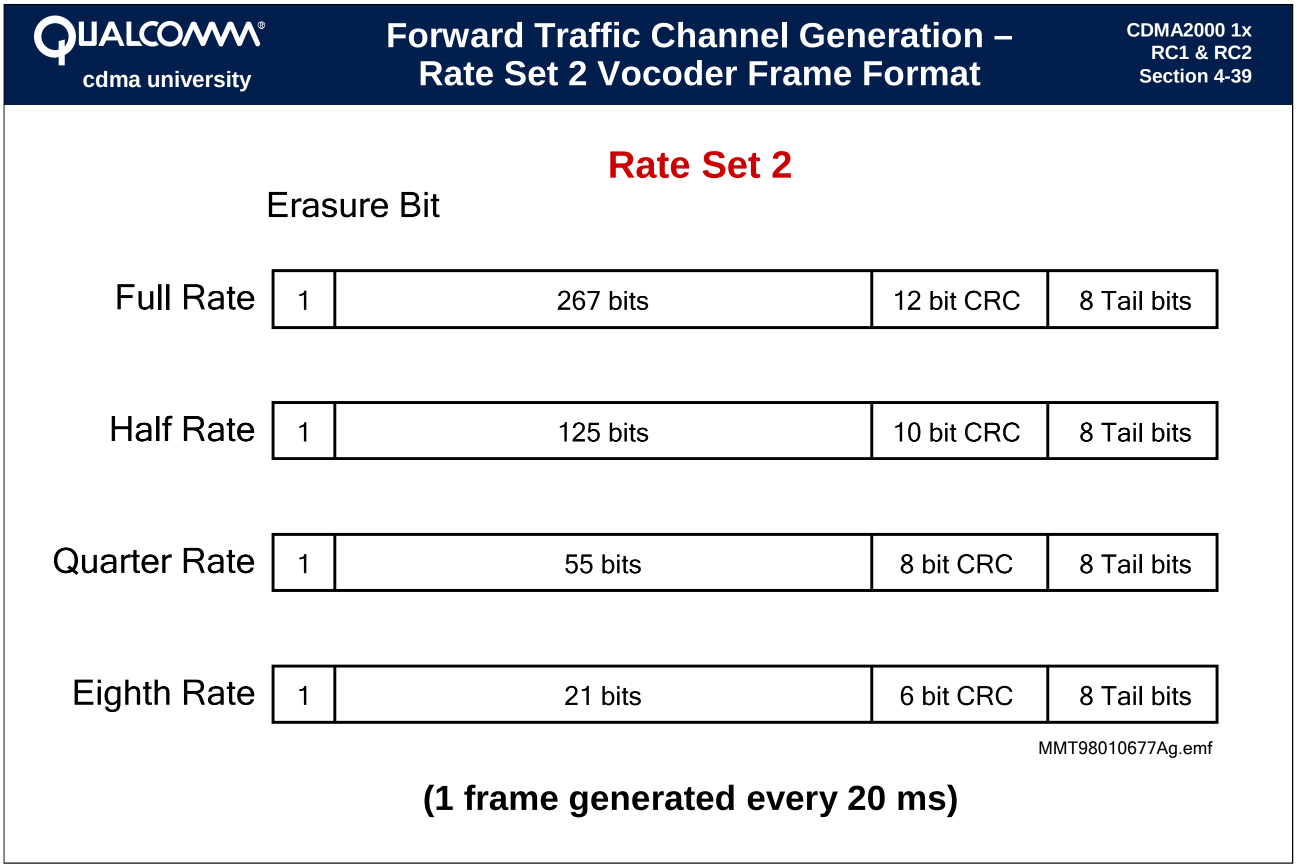
CDMA2000 1x RC1 & RC2 Section 4-38



(1 frame generated every 20 ms)

Traffic Channel Frame

The variable rate vocoder produces a frame every 20 ms using Code Excited Linear Prediction (CELP) technique. These frames are either at full, half, quarter or eighth rate. The frame rate depends on the voice activity. Both cellular and PCS band can use either Rate Set 1 or Rate Set 2 vocoder. The quality of Rate Set 2 vocoder is superior to that of the Rate Set 1.



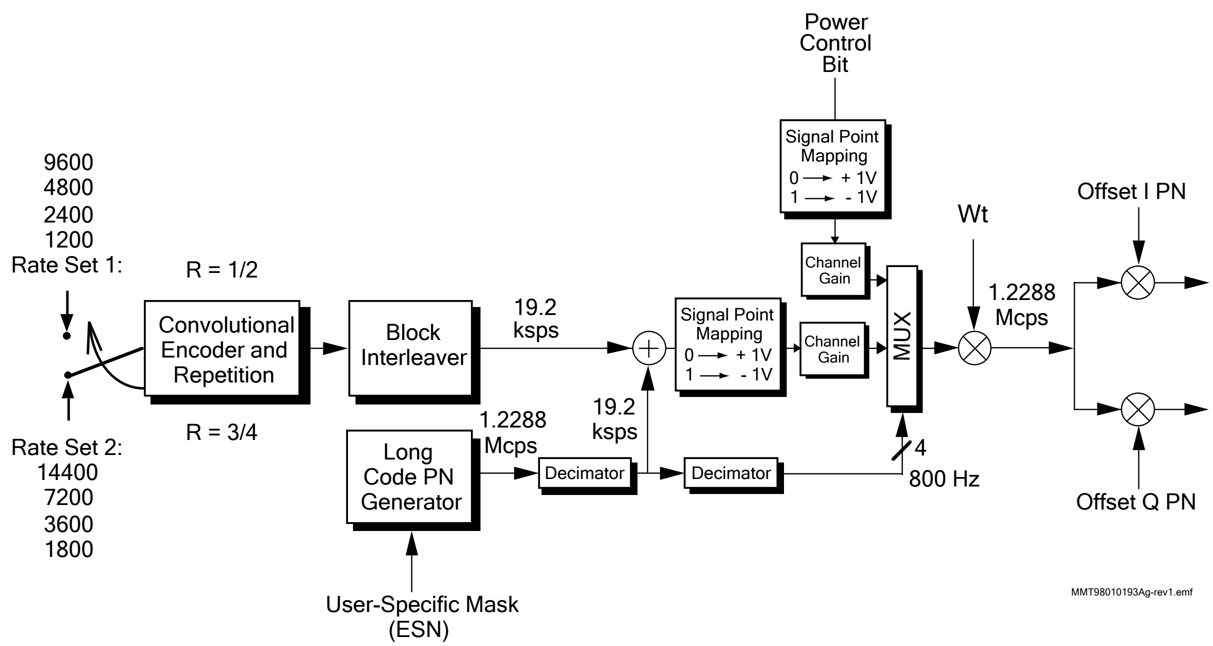
Rate Set 2 Vocoder Frames

Rate Set 2 frames contain the Erasure bit as the first bit of the frame. This allows the mobile to inform the Base Station of frame erasures on the Forward link using the Reverse link channel. This gives faster feedback (50 bps) to the Base Station about the quality of the Forward link than is available with Rate Set 1, which requires signaling messages.

QUALCOMM cdma university

Forward Traffic Channel Generation – Channel Overview

CDMA2000 1x RC1 & RC2 Section 4-40



Overview of the Forward Traffic Channel

- Both vocoder rates are supported.
- Convolutional coding is done differently for the two vocoders.
- The symbols are interleaved, then scrambled using the Long PN code.
- Power control information is “punctured” in and the signal is then orthogonally spread.
- The signal is next spread in quadrature using pseudorandom codes.

QUALCOMM cdma university

Forward Traffic Channel Generation – Rate Set 1 Symbol Repetition

CDMA2000 1x RC1 & RC2 Section 4-41

Repetition Maintains Constant 19.2 ksps Output

Data Rate	Code Rate	Repetition Rate	Symbol Rate
9600	19200	No repetition	19200
4800	9600	Repeat 1 time (2 symbols)	19200
2400	4800	Repeat 3 times (4 symbols)	19200
1200	2400	Repeat 7 times (8 symbols)	19200

MMT98010199Ag.emf

Rate Set 1 Symbol Repetition

In addition to the convolutional coding, the symbols are repeated when lower rate frames are produced by the vocoder. The repetition maintains a constant symbol rate of 19,200 symbols per second regardless of the rate of the vocoder.

QUALCOMM cdma university

Forward Traffic Channel Generation – Rate Set 2 Symbol Repetition

CDMA2000 1x RC1 & RC2 Section 4-42

Repetition Maintains Constant 19.2 ksps Output

Data Rate	Code Rate	Repetition Rate	Symbol Rate
14400	19200	No repetition	19200
7200	9600	Repeat 1 time (2 symbols)	19200
3600	4800	Repeat 3 times (4 symbols)	19200
1800	2400	Repeat 7 times (8 symbols)	19200

MMT98010201Ag.emf

Rate Set 2 Symbol Repetition

When the Rate Set 2 vocoder is used, the rate ¾ convolutional coding results in the same number of symbols as the Rate Set 1 vocoder. Symbol repetition can then be done in the same way to maintain a constant symbol rate of 19,200 symbols per second.

QUALCOMM cdma university

Forward Traffic Channel Generation – Symbol Repetition

CDMA2000 1x RC1 & RC2 Section 4-43

$$\text{Energy}_{\text{SYM}} = \text{Power} \times \text{Duration}_{\text{SYM}}$$

MMT98010202Bg.emf

Symbol Repetition

- Redundant symbols reduce the “energy per symbol” requirement.
- Lower energy in a symbol = lower power level = lower interference.

The symbols transmitted on each code channel are a function of the data rate:

- Full rate symbols are sent at full power for that code channel.
- ½ rate symbols are sent at a power 3 dB below the full rate code channel.
- ¼ rate symbols are sent at a power 6 dB below the full rate code channel power.
- $^{1}/_{8}$ rate symbols are sent at a power of 9 dB below the full rate code channel power.

With the lower rate symbols having a longer duration, they end up being sent with the same energy, so the BER of all rates is the same. The advantage of this technique is the reduction of interference to other code channels.

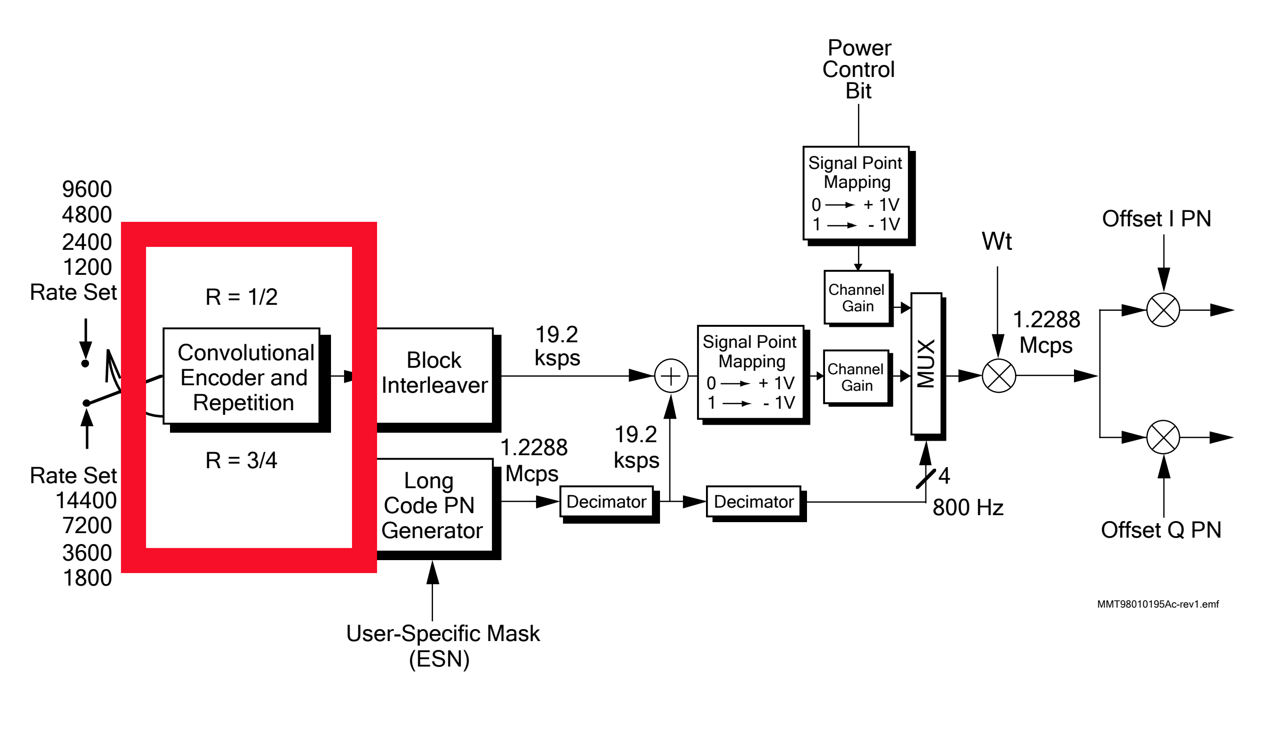
The symbol energy is adjusted by the Base Station on a frame-by-frame basis.

The Base Station adjusts each user according to the data rate of the frame.

cdma university

Forward Traffic Channel Generation – Convolutional Coding

CDMA2000 1x
RC1 & RC2
Section 4-44



Convolutional Coding

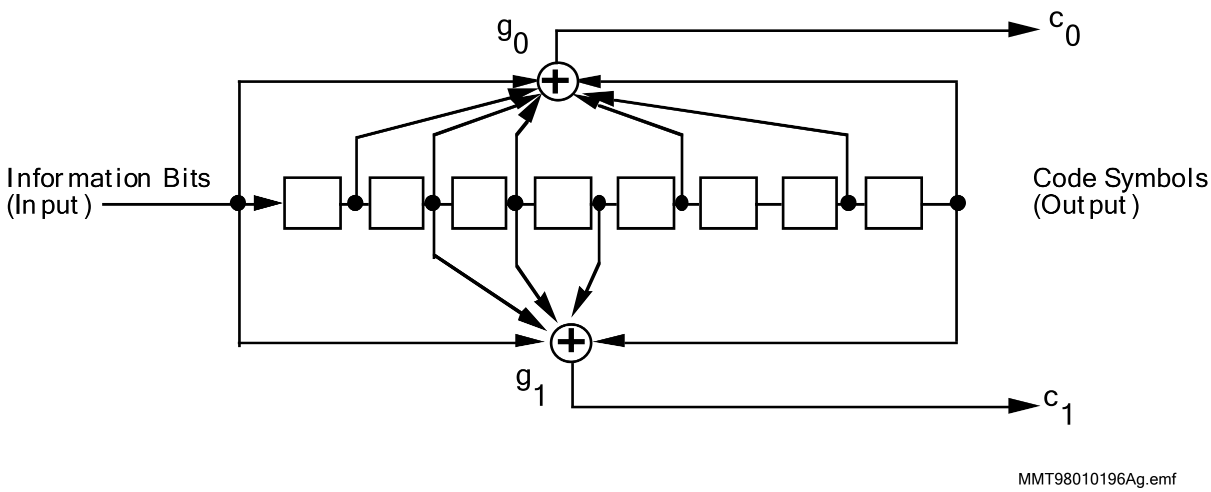
Powerful convolutional coding is employed to provide FEC capability. The convolutional coding provides redundancy that the receiver uses to correct errors.

- For Rate Set 1, two symbols are transmitted for each data bit.
- For Rate Set 2, 4 symbols are transmitted for each three data bits.

QUALCOMM cdma university

Forward Traffic Channel Generation – Rate ½ Coding

CDMA2000 1x RC1 & RC2 Section 4-45

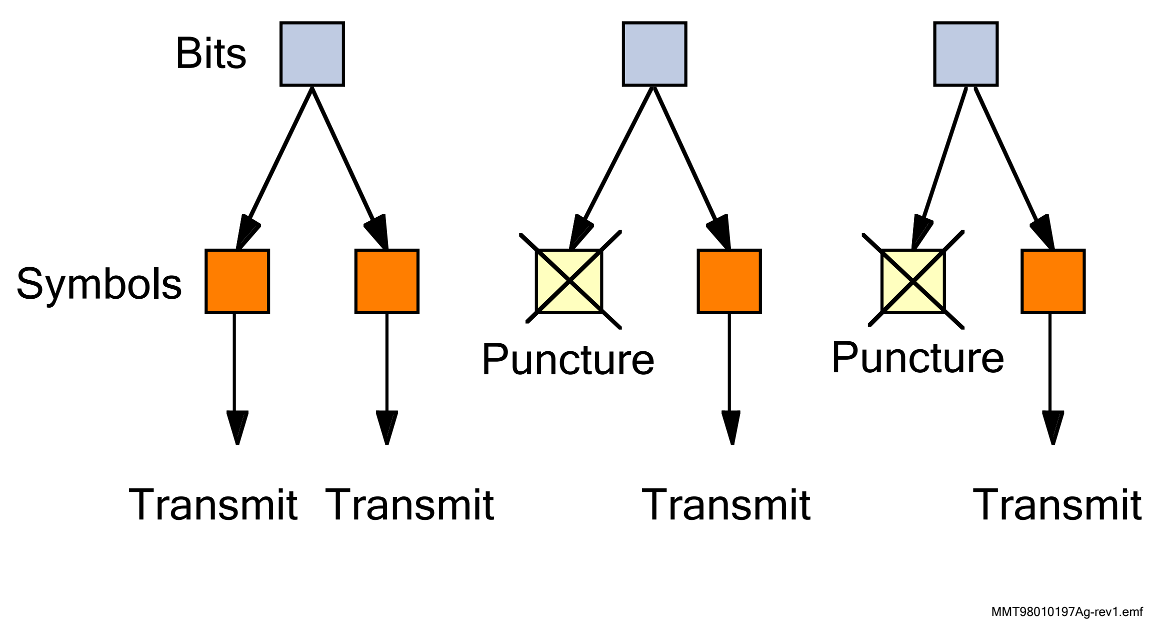


Rate ½ Coding

When the Rate Set 1 vocoder is used, the convolutional coding is performed at rate ½ , constraint length 9 as is shown in the figure. Complexity increases exponentially with the constraint length. Increasing the constraint length beyond 9 would increase the coding gain slightly with a great increase in complexity.

Constraint length 9 is the current state of the art for practical systems. Other wireless technologies use constraint lengths of 4 or 5.

Forward Traffic Channel Generation – Rate 3/4 Coding (Rate Set 2)



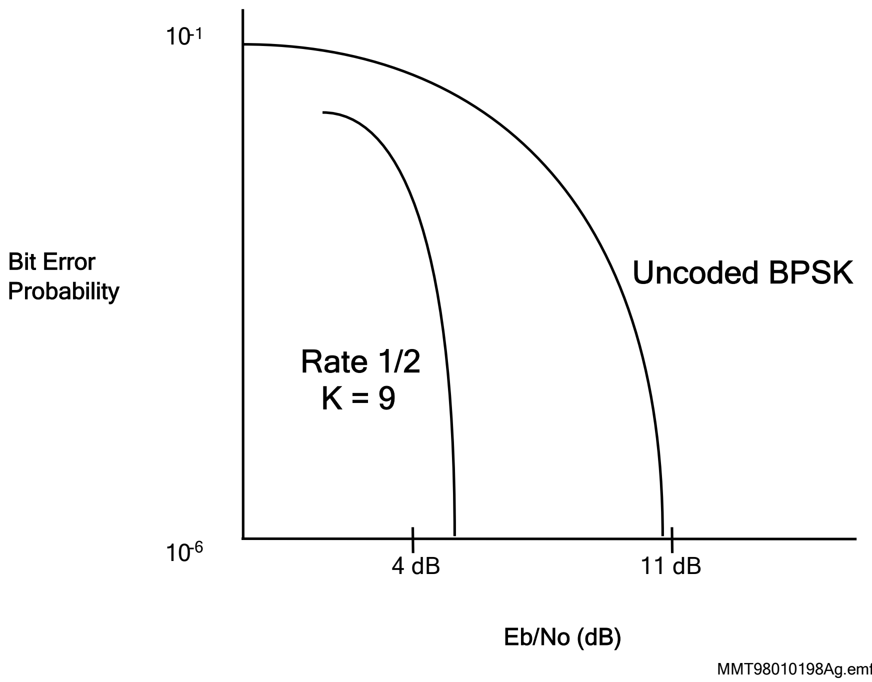
Rate ¾ Coding

When the Rate Set 2 vocoder is used, convolutional coding is performed at rate ¾ , constraint length 9. The ¾ code is achieved by “puncturing” the same rate ½ code. The puncturing is accomplished as shown in the figure. Rate ¾ is not as strong as Rate ½.

QUALCOMM cdma university

Forward Traffic Channel Generation – Coding Gain

CDMA2000 1x RC1 & RC2 Section 4-47



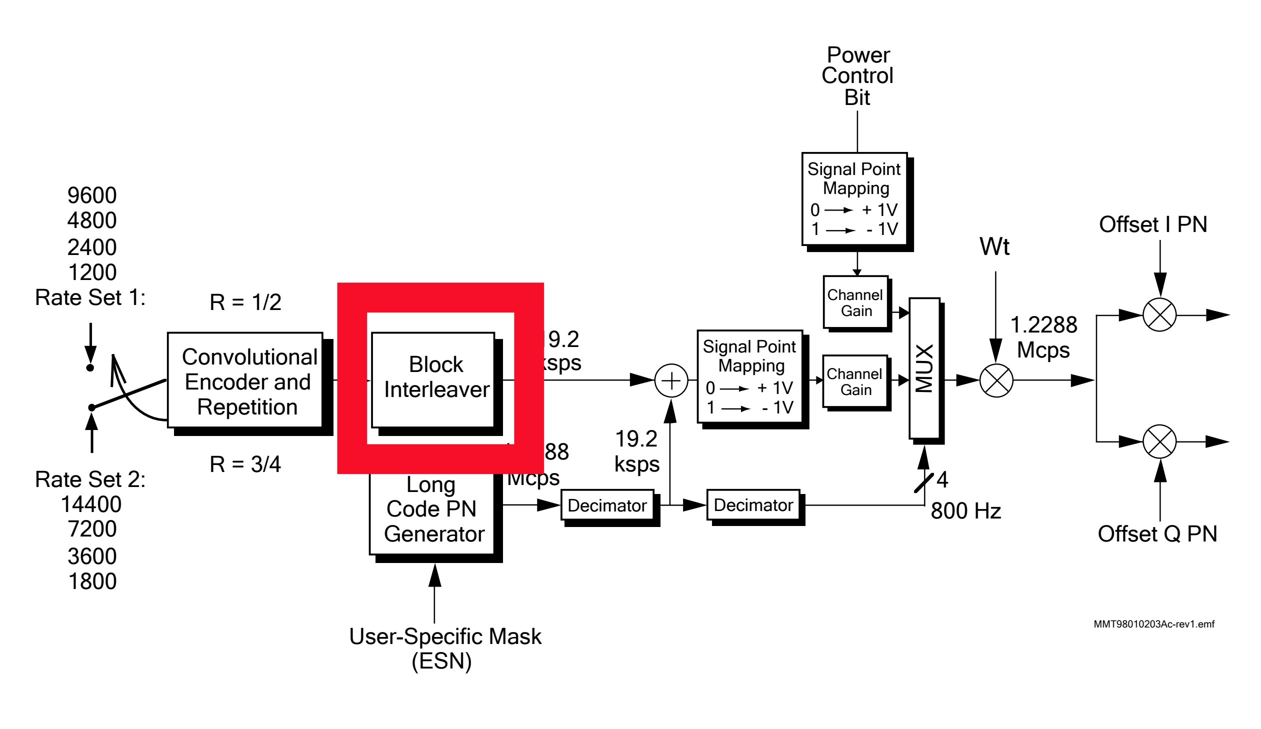
Coding Gain

The figure illustrates the benefits of FEC coding (not to scale). At a BER of approximately 10^{-3} in an AWGN environment, the rate ½ coding provides about 4 dB of coding gain. The puncturing of the rate ½ code to produce the rate ¾ code reduces the coding gain down to about 2.5 dB. This coding gain enables the transmitter to reduce power and achieve the same error rate.

QUALCOMM cdma university

Forward Traffic Channel Generation – Interleaving

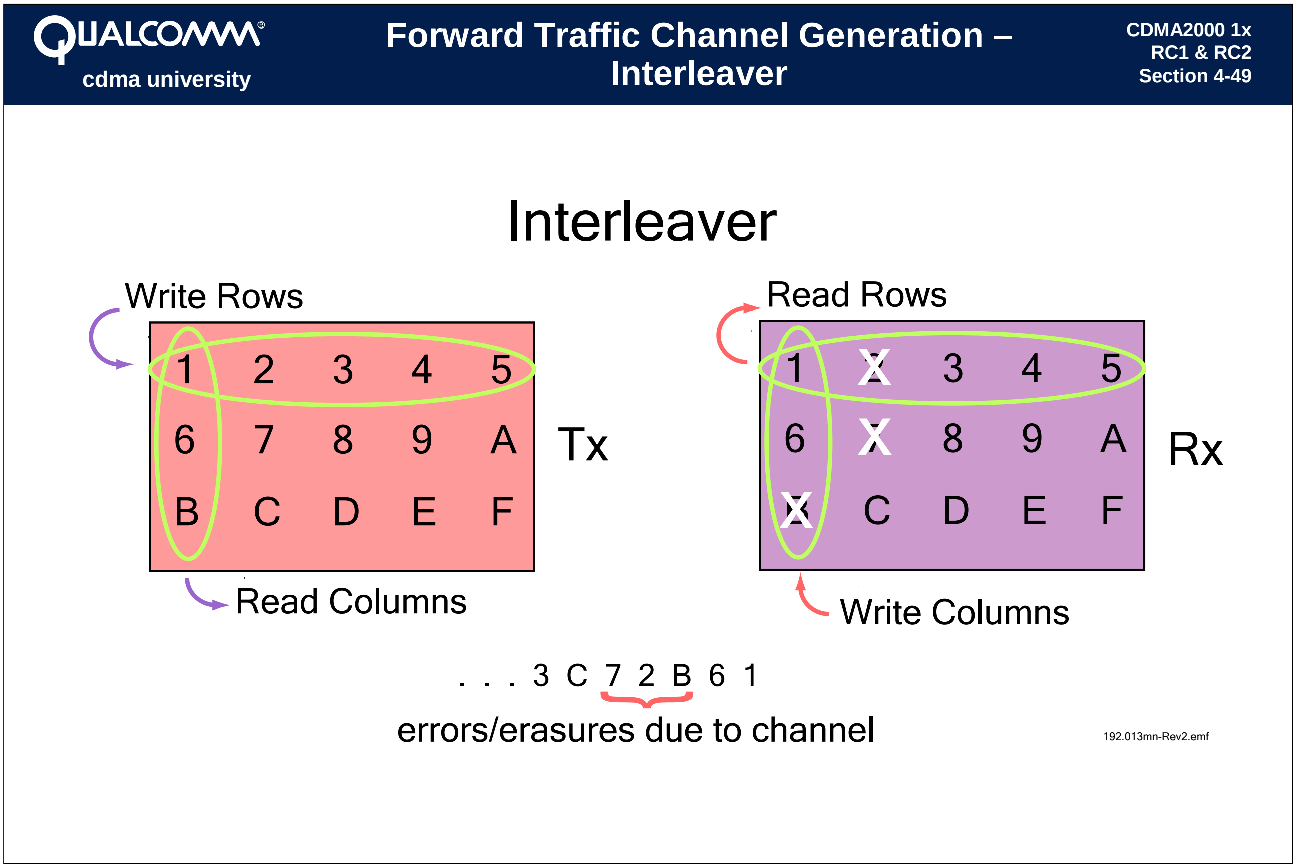
CDMA2000 1x RC1 & RC2 Section 4-48



Interleaving

Convolutional coding and repetition is followed by interleaving. Interleaving is a re-ordering of the symbols. The interleaving is performed on 20 ms blocks (exactly one vocoded frame). There is no interleaving across the frame boundaries. Each vocoder rate has a defined input and output array.

Interleaving is used to combat the effects of multipath fading. Since each bit input to the convolutional encoder is spread across nine output symbol times, it is advantageous to spread these nine symbols in time to defeat the effects of frequency selective (multipath) fading. When a fade occurs, it is most likely to cause erasures in several adjacent bits. If the bits are spread in time, there is a greater chance at successful recovery by the Viterbi decoder.



The Interleaver

To protect the Viterbi decoder from bursts of errors, an interleaver is used. At the transmitter, the data is delivered into the matrix rows. The data is read out of the matrix in column order. The receiver performs the opposite operation to restore the data to its original order.

Notice that the bursts of errors (symbols 7, 2, and B) are now more uniformly distributed in the output data. This improves the decoder performance in the fading channel experienced in cellular channels.

In IS-95 and CDMA2000, the interleaver matrix is larger than this example, and has up to 576 cells. For IS-95, or RC1/RC2 modes of CDMA2000, the over-the-air order is defined by

$$A_i = 2^m (i \bmod j) + BRO_m([i/j])$$

where $i = 0$ to $N-1$

$[x]$ largest interger $\leq x$

$BRO_m(Y)$ is the bit reversed m bit, value Y

for example, $BRO_m(6) = 3$

QUALCOMM cdma university

Forward Traffic Channel Generation – Interleaving at Full Rate

CDMA2000 1x RC1 & RC2 Section 4-50

16 Columns

WRITE — 24 rows

1	25	49	73	97	121	145	169	193	217	241	265	289	313	337	361
2	26	50	74	98	122	146	170	194	218	242	266	290	314	338	362
3	27	51	75	99	123	147	171	195	219	243	267	291	315	339	363
4	28	52	76	100	124	148	172	196	220	244	268	292	316	340	364
5	29	53	77	101	125	149	173	197	221	245	269	293	317	341	365
6	30	54	78	102	126	150	174	198	222	246	270	294	318	342	366
7	31	55	79	103	127	151	175	199	223	247	271	295	319	343	367
8	32	56	80	104	128	152	176	200	224	248	272	296	320	344	368
9	33	57	81	105	129	153	177	201	225	249	273	297	321	345	369
10	34	58	82	106	130	154	178	202	226	250	274	298	322	346	370
11	35	59	83	107	131	155	179	203	227	251	275	299	323	347	371
12	36	60	84	108	132	156	180	204	228	252	276	300	324	348	372
13	37	61	85	109	133	157	181	205	229	253	277	301	325	349	373
14	38	62	86	110	134	158	182	206	230	254	278	302	326	350	374
15	39	63	87	111	135	159	183	207	231	255	279	303	327	351	375
16	40	64	88	112	136	160	184	208	232	256	280	304	328	352	376
17	41	65	89	113	137	161	185	209	233	257	281	305	329	353	377
18	42	66	90	114	138	162	186	210	234	258	282	306	330	354	378
19	43	67	91	115	139	163	187	211	235	259	283	307	331	355	379
20	44	68	92	116	140	164	188	212	236	260	284	308	332	356	380
21	45	69	93	117	141	165	189	213	237	261	285	309	333	357	381
22	46	70	94	118	142	166	190	214	238	262	286	310	334	358	382
23	47	71	95	119	143	167	191	215	239	263	287	311	335	359	383
24	48	72	96	120	144	168	192	216	240	264	288	312	336	360	384

Full Rate Interleaver Input Array

Full Rate Interleaver Output Array

READ

1	9	5	13	3	11	7	15	2	10	6	14	4	12	8	16
65	73	69	77	67	75	71	79	66	74	70	78	68	76	72	80
129	137	133	141	131	139	135	143	130	138	134	142	132	140	136	144
193	201	197	205	195	203	199	207	194	202	198	206	196	204	200	208
257	265	261	269	259	267	263	271	258	266	262	270	260	268	264	272
321	329	325	333	323	331	327	335	322	330	326	334	324	332	328	336
33	41	37	45	35	43	39	47	34	42	38	46	36	44	40	48
97	105	101	109	99	107	103	111	98	106	102	110	100	108	104	112
161	169	165	173	163	171	167	175	162	170	166	174	164	172	168	176
225	233	229	237	227	235	231	239	226	234	230	238	228	236	232	240
289	297	293	301	291	299	295	303	290	298	294	302	292	300	296	304
353	361	357	365	355	363	359	367	354	362	358	366	356	364	360	368
17	25	21	29	19	27	23	31	18	26	22	30	20	28	24	32
81	89	85	93	83	91	87	95	82	90	86	94	84	92	88	96
145	153	149	157	147	155	151	159	146	154	150	158	148	156	152	160
209	217	213	221	211	219	215	223	210	218	214	222	212	220	216	224
273	281	277	285	275	283	279	287	274	282	278	286	276	284	280	288
337	345	341	349	339	347	343	351	338	346	342	350	340	348	344	352
49	57	53	61	51	59	55	63	50	58	54	62	52	60	56	64
113	121	117	125	115	123	119	127	114	122	118	126	116	124	120	128
177	185	181	189	179	187	183	191	178	186	182	190	180	188	184	192
241	249	245	253	243	251	247	255	242	250	246	254	244	252	248	256
305	313	309	317	307	315	311	319	306	314	310	318	308	316	312	320
369	377	373	381	371	379	375	383	370	378	374	382	372	380	376	384

MMT98010204Ag.emf

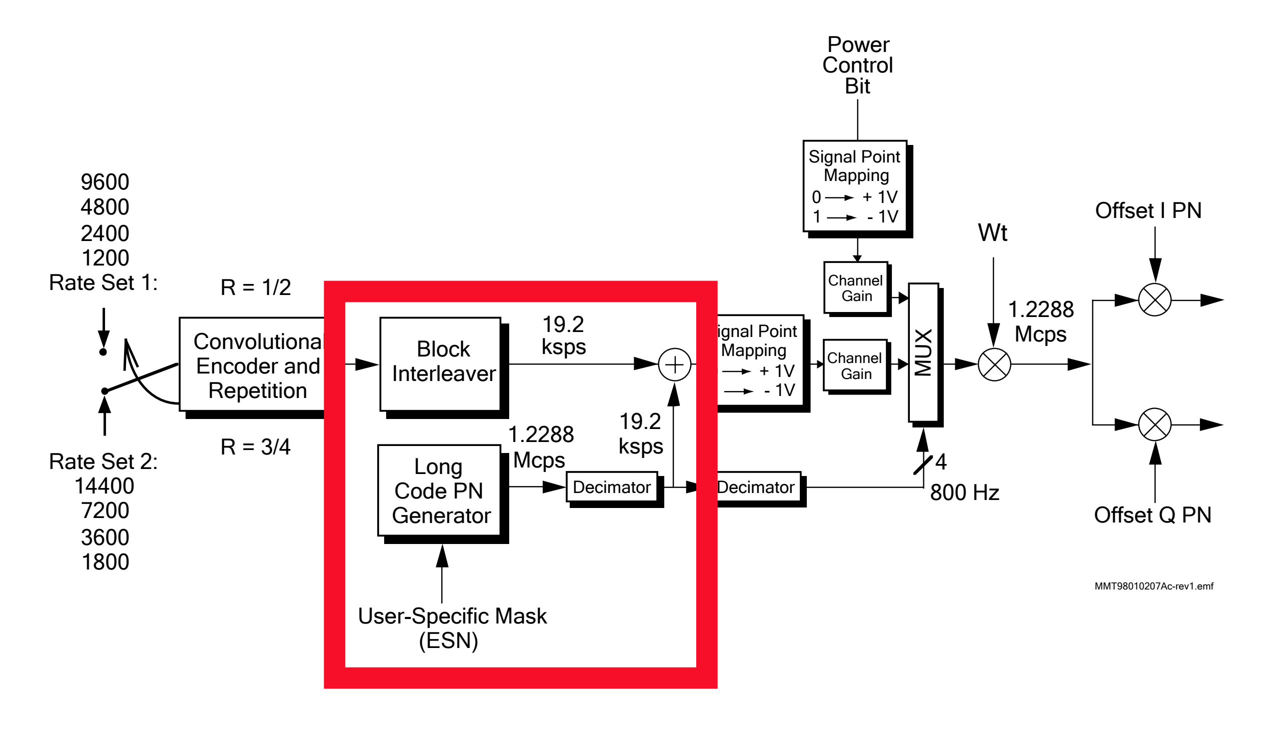
Interleaving at Full Rate

There are 384 symbols to transmit in each full rate frame. Once a full frame of symbols has been collected, they can be transmitted. The advantage is better performance against bursts of errors in the fading environment; the disadvantage is the delay associated with collecting an entire frame of symbols before transmission can start.

QUALCOMM cdma university

Forward Traffic Channel Generation – Scrambling the Signal

CDMA2000 1x RC1 & RC2 Section 4-51



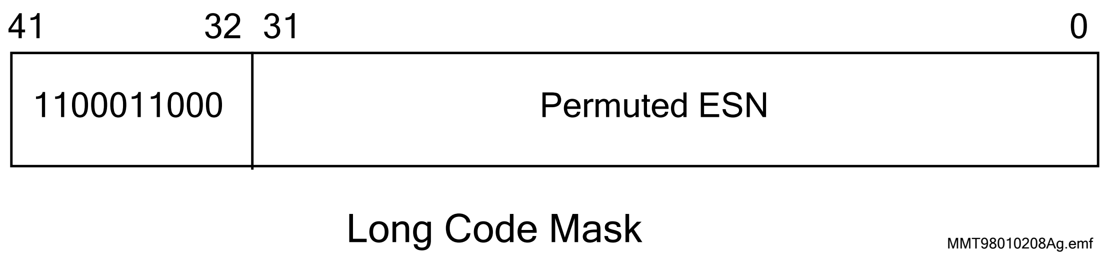
Scrambling the Signal

At this point, the Forward Traffic Channel is scrambled. The 19,200 symbols per second are multiplied by a Pseudorandom Noise sequence that is also generated at 19,200 chips per second. Each symbol is added modulo-2 with one chip of the scrambling sequence. This process ensures that the data appears random and that the data is more difficult to intercept.

cdma university

Forward Traffic Channel Generation – Signal Scrambled Using the Long Code

CDMA2000 1x
RC1 & RC2
Section 4-52



Signal is Scrambled Using the Long PN Code

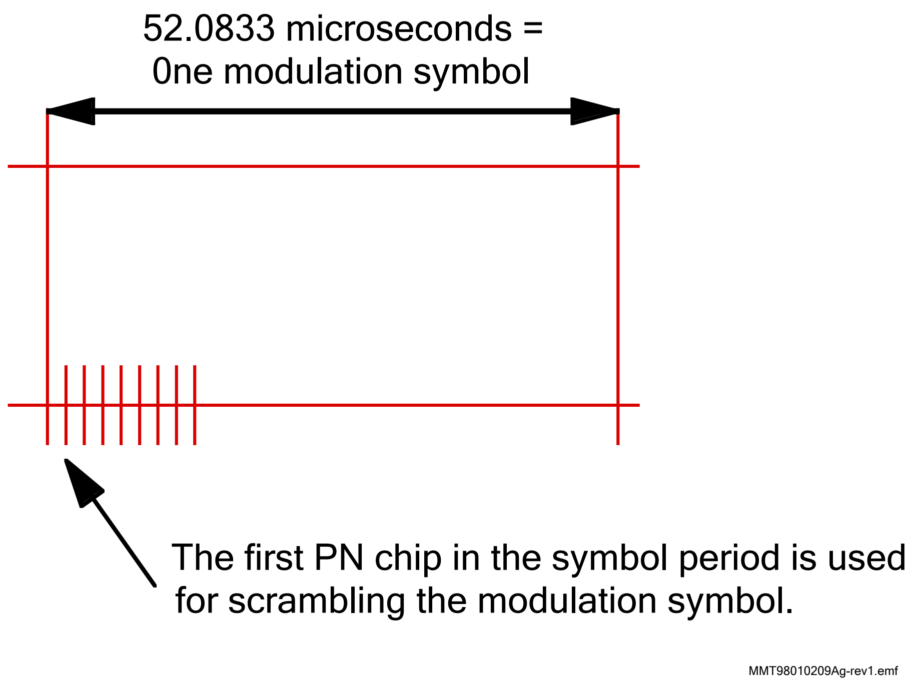
The scrambling sequence is produced by the Long code PN generator. The generator is masked using a 42-bit mask as shown in the figure. The 10 high order bits of the mask are fixed. The remaining 32 bits are based on the mobile’s ESN.

The Long Code generator produces 1.2288 Mcps. Only 19,200 chips per second are needed for scrambling. A decimator is used to cut down the rate of the PN sequence by selecting the first chip in every symbol period.

QUALCOMM cdma university

Forward Traffic Channel Generation – Data Scrambling Decimator

CDMA2000 1x RC1 & RC2 Section 4-53



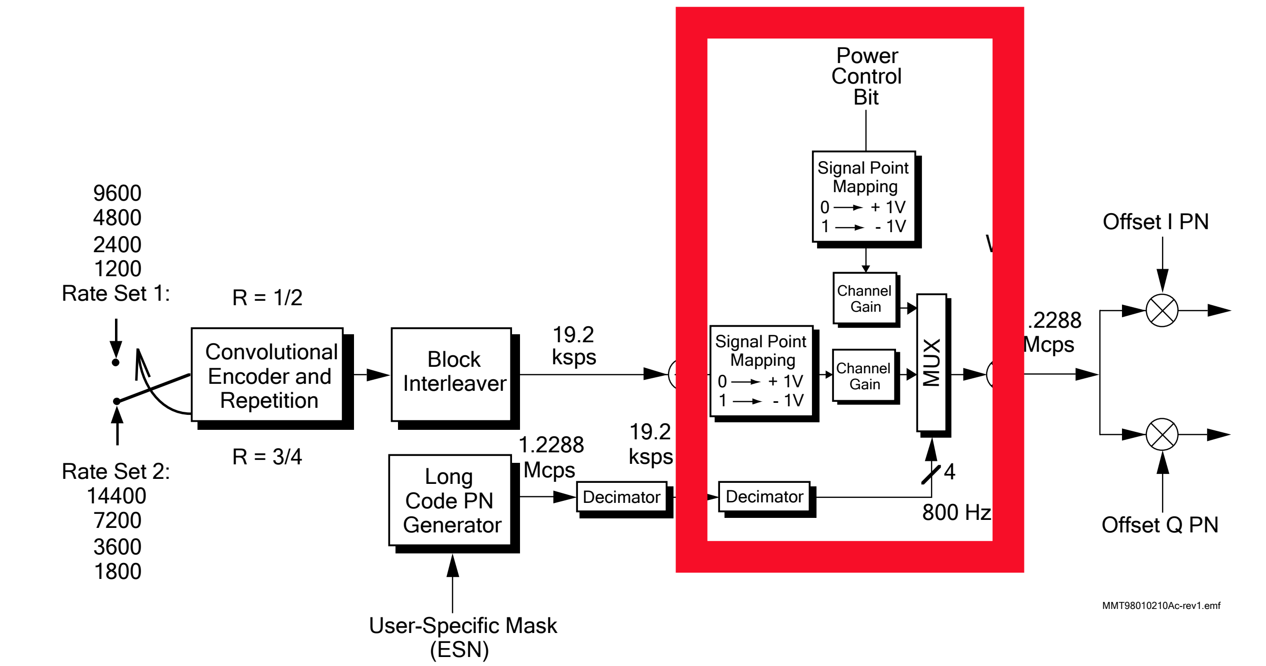
Data Scrambling Decimator

The Long Code PN generator is clocked at 1.2288 Mcps, and scrambling data is needed only at 19,200 cps, so the decimator is used to pick every 64^{th} bit.

QUALCOMM cdma university

Forward Traffic Channel Generation – Puncturing the Power Control Sub-Channel

CDMA2000 1x RC1 & RC2 Section 4-54



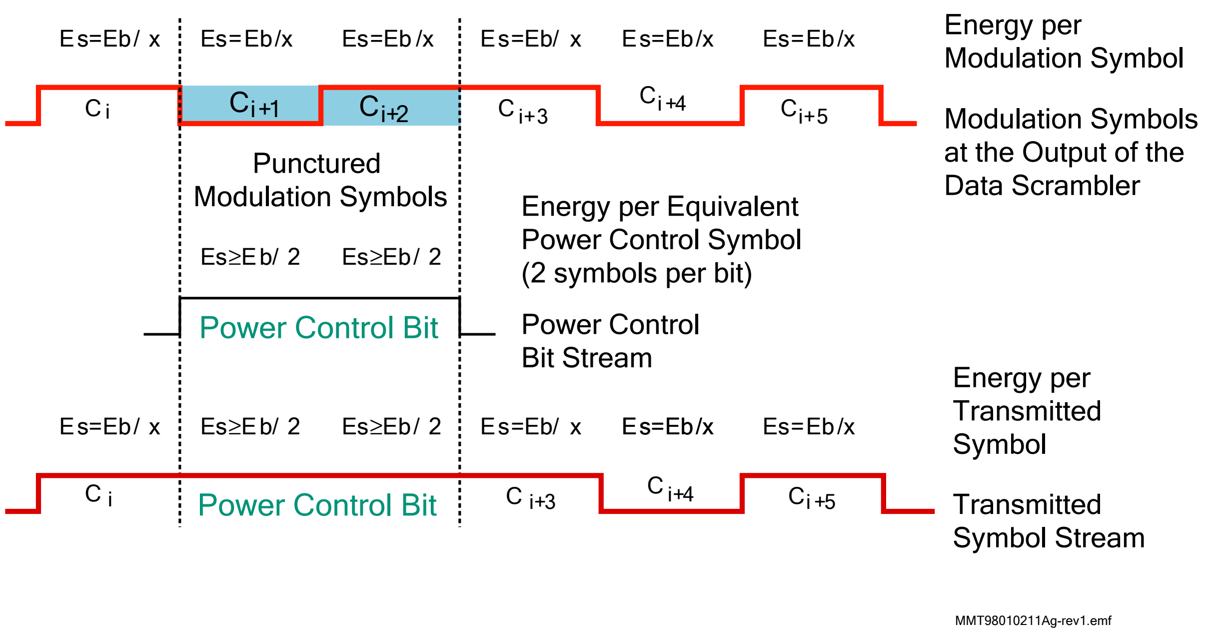
The Power Control Sub-Channel

The Reverse Closed Loop Power Control bits are punctured into the data at a rate of 800 Hz. The location of the puncture is pseudorandom and controlled by the Long Code PN stream.

cdma university

Forward Traffic Channel Generation – Puncturing the Power Control Bits

CDMA2000 1x
RC1 & RC2
Section 4-55



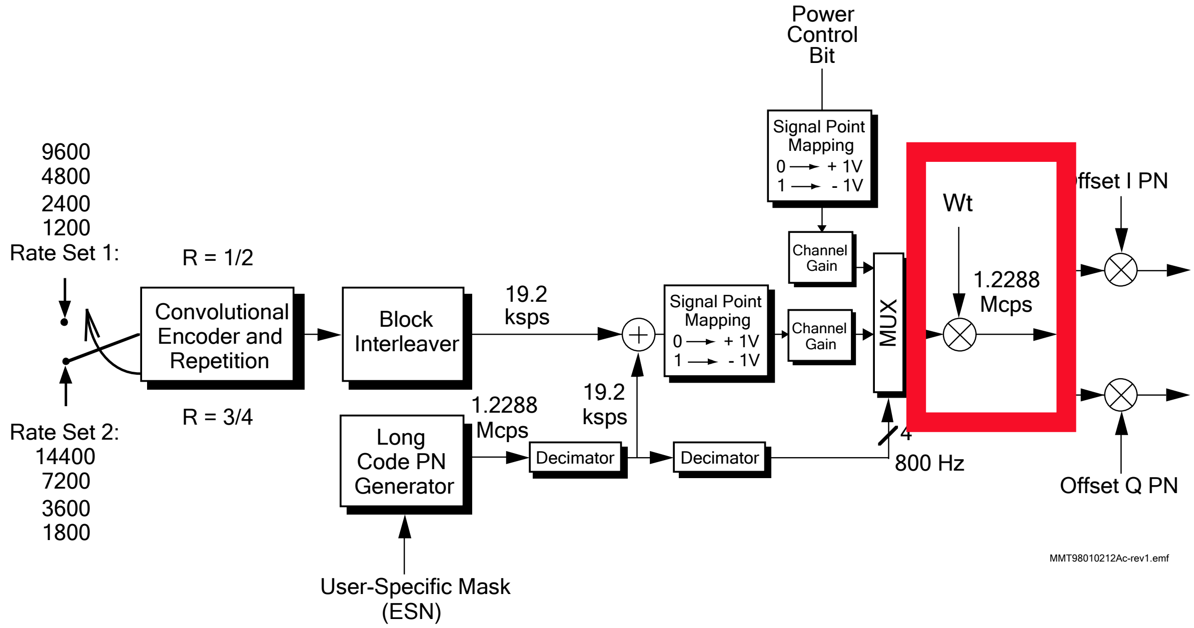
Puncturing Power Control Bits

The duration of the Power Control bit is two symbol periods for Rate Set 1. In Rate Set 2, only one code symbol is punctured.

Puncturing overwrites the data and introduces errors. The convolutional coding protects the user data from these errors; the receiver can correct the mistakes. The intentional puncturing reduces the coding gain.

cdma university

Forward Traffic Channel Generation – Orthogonal Spreading



Orthogonal Spreading: The Code That Divides

The signal is then orthogonally spread using the Walsh codes.

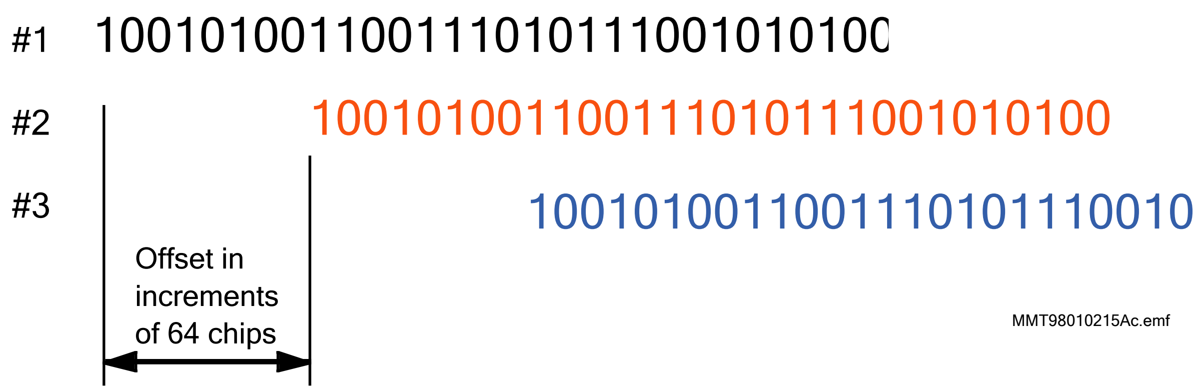
Each Traffic Channel in the Forward direction uses a unique Walsh code. The Walsh codes are reused in every sector. Traffic Channel Walsh assignments are determined at call setup by messages.

Different sectors are allowed to use different Walsh sequences when in soft handoff. The Walsh code is always clocked at a 1.2288 Mcps rate for 1x systems.

QUALCOMM cdma university

Forward Traffic Channel Generation – PN Offset Cell Identification

CDMA2000 1x RC1 & RC2 Section 4-57



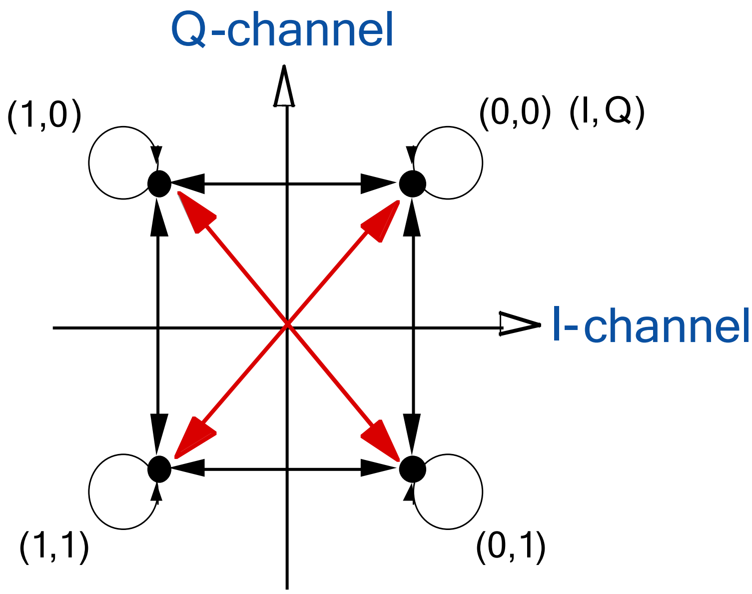
PN Offset Cell Identification

The short PN codes are uniquely offset for each sector. The minimum offset permitted is 64 PN chips. This results in a maximum of 512 possible offsets. System operators can choose to further restrict the number of available offsets. Deployed systems typically use a minimum offset of 128 or 256 chips.

QUALCOMM cdma university

Forward Traffic Channel Generation – Forward CDMA Channel I & Q Mapping

CDMA2000 1x RC1 & RC2 Section 4-58



I	Q	Phase
0	0	p/4
1	0	3p/4
1	1	-3p/4
0	1	-p/4

MMT98010254Ag_rev2.emf

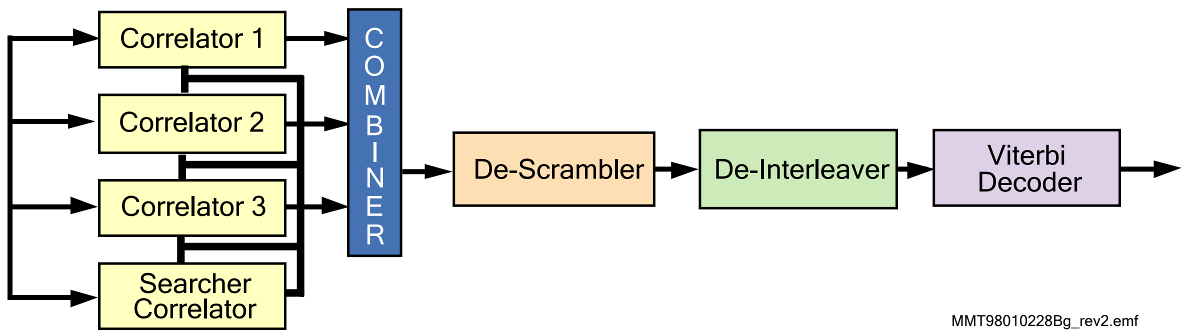
Forward CDMA Channel I & Q Mapping

The I and Q channel chips are mapped into phase shifts of the carrier signal, as shown in the figure. When the value of both the I and Q chips changes simultaneously, a 180° phase shift results.

QUALCOMM cdma university

Forward CDMA Channel Demodulation

CDMA2000 1x RC1 & RC2 Section 4-59



Demodulation of the Forward CDMA Channel

- The signal is down-converted from the 800 MHz or 1.9 GHz bands down to baseband. A/D conversion is performed. The signal is now at digital baseband.
- The mobile implements a rake receiver design. The QUALCOMM implementation has multiple demodulating elements (fingers) and a searcher. The searcher identifies strong multipath arrivals and a finger is assigned to demodulate at the offset identified.
- The correlators perform a product integration in order to despread both the Short PN codes and the appropriate Walsh code.
- The outputs of the correlators are combined at the symbol rate.
- The signal is then de-scrambled and de-interleaved.
- The next step is Viterbi decoding. The decoder does not know the rate of the vocoded frame and must decode at all four rates, then use metrics to decide which rate was the most likely one transmitted.

QUALCOMM cdma university

Reverse Link Characteristics – RC1 and RC2

CDMA2000 1x RC1 & RC2 Section 4-60

- 1x spreading rate
- Long PN Code multiplexed
- Orthogonal modulation
- FEC is convolutional K=9
- Fixed 20 ms frames

RC1 and RC2

The spreading rate for RC1 and RC2 (TIA/EIA-95) is always 1.2288 Mcps.

The users are channelized by using different Long Code offsets for spreading. Walsh functions are not used on the Reverse link because the mobile signals do not arrive at the Base Station antenna time-synchronized, due to the mobiles being at different distances from the Base Station.

Walsh functions are used as modulation symbols on the Reverse link.

QUALCOMM cdma university

Reverse Link Characteristics – RC>2

CDMA2000 1x RC1 & RC2 Section 4-61

- Channels primarily code multiplexed.
- Separate channels used for different QoS and Physical Layer characteristics.
- Transmission continuous to avoid EMI issues.
- Code multiplexed channels orthogonalized by Walsh functions and I/Q split so that performance equivalent to BPSK.
- Hybrid combination of QPSK and Pi/2 BPSK:
  - By restricting alternate phase changes of the complex scrambling sequence, power peaking is reduced (1 dB improvement) and side lobes are narrowed.

RC>2

The mobile now transmits multiple channels simultaneously, using Walsh codes. The data on the Reverse link is now modulated QPSK. With the addition of the Pilot, the capacity of the Reverse link has been increased.

QUALCOMM cdma university

Reverse Link Characteristics – RC>2 (continued)

CDMA2000 1x RC1 & RC2 Section 4-62

- Code multiplexed channels:
  - Walsh sequence separate physical channels.
- Forward error correction:
  - Convolutional codes (K=9) are used for voice and data.
  - Parallel turbo codes (K=4) are used for high data rates on Supplemental.
- Fast Reverse power control:
  - 800 Hz update rate
- Frame lengths:
  - 5 ms, 10 ms, 20 ms, 40 ms, and 80 ms frames

RC>2 (continued)

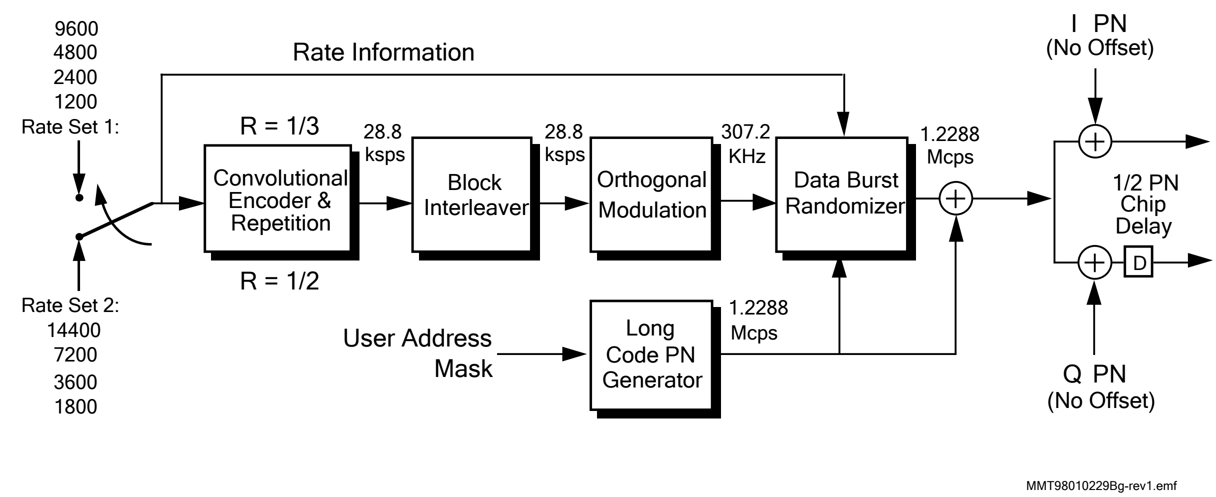
For the CDMA2000 modes, the Reverse link is more complex. Multiple channels are transmitted simultaneously (i.e., Pilot + Traffic) and these are separated by Walsh functions.

Turbo codes are an option in the CDMA2000 Reverse link for higher data rates.

QUALCOMM cdma university

Reverse Traffic Channel Generation RC1 and RC2

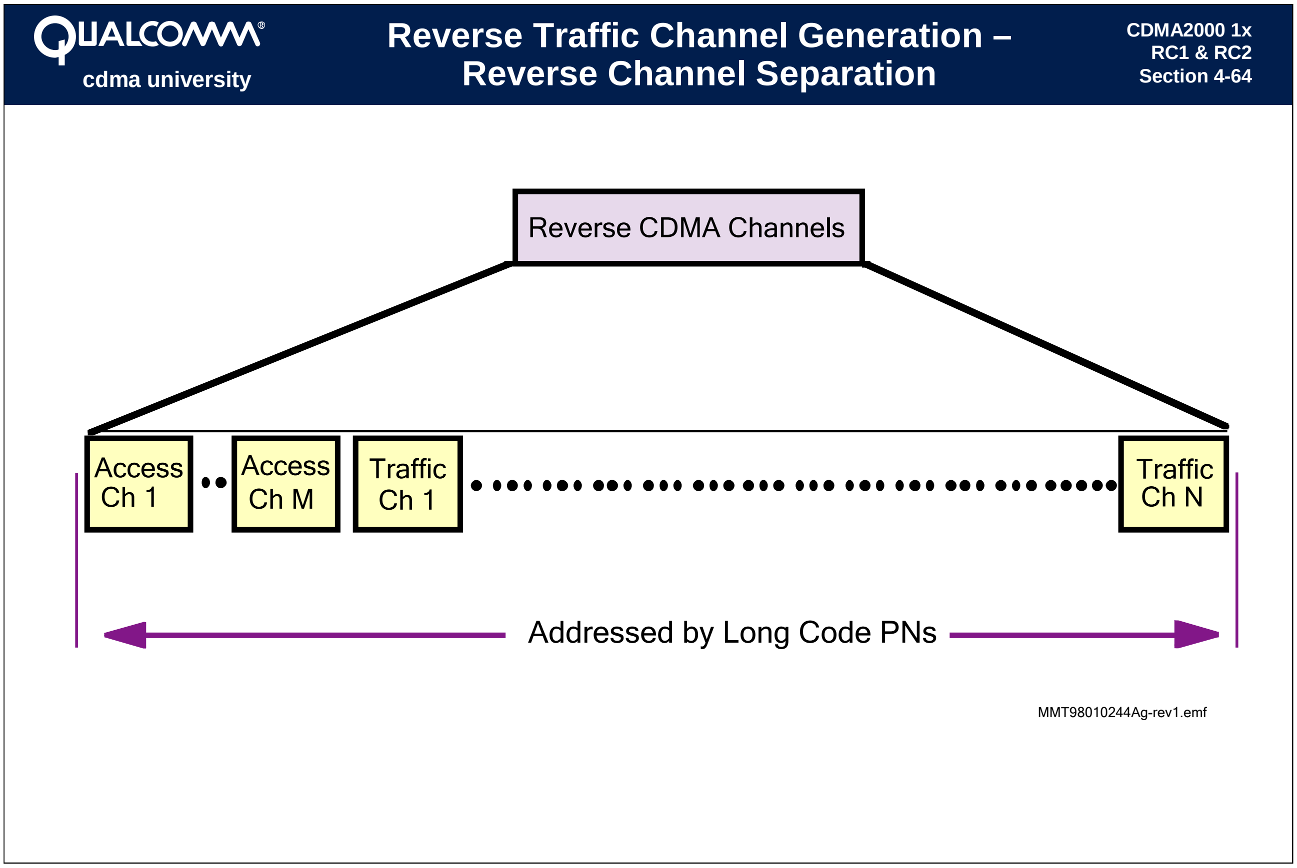
CDMA2000 1x RC1 & RC2 Section 4-63



Reverse Traffic Channel Generation - RC1 and RC2

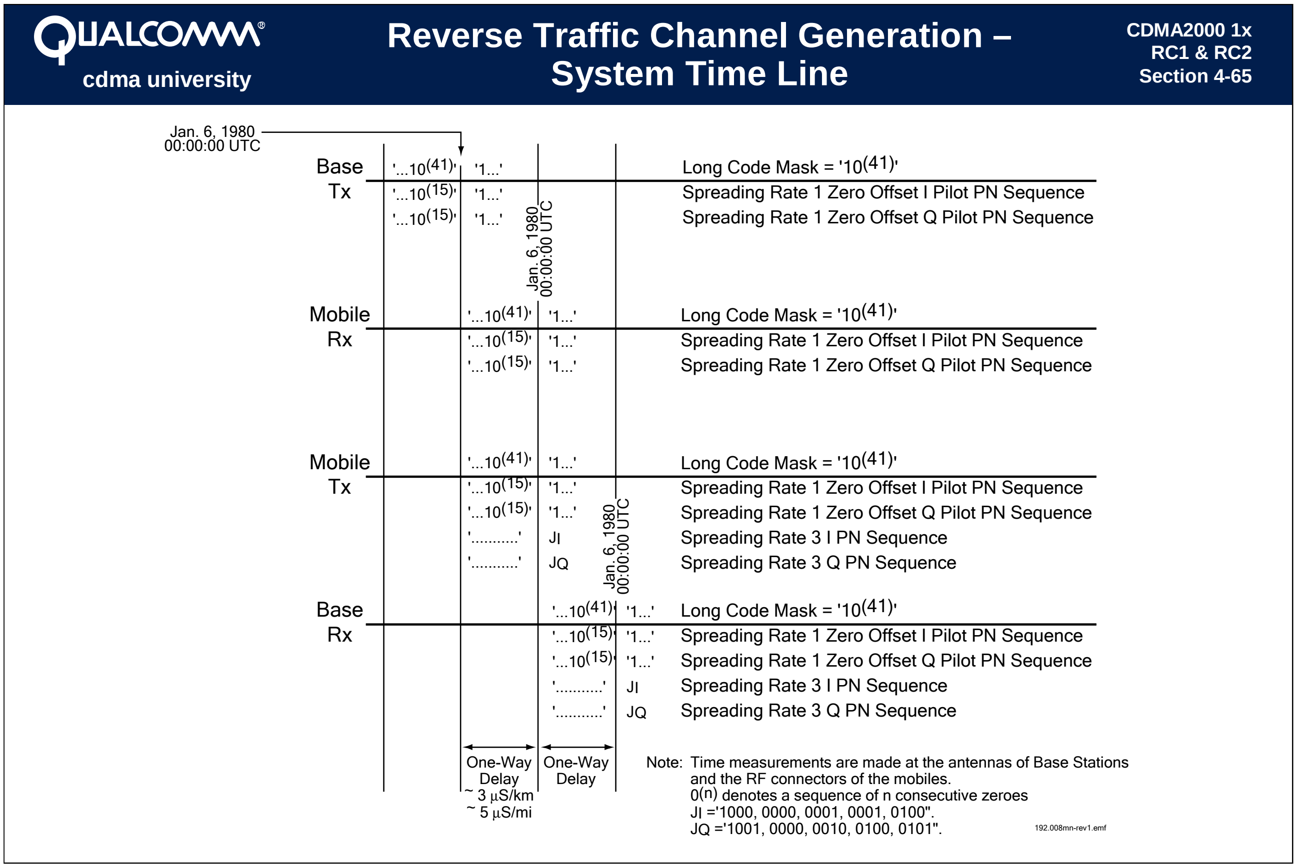
Generation of the Reverse Traffic Channel is considerably different than generation of the Forward Traffic Channel.

Both vocoder Rates 1 and 2 are supported. Convolutional coding and interleaving are performed as in the Forward direction, but several new processes then follow. An orthogonal modulation scheme is used, followed by a data burst randomizer that determines when to turn off the mobile transmitter to reduce average transmit power.



Reverse Channel Separation

All channels in the Reverse direction are isolated from each other using the Long PN code. There are billions of possible offsets to this code, allowing for an immense address space.



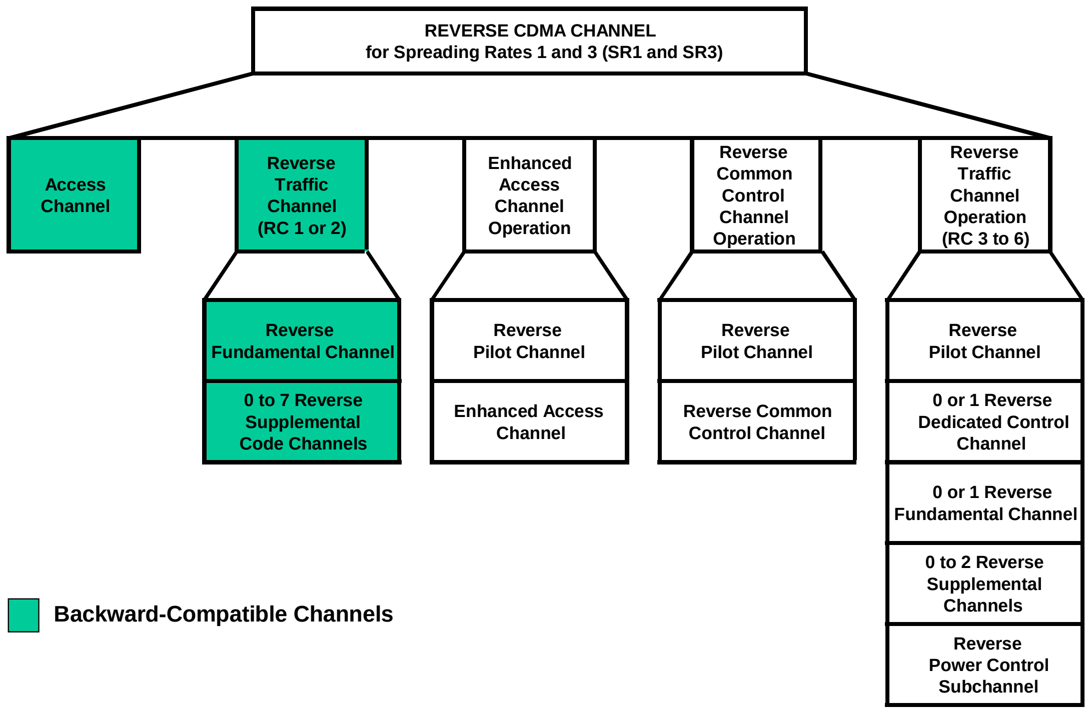
System Time Line

All Base Stations in CDMA2000 are time synchronous. The mobile transmission is not corrected for the path loss delay.

QUALCOMM cdma university

Reverse Traffic Channel Generation – Reverse Link Code Channels

CDMA2000 1x RC1 & RC2 Section 4-66



Reverse Link Code Channels

The CDMA2000 Reverse link code channels are:

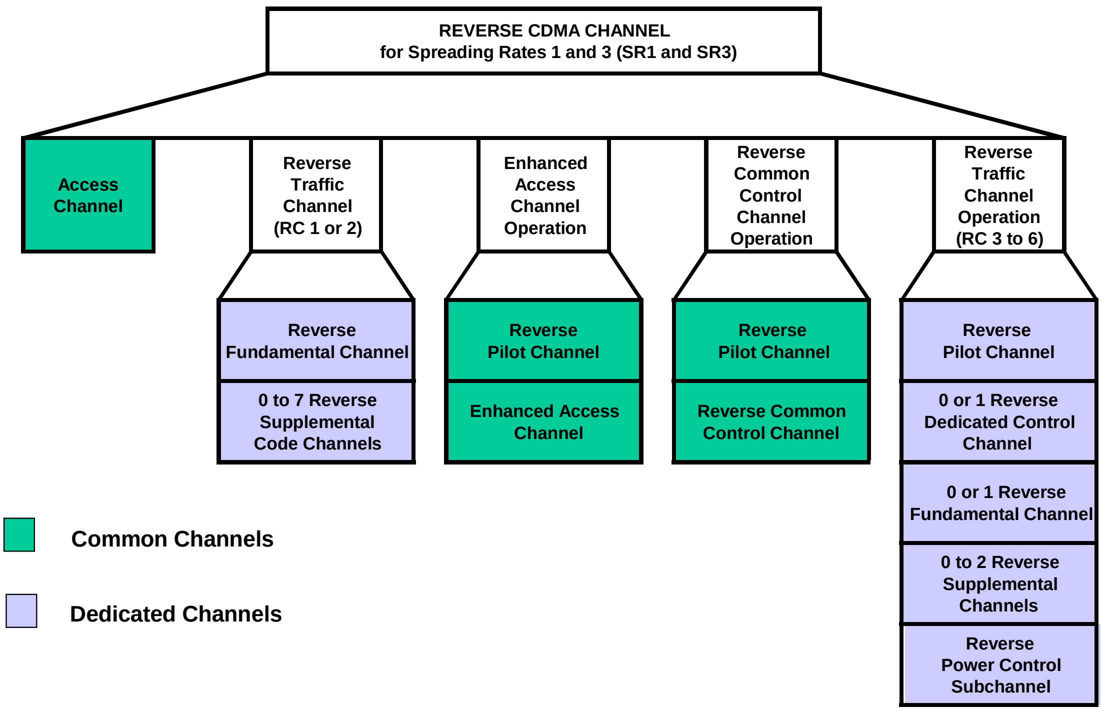
- R-ACH Access Channel
- R-PICH Reverse Pilot Channel
- R-EACH Enhanced Access Channel
- R-CCCH Reverse Common Control Channel
- R-DCCH Reversed Dedicated Control Channel
- R-FCH Reverse Fundamental Channel
- R-SCH Reverse Supplemental Channel
- R-SCCH Reverse Supplemental Code Channel

The Access Channel and Reverse Supplemental Code Channel are retained for backward compatibility with TIA/EIA-95A/B. For Radio Configurations 1 and 2, the channel structure for Reverse Fundamental Channel and Reverse Supplemental Code Channel is the same as the channel structure of Rate Set 1 and Rate Set 2 used in TIA/EIA-95A/B.

Only the Access Channel and Reverse Traffic Channel are available in Release 0.

The Enhanced Access Channel and the Reverse Common Control Channel become available in Release A.

Reverse Traffic Channel Generation – Reverse Common and Dedicated Channels



Reverse Common and Dedicated Channels

Reverse link common channels are used by multiple mobiles primarily for a brief exchange of information between a mobile and a Base Station. The Reverse link common channels are:

- Access Channel
- Enhanced Access Channel
- Reverse Common Control Channel

Reverse link dedicated channels are assigned to a single mobile for the duration of a call. The Reverse link dedicated channels include:

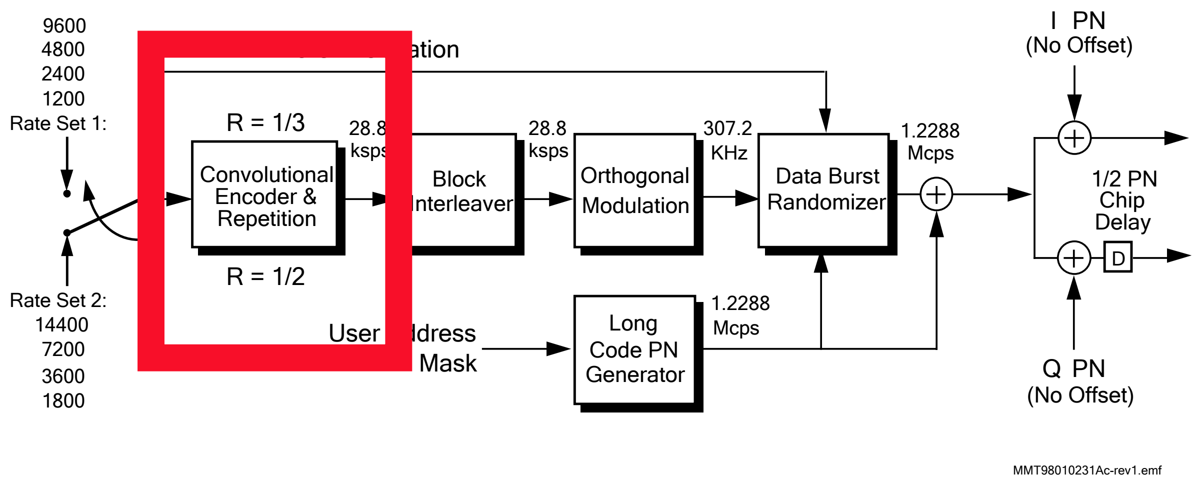
- Reverse Dedicated Control Channel
- Reverse Fundamental Channel
- Reverse Supplemental Channel
- Reverse Supplemental Code Channel

The Reverse Pilot Channel is used with both common and dedicated channels.

QUALCOMM cdma university

Reverse Traffic Channel Generation – Convolutional Coding

CDMA2000 1x
RC1 & RC2
Section 4-68



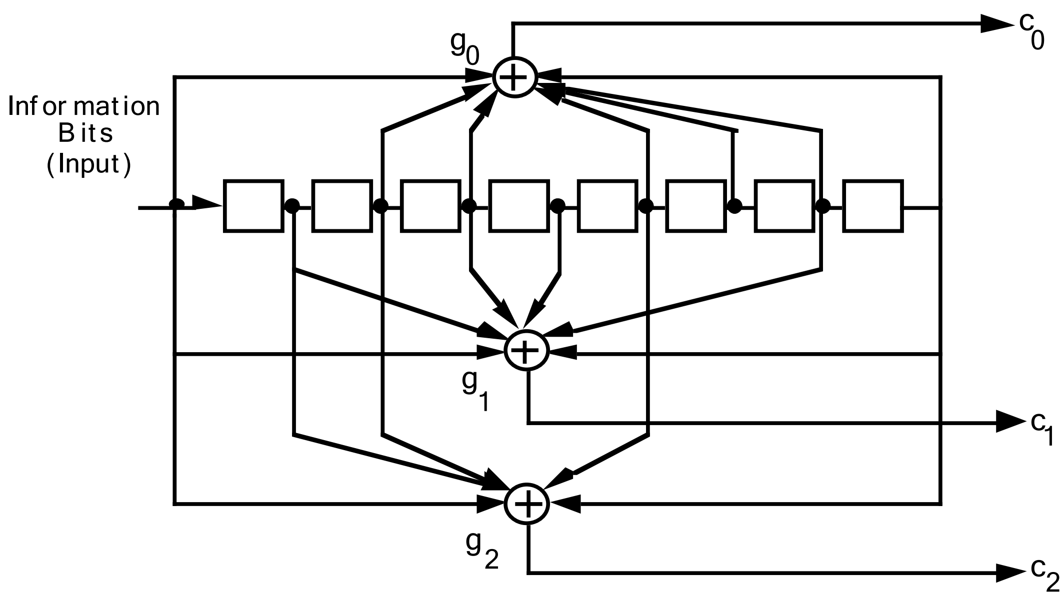
Convolutional Coding

Convolutional coding is employed to provide an FEC capability and reduce the required signal-to-noise ratio necessary to achieve an acceptable error rate. A very powerful rate $^1/_3$ code is used whenever the mobile is using the Rate Set 1 vocoder. When the Rate Set 2 vocoder is in use, a rate ½ code is used. This rate ½ code is the same as used in the Forward direction.

QUALCOMM cdma university

Reverse Traffic Channel Generation – Rate 1/3 Encoding

CDMA2000 1x
RC1 & RC2
Section 4-69



MMT98010232Ag.emf

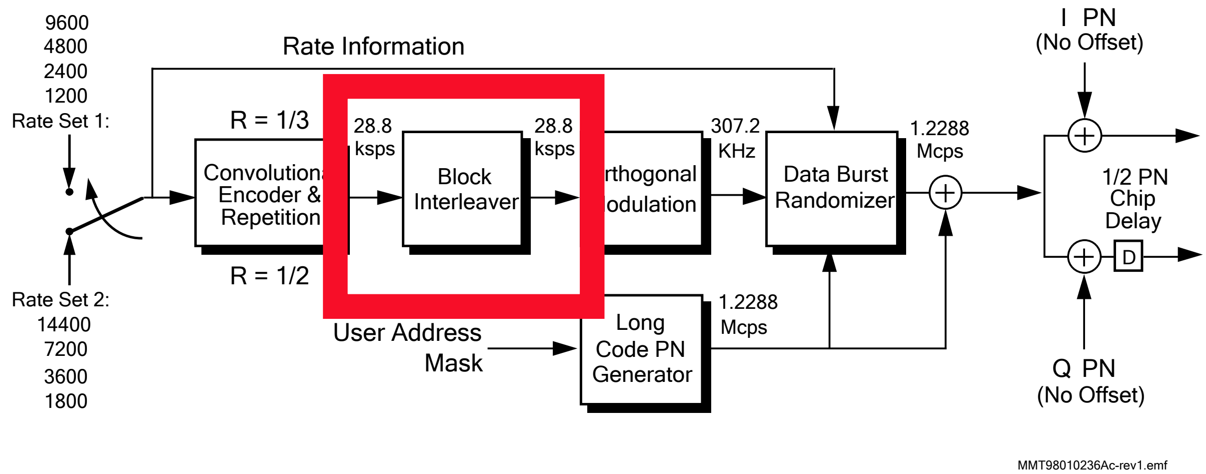
Rate 1/3 Encoding

The Rate 1/3 Convolutional code generates 3 symbols to transmit for each data bit.

QUALCOMM cdma university

Reverse Traffic Channel Generation – Interleaving

CDMA2000 1x
RC1 & RC2
Section 4-70



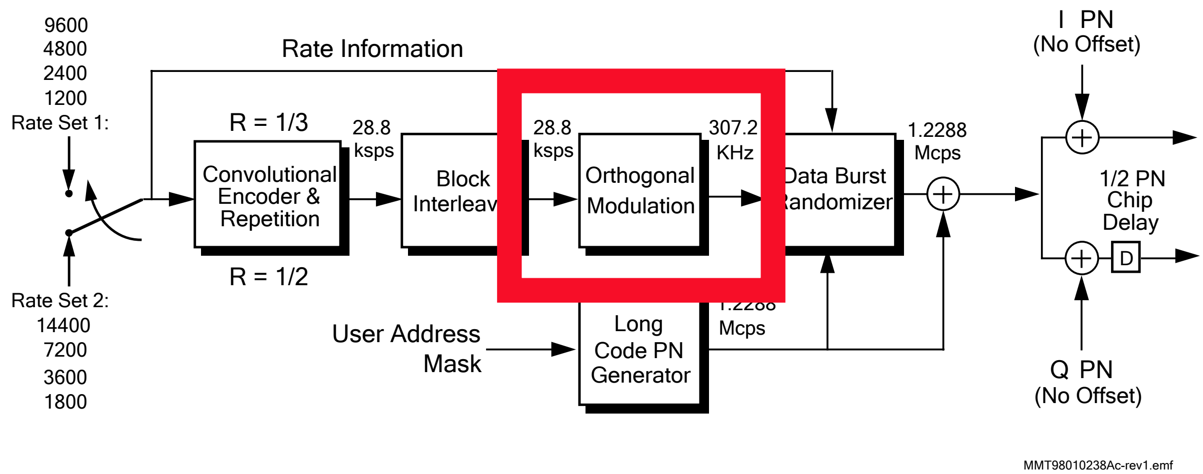
Interleaving

Block interleaving is performed over the span of one Traffic Channel frame. The symbols are read into the buffer by columns and transmitted out by alternating rows (i.e., rows 1, 3, 2, 4, and so on).

QUALCOMM cdma university

Reverse Traffic Channel Generation – Orthogonal Modulation

CDMA2000 1x RC1 & RC2 Section 4-71



Orthogonal Modulation

The Base Station must demodulate the mobile transmission non-coherently. To improve the non-coherent demodulation, the system designers chose to use an orthogonal modulation scheme. Rather than transmitting the antipodal signals +1 and -1, a set of orthogonal signals is used.

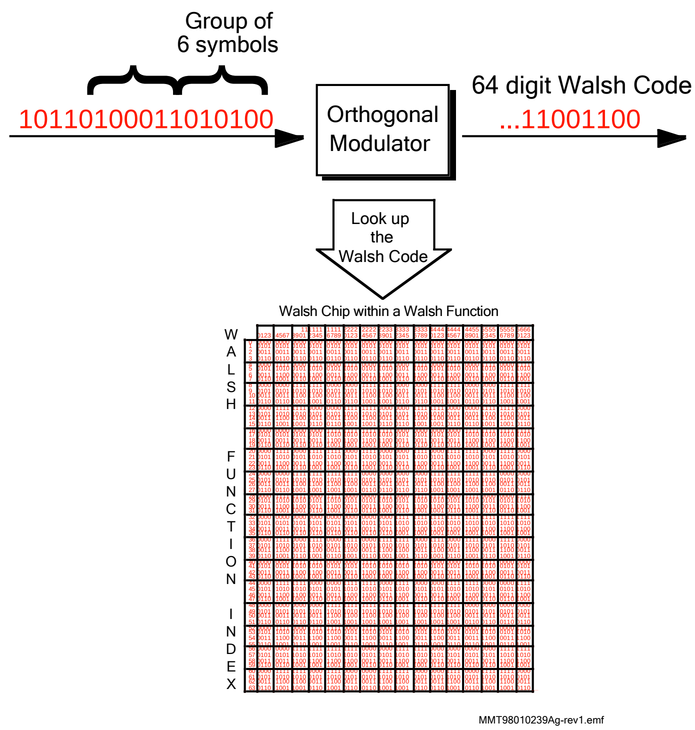
The signal duration should be as long as possible, but not longer than the coherence time of the channel (the time frame during which the channel is relatively stable). The Walsh codes were chosen for this purpose. On the Forward link, the Walsh codes isolated one subscriber from another. Here the Walsh codes provide isolation between "symbols."

The orthogonal signaling set contains 64 possible signals. The information to be modulated is segregated into groups of six symbols. These six symbols then correspond to a value from 0 to 63. This value is used to select a Walsh code for transmission.

cdma university

Reverse Traffic Channel Generation – Walsh Lookup Table

CDMA2000 1x
RC1 & RC2
Section 4-72



Walsh Lookup Table

On the Reverse link, Walsh functions are used to map groups of 6 symbols into a modulation vector.

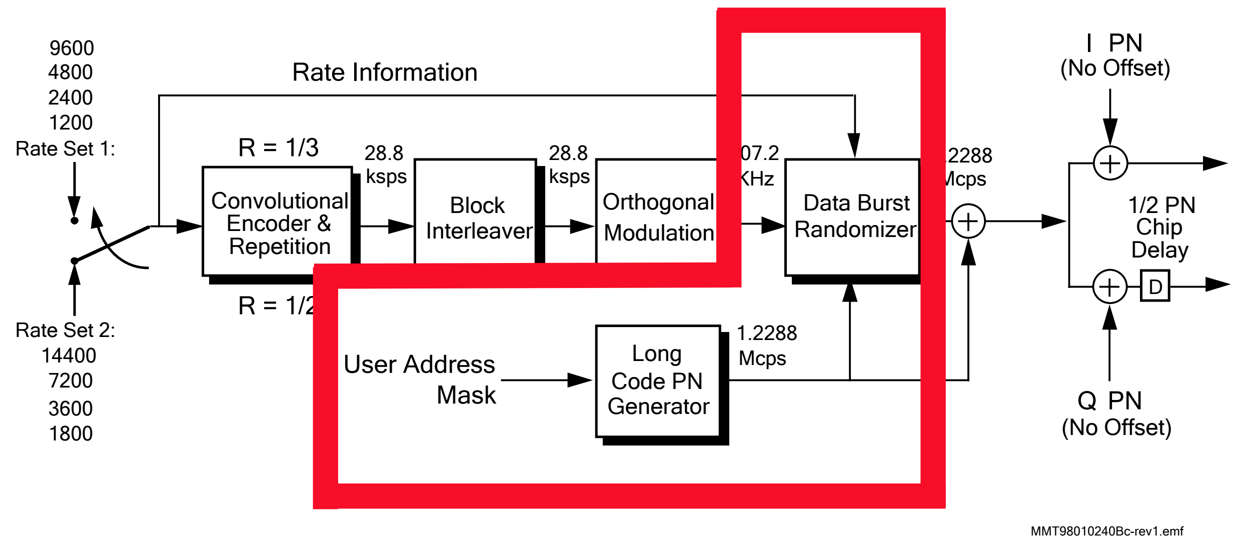
A group of 6 symbols is used to pick one of the 64 Walsh functions to transmit. Each Walsh function is 64 bits in length, and is sent during the period of the 6 data symbols.

The Base Station correlates the received modulation vector (Walsh function) against the set of 64 known Walsh functions to decide which function was received.

QUALCOMM cdma university

Reverse Traffic Channel Generation – Data Burst Randomizer

CDMA2000 1x RC1 & RC2 Section 4-73



Data Burst Randomizer

To take advantage of periods of reduced speech activity, the vocoder reduces its data rate allowing the transmission of the signal at a lower average level of power. On the Forward Traffic Channel, this was done by repeating symbols and then transmitting each symbol at reduced power. The disadvantage of this method is that it spreads bit energy out over time. It takes longer to collect the energy at the receiver. The requirement for rapid power control of the Reverse Traffic Channel necessitated an alternative method of reducing average power.

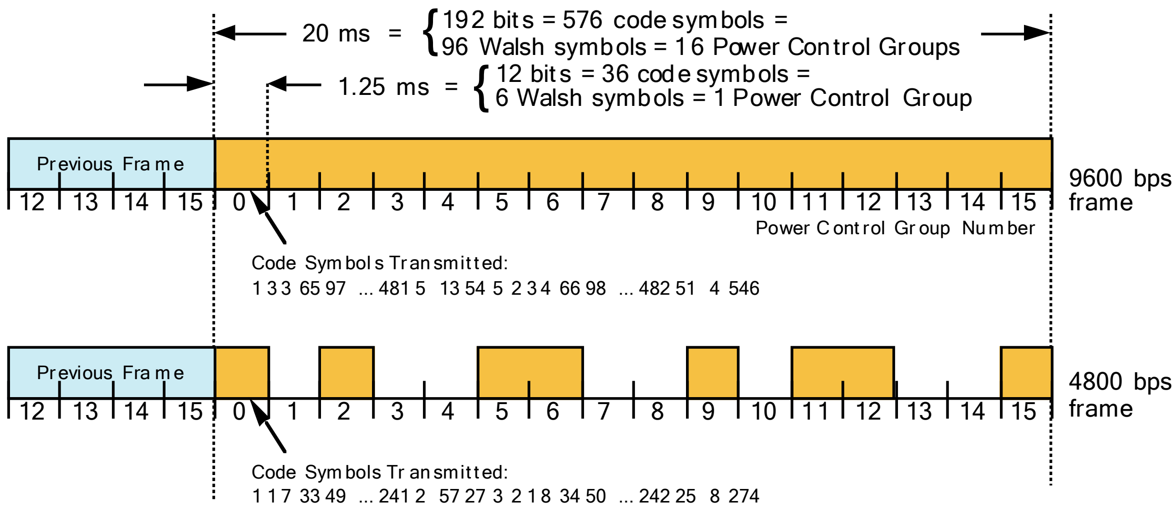
On the Reverse Traffic Channel, the mobile uses full rate power when it transmits. When redundant information is produced by the symbol repetition scheme, the data burst randomizer turns off the transmitter, reducing the average transmission power.

The *gating off* of the transmitter is done pseudorandomly.

QUALCOMM cdma university

Reverse Traffic Channel Generation – Pseudorandom Selection of Power Control Groups

CDMA2000 1x RC1 & RC2 Section 4-74

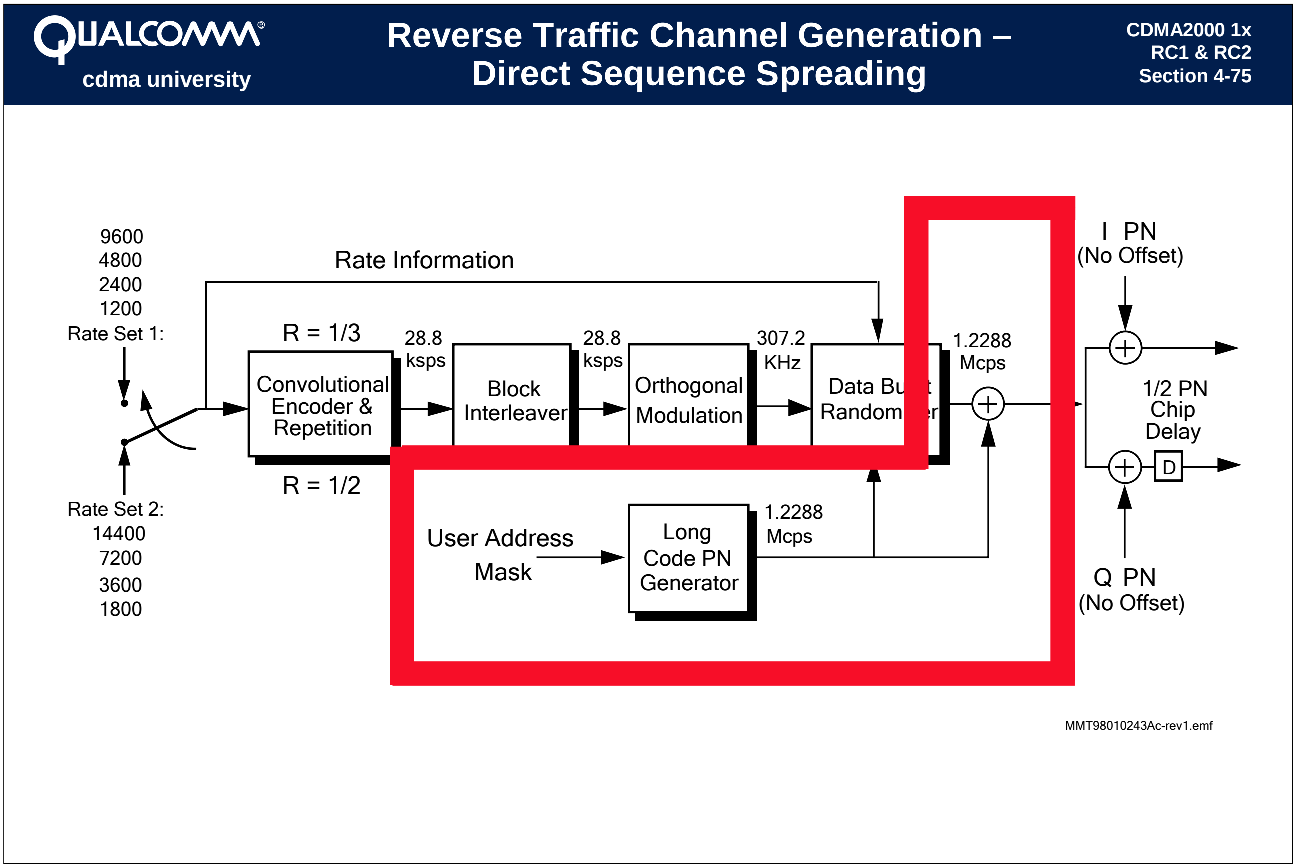


MMT98010241Ac-rev1.emf

Pseudorandom Selection of Power Control Groups

For full rate transmission, data is transmitted in each power control group.

As the rate is reduced, the transmitter is gated off so as to not transmit the repeated symbols.



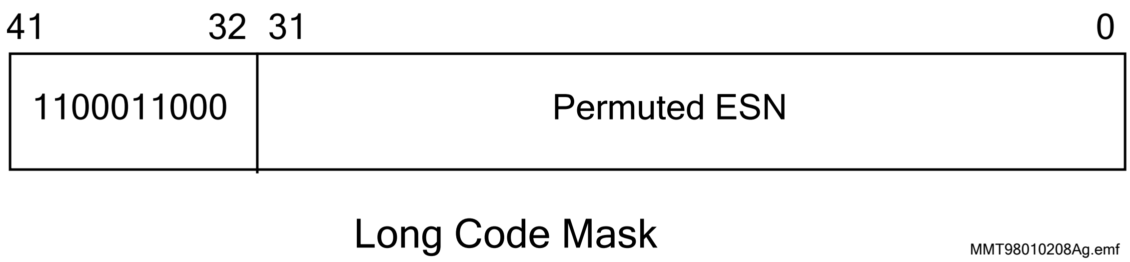
Direct Sequence Spreading

The signal is then channelized using the Long PN code. At this point, the signal already occupies a bandwidth of 307.2 KHz due to the orthogonal modulation scheme. This PN spreading rate is 1.2288 Mcps.

QUALCOMM® cdma university

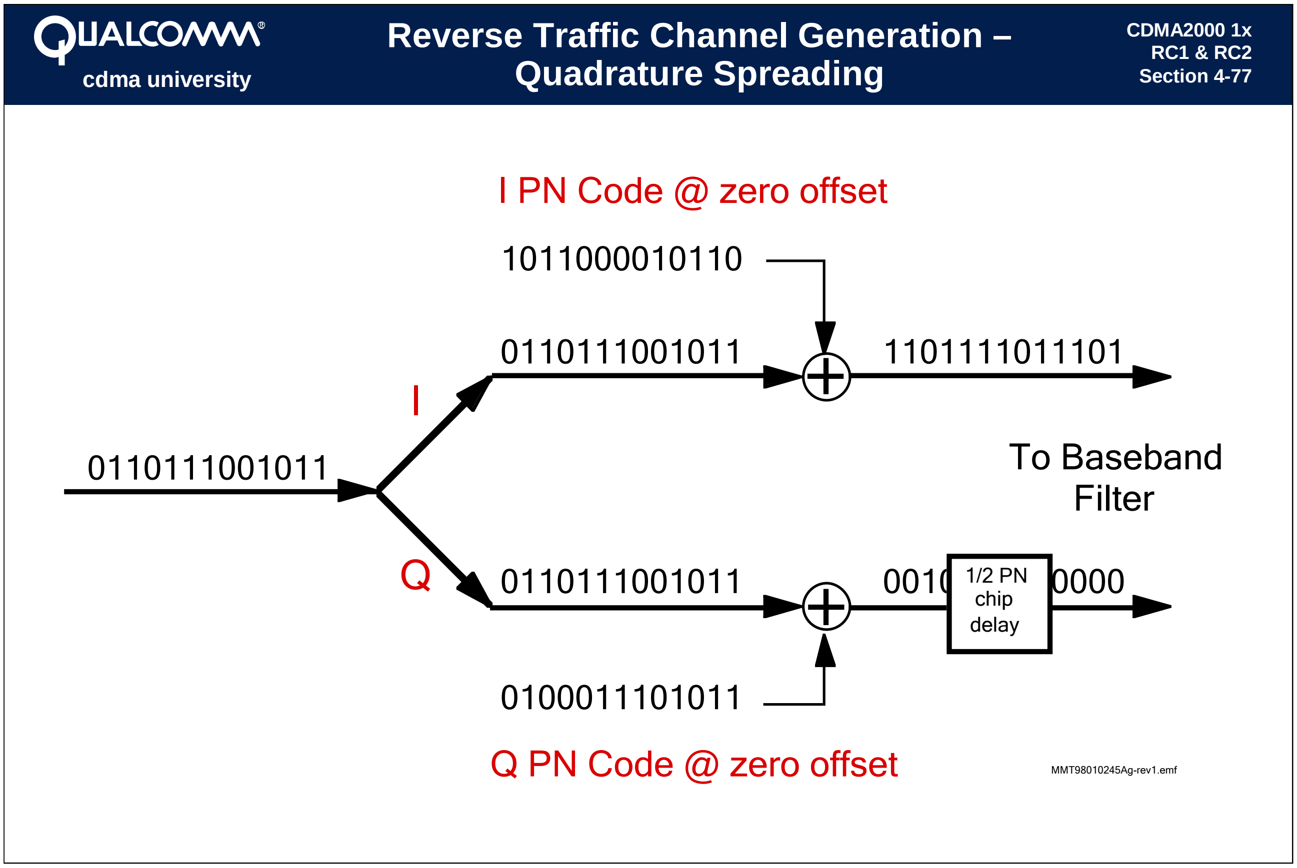
Reverse Traffic Channel Generation – Reverse Traffic Channel Mask

CDMA2000 1x RC1 & RC2 Section 4-76



Reverse Traffic Channel Mask

The PN generator is masked with the same mask that was used to scramble the Forward Traffic Channel.



Quadrature Spreading

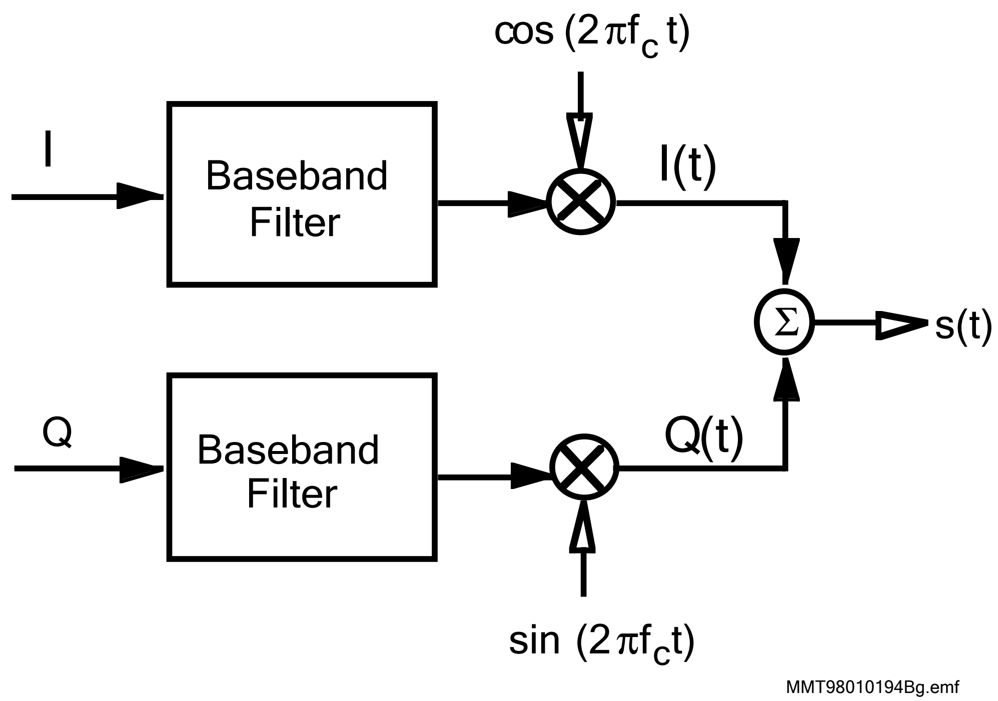
Direct sequence spreading is followed by spreading in quadrature. The Short PN codes are used for this purpose, but no offset is applied. All mobiles use the zero offset. The quadrature branch is delayed ½ of a PN chip to produce Offset QPSK rather than QPSK.

After baseband filtering, the signal is upconverted to the proper RF channel in a complex upconversion process. The baseband filtering process uses digital (48 tap FIR) and analog techniques.

QUALCOMM cdma university

Reverse Traffic Channel Generation – Filtering and Up Conversion

CDMA2000 1x RC1 & RC2 Section 4-78



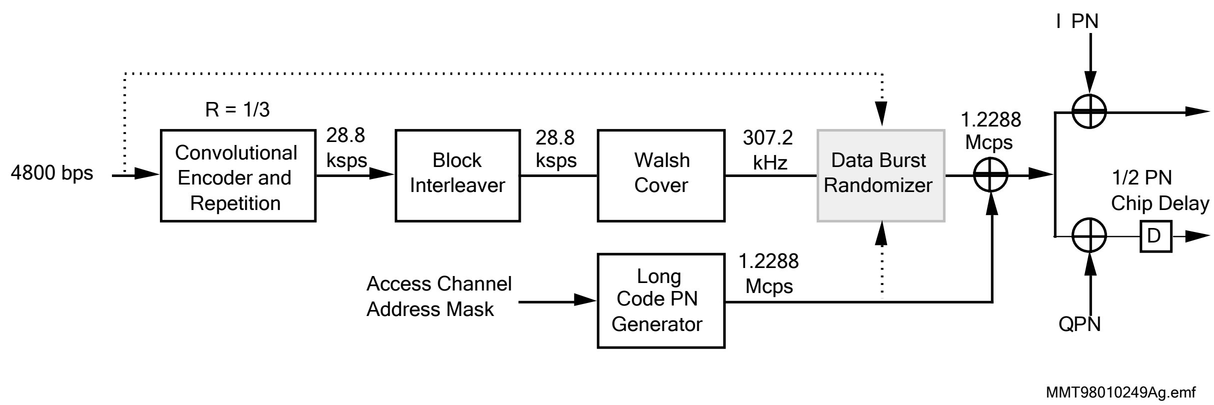
Filtering and Up Conversion

Filtering and up conversion is specified in the same way as the Forward link. The mobile, however, is not required to perform pre-equalization.

QUALCOMM cdma university

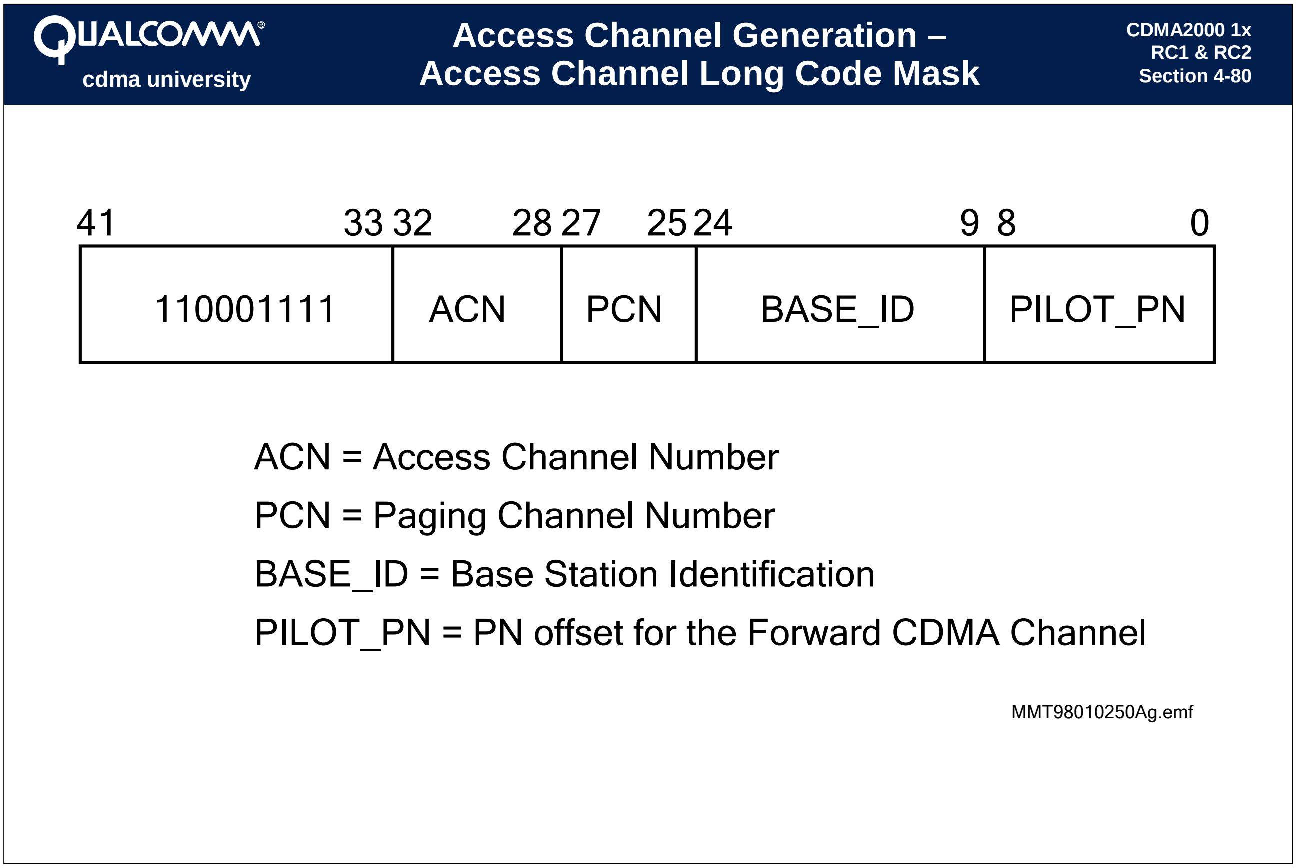
Access Channel Generation

CDMA2000 1x
RC1 & RC2
Section 4-79



Access Channel Generation

The Access Channel is generated in the same manner as the Reverse Traffic Channel with one exception: the data burst randomizer is not used. The data burst randomizer is used to reduce average power when speaker activity subsides. There is no speech activity on the Access Channel.



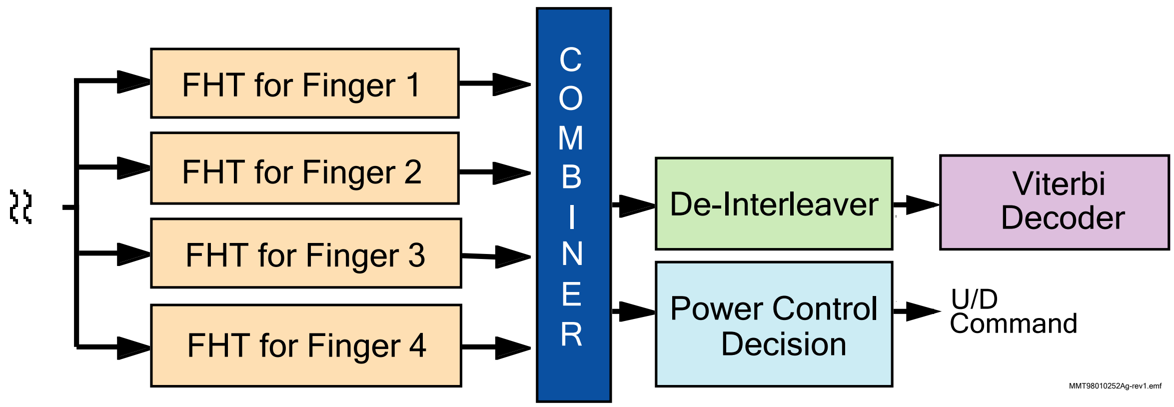
Access Channel Mask

The Long PN generator is masked as shown.

cdma university

Reverse CDMA Channel Demodulation

FHT: Fast Hadamard Transform



Demodulation of the Reverse CDMA Channel

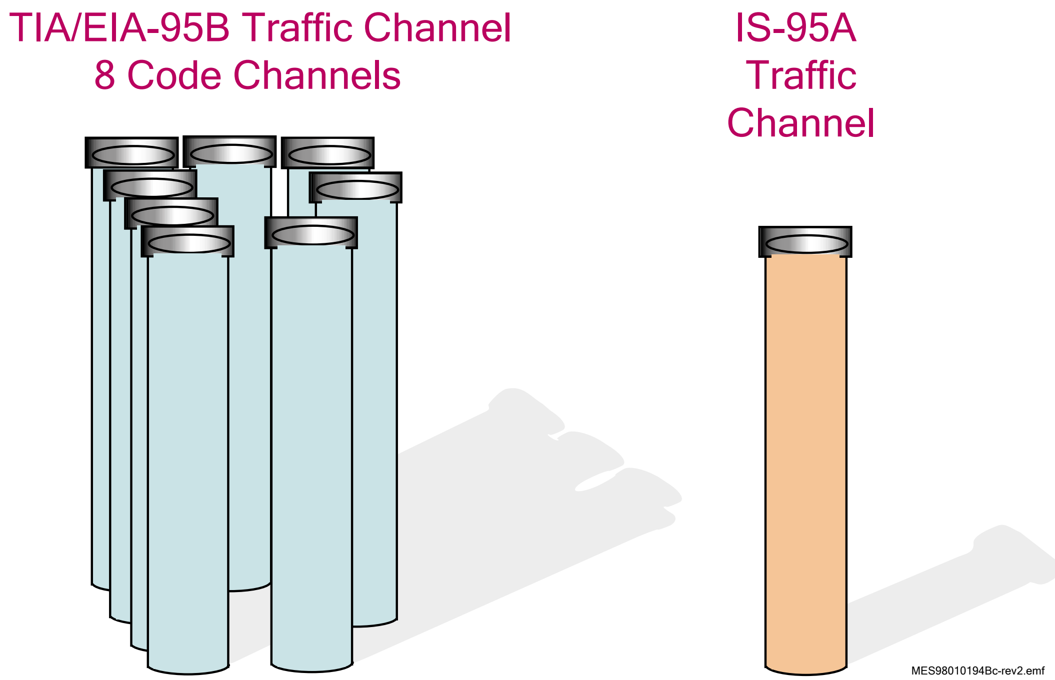
The signal is down converted from the 800 MHz or 1.9 GHz bands down to baseband. This down conversion is normally done in several steps:

- A/D conversion is performed. The signal is now at digital baseband.
- The Base Station also implements a rake receiver design. The QUALCOMM implementation has multiple demodulating elements (fingers) per antenna. The searching function is distributed among these elements. The Searching identifies strong multipath arrivals and a finger is assigned to demodulate at the offset identified.
- The correlators perform a product integration in order to despread the Short PN codes. Fast Hadamard Transformers are then used to detect the Walsh Modulation Symbols.
- The outputs of the FHT's are non-coherently combined.
- The signal is then de-interleaved.
- The next step is Viterbi Decoding. The decoder does not know the rate of the vocoded frame and must decode at all four rates, then use metrics to decide which rate was the most likely rate transmitted.

cdma university

Medium Data Rate Option – Overview

CDMA2000 1x RC1 & RC2
Section 4-82



Medium Data Rate Option Overview

To help satisfy the growing appetite for wireless data applications TIA/EIA-95 includes an optional Medium Data Rate (MDR) feature, which may operate on both Forward and Reverse links.

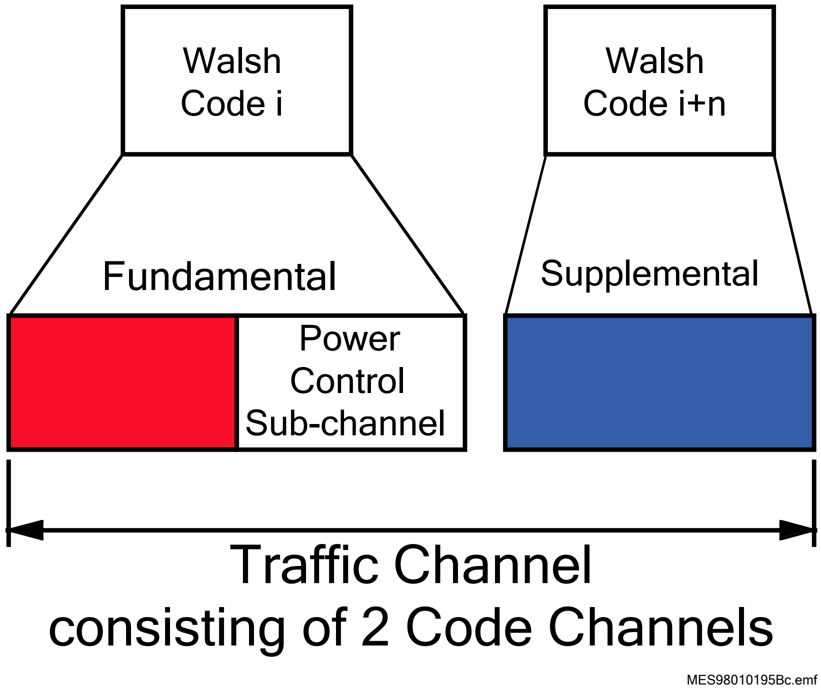
To support data rates higher than Rate Set 1 or Rate Set 2, there must be some way to combine multiple channels together. Remember that CDMA users are channelized by unique codes. For higher speed data requirements, the transmitter will simultaneously use multiple code channels to deliver data to the receiver. The MDR feature allows up to eight code channels to be bundled together to support up to eight times the current maximum data rate of a single channel.

All these Code Channels are Traffic Channels as currently defined in IS-95. This methodology, however, requires that a distinction be made between these Code Channels. TIA/EIA-95 defines a Traffic Code Channel as either a Fundamental or Supplemental Code Channel. Both Forward and Reverse link rate extensions are included and are optional.

QUALCOMM cdma university

Medium Data Rate Option – Fundamental, Supplemental Code Channels

CDMA2000 1x RC1 & RC2 Section 4-83



Fundamental Channel

For MDR, the Fundamental Channel will serve as the Primary Code Channel for all traffic communications in the Forward and Reverse links and will support both variable Rate Sets using the same rules as IS-95. The Fundamental Channel will always be supported by the mobile and is used for transporting primary, secondary, and/or signaling traffic. A key point to note is that signaling will occur only on the Fundamental Code Channel. The Power Control Subchannel will also be exclusive to the Forward Fundamental Code Channel.

Supplemental Channels

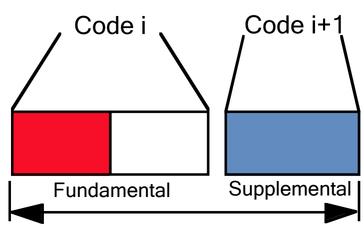
For MDR, up to seven Supplemental Code Channels can be used to deliver higher data rates over the air. Each Supplemental Code Channel may carry primary or secondary traffic, but not both. Supplemental Channels are capable of operating at both rate sets, but must be the same rate as the Fundamental Code Channel. Supplemental Code Channels will only operate at the full rate of the selected rate. Supplemental Channels will not have a Power Control Subchannel.

cdma university

Medium Data Rate Option – Code Channel Summary

CDMA2000 1x RC1 & RC2 Section 4-84

	Signaling	Primary Traffic	Secondary Traffic	Power Control Bit Puncturing	Variable Rate	Rate Set 1	Rate Set 2
Fundamental Code Channel	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Supplemental Code Channel	No	Yes (not mixed with secondary)	Yes (not mixed with primary)	No	No	Yes (same as Fundamental)	Yes (same as Fundamental)



MES98010196Ac-rev1.emf

MDR Forward Link

Just as defined in the original IS-95, the Fundamental Code Channel will also transmit a Power Control Subchannel for Reverse closed loop power control. If using Rate Set 2 in the Forward link the reserved bit may be used to tell the mobile whether or not to continue processing supplemental frames.

MDR Reverse Link

The Reverse Channels can operate at either Rate Set 1 or Rate Set 2. The Reverse link data rate is not dependent on the Forward link data rate.

The mobile will transmit frames on Supplemental Code Channels in time alignment with the Fundamental Code Channel.

qualcomm cdma university

Forward/Reverse Multi-Channel Spreading – Long Code Channel Assignment

CDMA2000 1x RC1 & RC2 Section 4-85

MES98010201Ac.emf

Public Long Code Mask

41 – 32	31 – 0
1100011000	Permuted ESN

Reverse Supplemental Channel number isXORed into bits 39-37 of LC mask

MES98010202Ac.emf

Long Code Channel Assignment

Reverse link Channels are identified by their Long code PN offset. To support a subscriber's use of multiple channels on the Reverse link, the mobile will require multiple non-conflicting Long code PN offsets.

For example, when a mobile is transmitting on four code channels (one Fundamental Code Channel and three Supplemental Code Channels), the Reverse Fundamental Code Channel will be assigned the channel number 0, and each of the Reverse Supplemental Code Channels will be assigned the numbers 1 through 3.

Recall that the IS-95 standard defines the Long code mask generation as a 42 digit sequence with the following values:

41 40	39 37	36 32	31 0
11	000	11000	Permuted ESN

MES98010256Ag.eps

With bits 39 through 37 of the public Long code mask set to all zeros, this provides a perfect insertion point for Supplemental Channel assignments.

QUALCOMM cdma university

Data Channels for RC>2

CDMA2000 1x RC1 & RC2 Section 4-86

- RC1 and RC2 use the MDR system of parallel Rate Set 1 or 2 channels for extra bandwidth.
- 1x Release 0 allows the use of the Supplemental Channel (SCH). This channel operates between 9.6 kbps and 153.6 kbps. Up to two SCHs are allowed.
- 1x Release A increases the maximum to 307.2 kbps.

Data Channels for RC>2

RC1 and RC2 use extra channels at Rate Set 1 (9.6 kbps) or Rate Set 2 (14.4 kbps) to increase the overall data rate.

CDMA2000 Release 0 introduces a special type of Traffic Channel called the Supplemental Channel, which can operate at much higher rates. Up to two of these high-rate channels are allowed per user.

What We Learned in This Section

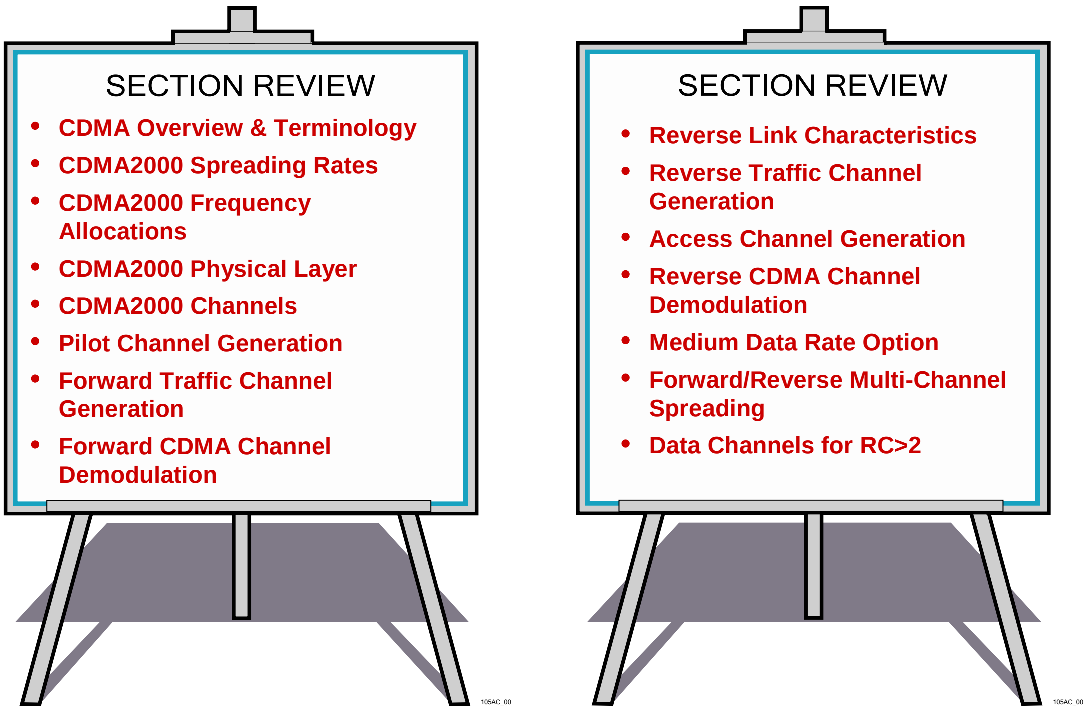
- ✓ The generation of the CDMA waveforms in both the Forward and Reverse directions.
- ✓ The CDMA code channels.
- ✓ The steps in the generation of each code channel.
- ✓ The rationale for each step.
- ✓ The demodulation of the Forward and Reverse CDMA channels.

Notes

QUALCOMM cdma university

CDMA Physical Layer – Review

CDMA2000 1x
RC1 & RC2
Section 4-88



Notes

QUALCOMM cdma university

Section 5: Power Control

CDMA2000 1x RC1 & RC2 Section 5-1

SECTION 5

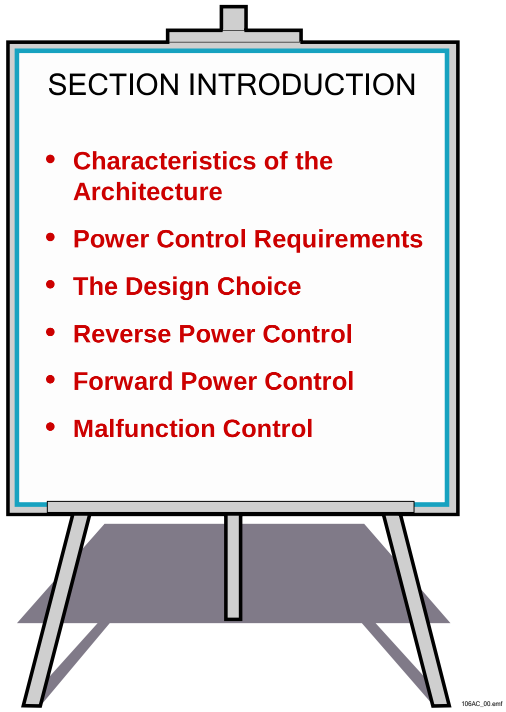
Power Control

Notes

cdma university

Section Introduction

CDMA2000 1x
RC1 & RC2
Section 5-2



- **Characteristics of the Architecture —** The characteristics of an architecture have an impact on the strategy used to control transmit power.

- **Power Control Requirements —** Universal frequency reuse requires that power be carefully allocated.

- **The Design Choice —** An outline of the power control strategy.

- **Reverse Power Control —** Control of mobile transmit power requires extensive processes.

- **Forward Power Control —** Forward Power Control is generally less critical than Reverse, but important gains can be achieved through effective power control of the Forward Channel.

- **Malfunction Control —** Mobiles that transmit too much power can reduce system capacity. Methods are specified to mitigate malfunctions.

QUALCOMM cdma university

Section Learning Objectives

CDMA2000 1x RC1 & RC2 Section 5-3

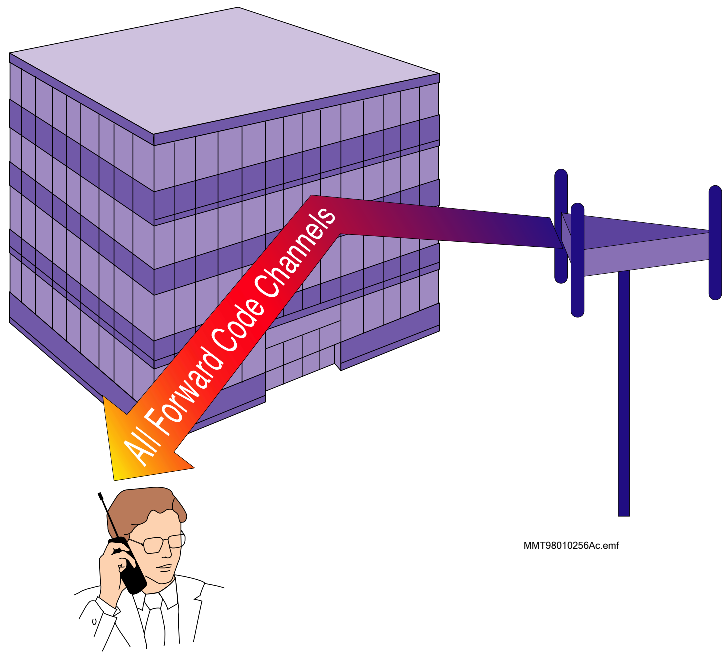
- Describe the power control processes used in a CDMA system and explain the rationale for them.
- State the requirements for Power Control.
- Calculate an Open Loop Power Estimate.
- Describe the Closed Loop Power Control process.
- Describe Outer Loop Power Control.
- Describe Forward Power Control.
- State the use of a Power Measurement Report Message.

Notes

QUALCOMM cdma university

Characteristics of the Architecture – Forward Link

CDMA2000 1x
RC1 & RC2
Section 5-4



Forward Link Characteristics

- **Same Channel** — All of the Code Channels transmitted from the Base Station take the same paths to the mobile. For this reason, they experience the same path attenuation and fading environment.
- **Better Codes for Separation** — Transmitting all the Forward Channels from the same source allows us to synchronize all the Forward Channels. This allows for the use of Walsh codes to separate users in the Forward direction.
- **Coherent Demodulation at the Mobile** — The *one-to-many* relationship of the Base Station to the mobiles makes the use of a Pilot signal efficient. The mobile can use a Pilot transmitted from the Base Station in order to demodulate coherently.

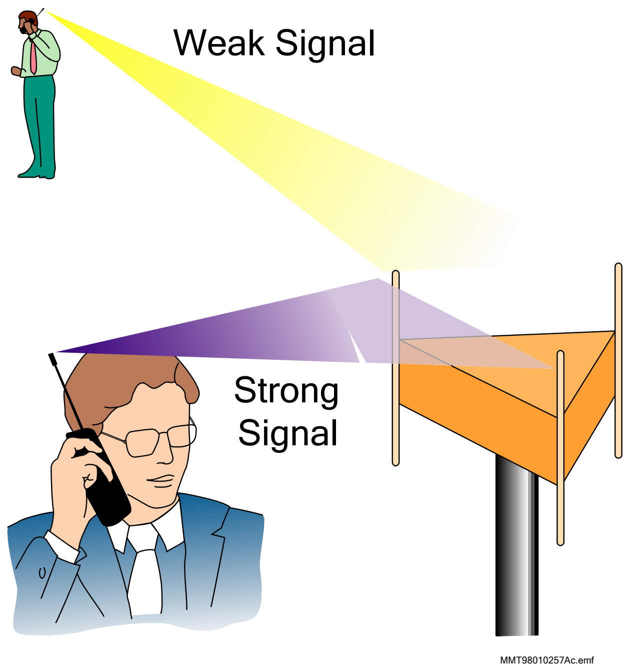
Impact on Forward Power Control

For these reasons, the requirement for Forward power control is less demanding. Traffic Channels will vary in strength by only ±4 dB from the nominal value. The typical Traffic Channel operates about 10 dB below the Pilot Channel.

Characteristics of the Architecture – Reverse Link

QUALCOMM cdma university

CDMA2000 1x RC1 & RC2 Section 5-5

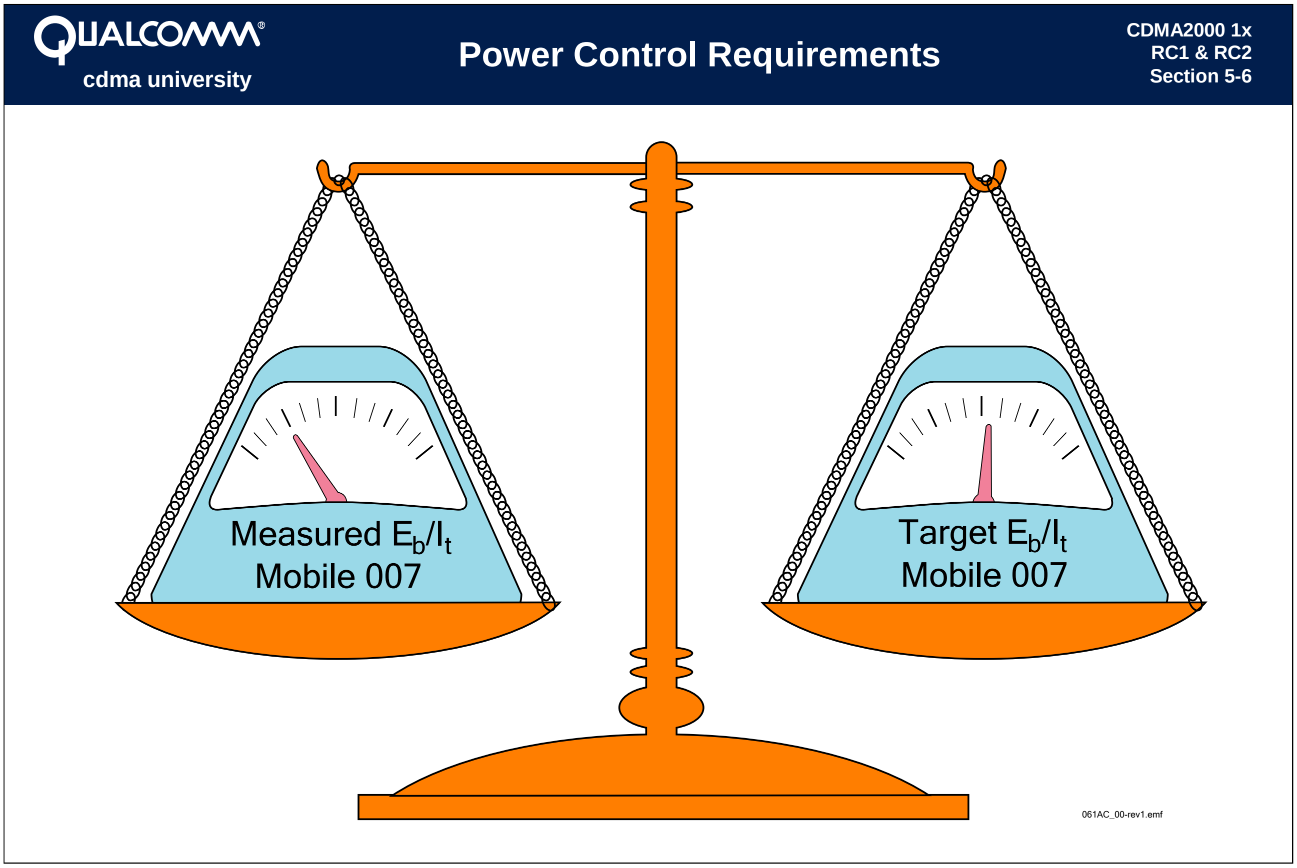


Reverse Link Characteristics

Mobiles, of course, may be anywhere in the cell. One mobile may be 10 miles from the Base Station, while another mobile may be only a few hundred yards away. As a result, mobiles can experience greatly differing amounts of path loss due to their varying distance from the Base Station and varying multipath environments. Path loss can easily vary by 80 dB. If all mobiles attempted to transmit at the same power level, some signals could arrive at the Base Station 80 dB stronger than others. Each mobile must be carefully power-controlled to ensure that transmissions arrive at the Base Station at an appropriate level. Additionally, the mobiles' transmissions do not fade together. They typically take different paths and are subject to different propagation conditions. Lastly, the BTS will demodulate non-coherently due to the lack of a coherent phase reference.

Impact on Reverse Power Control

Reverse power control demands a very large dynamic range and a rapid response to compensate for rapidly changing conditions.



Ensure Sufficient E_b/I_t

All mobiles transmit in the same bandwidth at the same time, and each user's transmission is interference to everyone else. The receiver needs some way of overcoming this interference; the demodulator must have a sufficient E_b/I_t ratio in order to demodulate the signal at an acceptable probability of error.

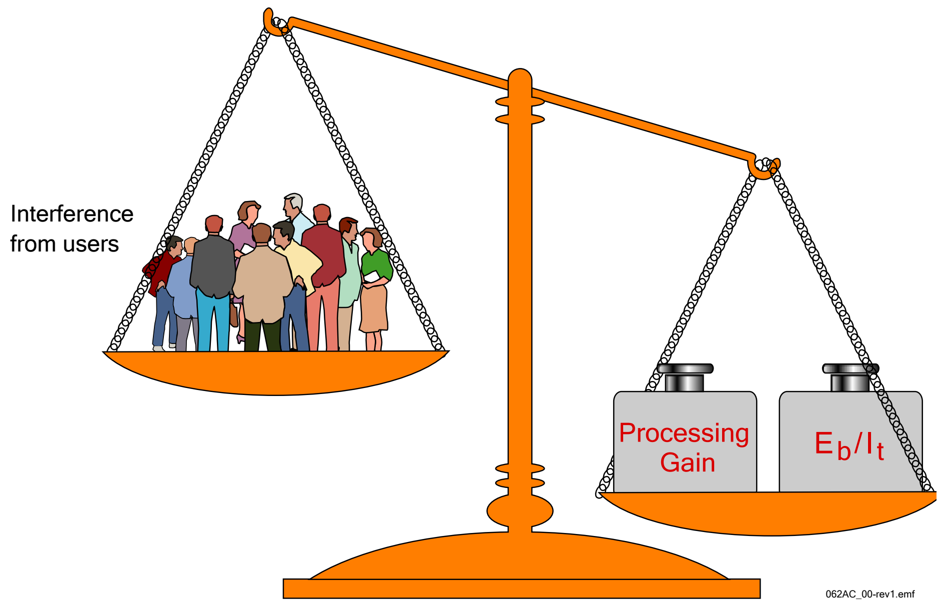
The first requirement of the power control process is to adjust mobile transmitter power to achieve at least the minimum required E_b/I_t at the receiver.

E_b/I_t = Bit Energy / Interference Power Spectral Density

QUALCOMM cdma university

Power Control Requirements (continued)

CDMA2000 1x RC1 & RC2 Section 5-7



No more than needed E_b / I_t

Maintain Transmit Power At No Higher Than the Minimum

Power control has an additional responsibility to ensure that each user does not get any more than the minimum E_b/I_t. Achieving more than minimum E_b/I_t will benefit that single mobile, but will also provide additional interference to every other user and may result in unacceptable performance for other users (unless capacity is reduced).

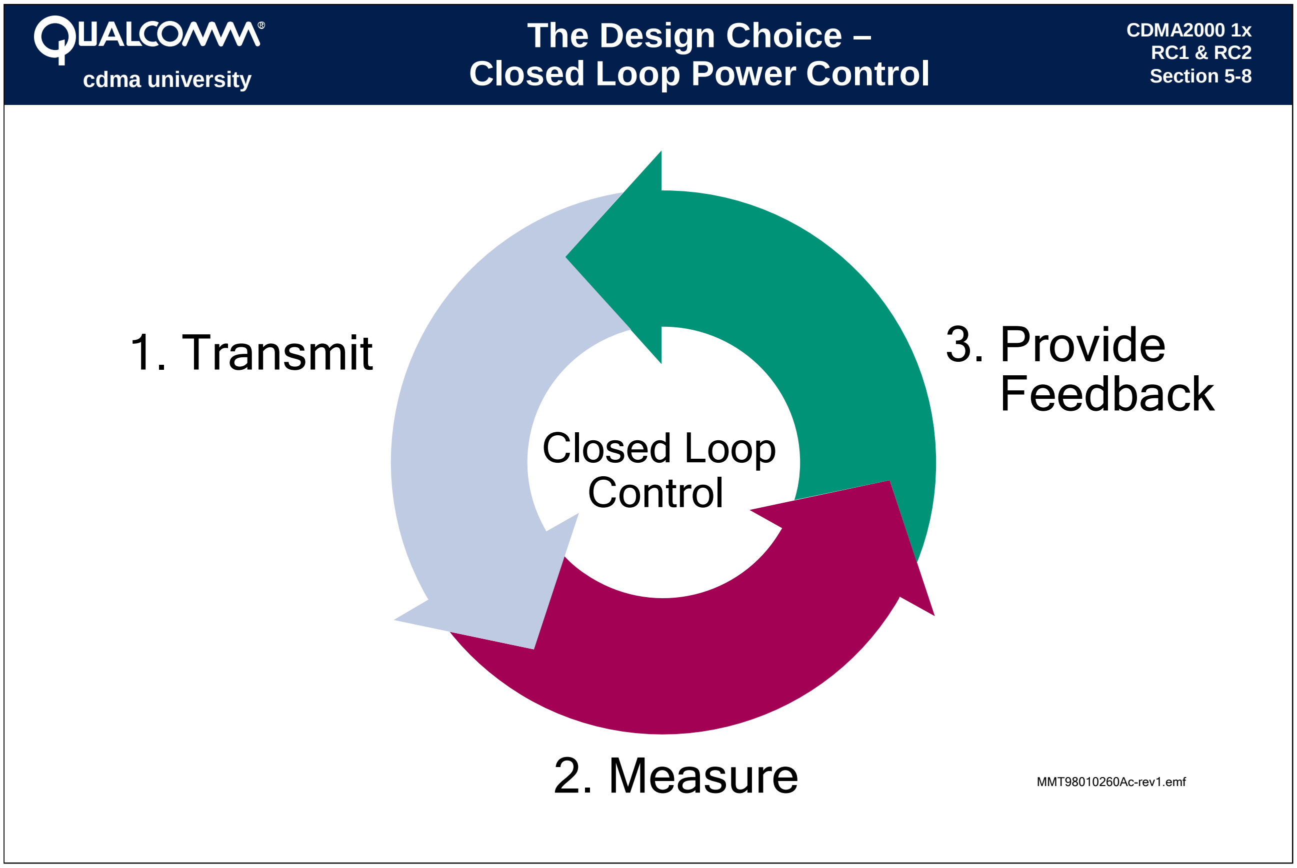
System capacity is proportional to processing gain. Processing gain is the ratio of the transmission bandwidth, W, to the data rate, R. Processing gain can overcome only a finite amount of interference from other users (total noise N).

Power control ensures that each user transmits only the minimum power necessary, but no higher, thereby making the smallest possible contribution to the total noise seen by other users (N). In this way, effective power control maximizes the number of subscribers that can simultaneously transmit.

The relationship between E_b/I_t and the Signal-to-Noise ratio (S/N) is:

$$\frac{\frac{E_b}{I_t}}{\frac{W}{R}} = \frac{S}{N}$$

The required E_b/I_t is commonly around 6 dB. W/R is generally around 21 dB. Acceptable quality can typically be achieved with a S/N ratio on the order of -15 dB.



Closed Loop Power Control

A closed loop control process is used to control transmission power on both the Forward and Reverse links. Control of the Reverse link, however, is more critical. Closed loop control is basically a three-step process. A transmission is made, a measurement is made at the receiver, and feedback is provided to the transmitter.

Determining the Initial Transmit Level

The closed loop process can eventually correct the mobile's transmit power regardless of the initial transmit level. Significant gain can be achieved, however, if the mobile's initial transmit level is close to the appropriate power.

Determining a Metric

Selection of a metric is affected by the speed that is required of the closed loop process. Frame error rate is a good metric, for example, but measuring frame error rate can be a slow process. If faster response is needed, another indicator such as E_b/I_0 may be more appropriate.

Providing Feedback By:

- Messages
- Acknowledgment protocol
- Reserved bits
- Stolen or "punctured" bits

cdma university

The Design Choice – TIA/95-A/B vs. CDMA2000 RL Power Control

CDMA2000 1x RC1 & RC2 Section 5-9

With Radio Configurations 1 and 2:

- The Base Station estimates the E_b/N_o, using six consecutive Walsh functions transmitted by the MS.
- The E_b/N_t estimate is then compared to a threshold to determine the sign of the power control bit.

With Radio Configurations 3 through 6:

- The Base Station filters the R-PICH to obtain an E_b/N_t estimate.
- The E_b/N_t estimate is then compared to a threshold to determine the sign of the power control bit.

CDMA2000 power control:

- A constant 800 bps.
- Independent of data rate except when gating modes are used.

Power Control on Dedicated Channels

For Radio Configurations 1 and 2, the Base Station uses the same technique as in TIA/EIA-95 to measure the mobile's transmit power. For Radio Configurations 3 and above, the mobile transmits a Pilot channel, so the Base Station can use this to estimate the E_b/N_t of the mobile.

QUALCOMM cdma university

The Design Choice – Power Control in CDMA2000

CDMA2000 1x RC1 & RC2 Section 5-10

Reverse Link:

- RC1 and RC2 are the same 800 bps.
- ≥RC3 power control bits adjust R-PICH.
- Reservation Access mode has power control.

Forward Link:

- RC1 and RC2 are the same 50 bps.
- ≥RC3 has fast 800 bps available.
- ≥RC3 has seven different PC modes.

Power Control in CDMA2000

The power control available in TIA/EIA-95 is available in the RC1 and RC2 modes.

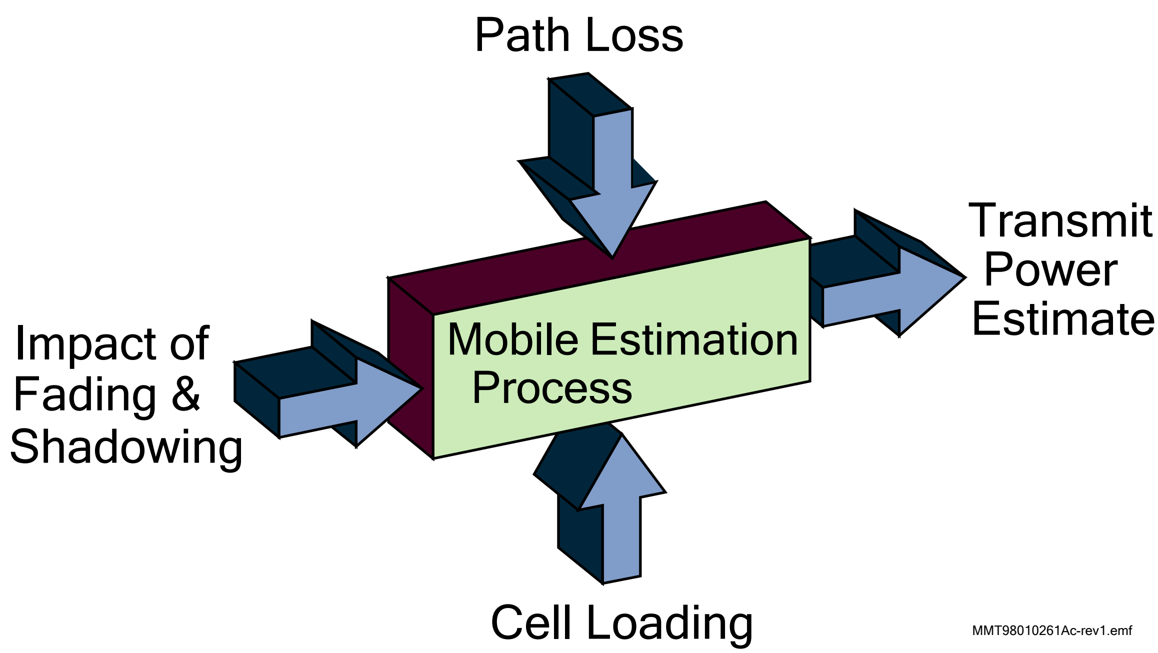
For CDMA2000, the Reverse Link power control bits are used to adjust the Reverse Link Pilot signal. The other Reverse Link Code Channels are transmitted at a power with a fixed offset with respect to the Pilot. The Reservation Access mode now has fast power control so that long messages can be carried on the Access Channel.

For the CDMA2000 Forward Link Channel, there are many new modes of power control available, including fast power control for both the control and supplemental channels. The Forward Link power control bits are time multiplexed on the the R-PICH.

QUALCOMM cdma university

Reverse Power Control – Reverse Open Loop Process

CDMA2000 1x RC1 & RC2 Section 5-11



The Reverse Open Loop Process

Required mobile transmit power is a function of distance from the cell, cell loading, and environmentally induced phenomena such as fast fading and shadowing. If the mobile can take all of these factors into account, it can arrive at a close approximation of the proper level of transmit power. Fast fading on the Forward link as measured by the mobile, however, is generally not the same as fast fading on the Reverse link measured by the cell. The mobile's approximation, therefore, shouldn't try to compensate for fast fading.

For the mobile to compensate for the other factors mentioned here, the Base Station must provide some information to the mobile regarding the cell's Effective Radiated Power (ERP) and the level of cell loading. Armed with this information the mobile could then measure received power and estimate Path Loss.

To simplify this process, the CDMA standards specify that the mobiles use a "hard-wired" constant to compensate for Path Loss and the effects of cell loading. The constant satisfies the nominal case. The Base Station then informs the mobile of any required deviation from the nominal EIRP, and the mobile estimates the cell loading by measuring interference.

Reverse Power Control – Open Loop Equation

QUALCOMM cdma university — CDMA2000 1x RC1 & RC2 Section 5-12

Transmit Power (dBm) =

k - Mean Receive Power (dBm)

+ NOM_PWR + INIT_PWR

+ Access Probe Corrections

The Open Loop Equation

The CDMA standards define an equation to be used by the mobile to develop an Open Loop Estimate of transmission power. To estimate the path loss, the mobile measures total mean receive power. By monitoring the TOTAL power rather than using a demodulated channel, this estimate can be made rapidly without any knowledge of timing, Base Station identification, or path conditions. The difference between mean receive power and the constant, k, is the transmit power necessary to compensate for path loss (assuming a nominal cell ERP and nominal cell loading).

Information about variations from nominal cell ERP and nominal cell loading is communicated to the mobile using the additional parameter NOM_PWR. The INIT_PWR parameter is used to adjust the power of the first Access probe.

The constant k is -73 for cellular systems and is -76 for PCS systems. PCS systems use an additional parameter, NOM_PWR_EXT to indicate that the cell is a microcell, with an EIRP 16 dB smaller than nominal.

Reverse Power Control – Mobile Access Channel Modes

- Backward-compatible access procedure and access channel (R-ACH) mode.
- Two additional modes through the Enhanced Access Channel (R-EACH) and Common Control Channel (R-CCCH):
  - Basic Access Mode
  - Reservation Access Mode

Mobile Access Channel Modes

In Basic Access Mode, the mobile transmits a preamble on the R-PICH and data on the Reverse Enhanced Access Channel (R-EACH), in a method similar to that used in the Access Channel.

In Reservation Access Mode, the mobile transmits a preamble on the R-PICH and a small header on the R-EACH. The data is then transmitted on a R-CCCH, which is operated under closed loop power control.

QUALCOMM cdma university

Reverse Power Control – Common Channels

CDMA2000 1x RC1 & RC2 Section 5-14

- Common Reverse channels (R-CCCH, R-EACH, R-ACH) are used in a brief (for example, less than a second) exchange of information between a mobile and a Base Station.
- Power control on the R-ACH and R-EACH is always open loop.
- Power control on the R-CCCH is both open loop and closed loop.

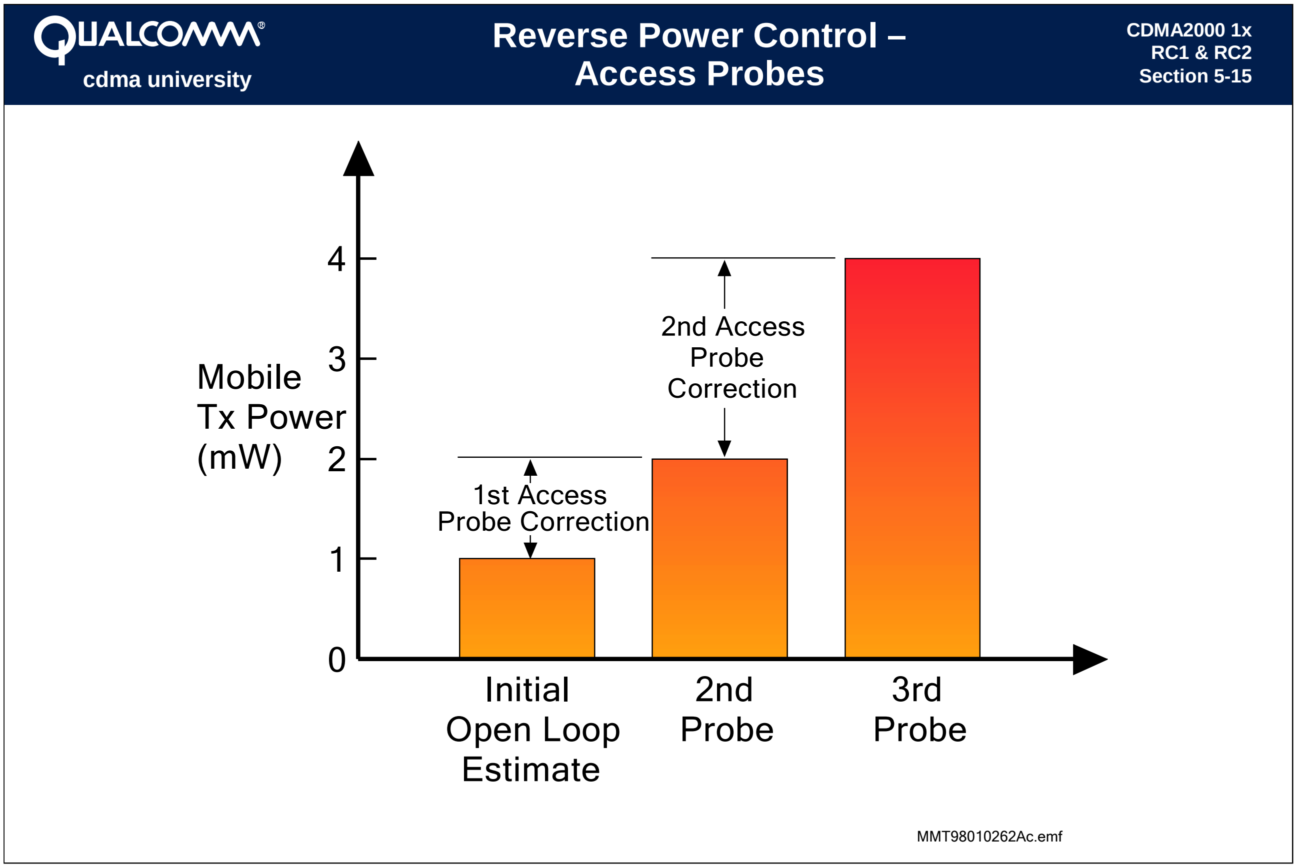
Power Control on Common Channels

Power control on the common Reverse channels always uses open loop, and the R-EACH Reservation Mode on the R-CCCH uses both open and closed loop power controls.

The R-ACH is the only Access method allowed in RC1 and RC2.

CDMA2000 Release 0 uses only the old R-ACH channel.

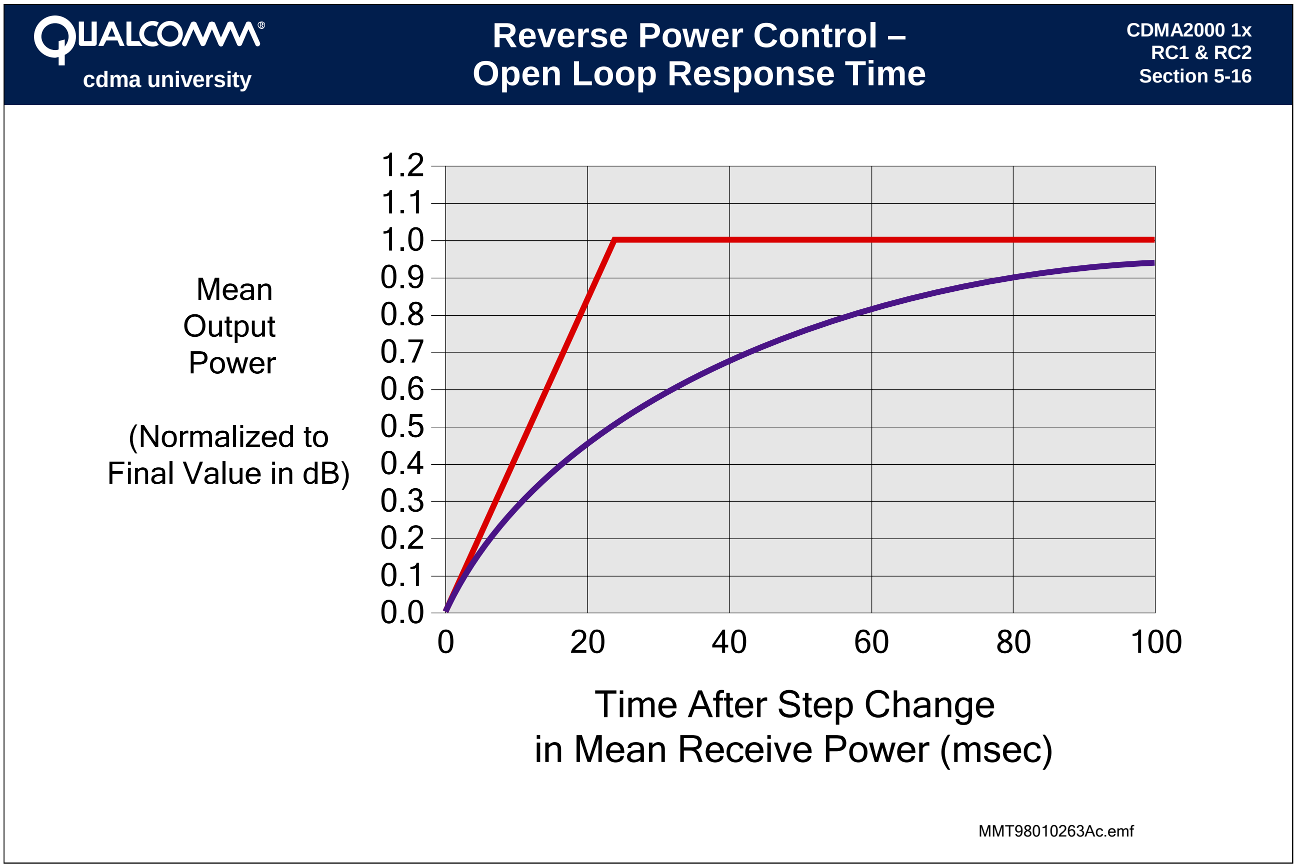
CDMA2000 Release A uses the new R-EACH and R-CCCH channels in the new Access procedures.



Access Probing

The Open Loop Estimate is refined by *probing* on the Access Channel. The mobile transmits at the level indicated by the equation, then waits for an acknowledgment from the Base Station. If no acknowledgment is received, the mobile increases transmitter power and transmits again. This increase is an *Access Probe Correction*.

Typically, only one or two probe increases are required before acknowledgment. Once an acknowledgment has been received, the sum of all access probe corrections will continue to be used to determine the transmit power level on the Traffic Channel.



Open Loop Response Time

The speed of the Open Loop response is constrained within certain boundaries (the two lines shown on the graph). This is intentionally done to cause the Open Loop response to be too slow to compensate for fast fading on the Forward link. Remember that the Forward and Reverse links are 45 MHz apart in cellular networks and 80 MHz apart in PCS systems. As a result, fading in the two directions is generally uncorrelated.

QUALCOMM cdma university

Reverse Power Control – Open Loop Power Control in TIA/EIA-95

CDMA2000 1x RC1 & RC2 Section 5-17

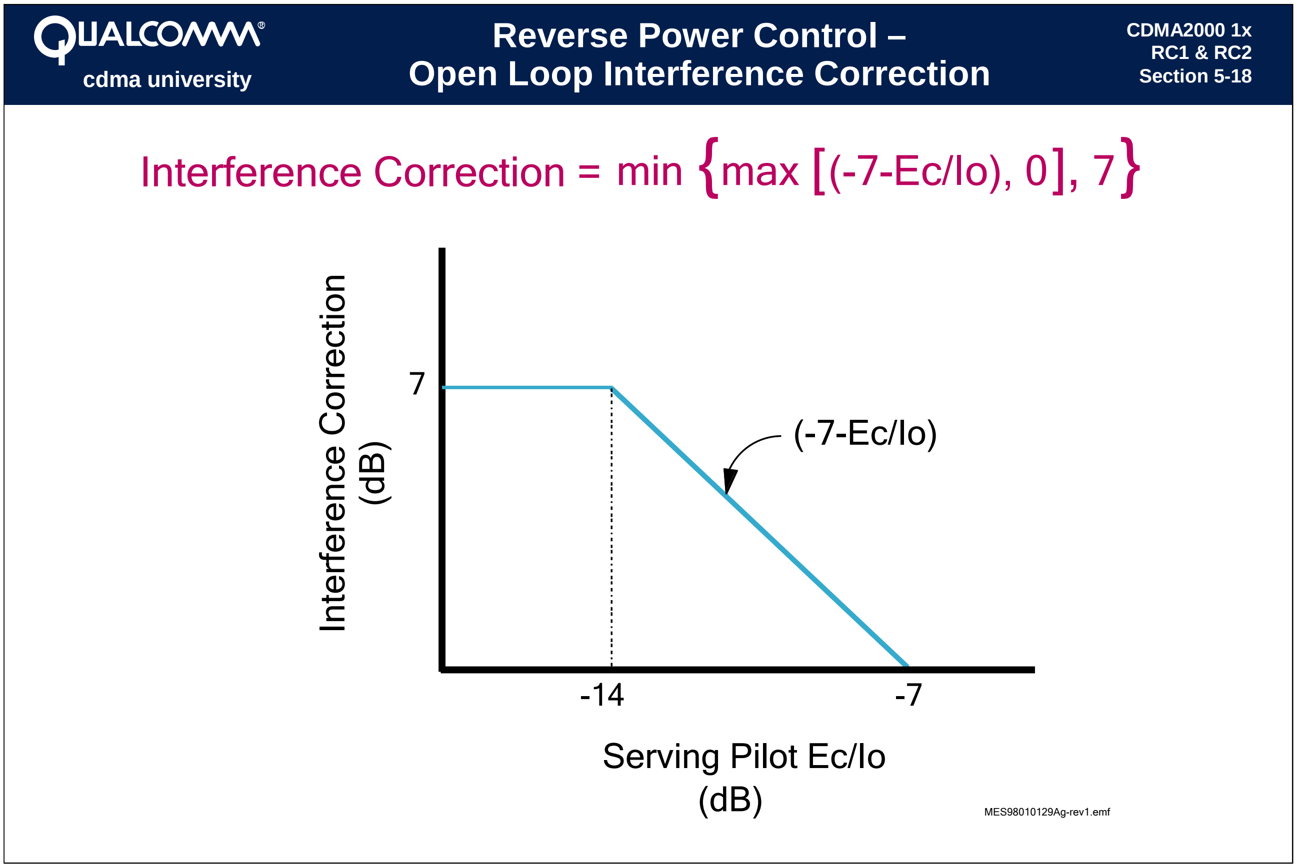
Mean Output Power (dBm) = - Mean Receive Power (dBm)
+ offset power
+ *interference correction*
+ NOM_PWR
- 16 X NOM_PWR_EXT
+ INIT_PWR

A Weakness in the Open Loop Estimate

The mobile may underestimate the path loss when it is slow to perform an idle handoff, is near the edge of coverage, or in a soft handoff region. The idle handoff underestimate occurs when the mobile is receiving a strong signal from a neighboring Base Station while the serving Base Station is becoming weak. An idle handoff is about to take place, but has not yet happened. In this scenario, the strong neighbor causes the mobile to measure a high receive power level and consequently calculate a low transmit power estimate. The mobile, however, has not yet transitioned to the new Base Station and is still being served by the weaker Pilot. When the Access attempt begins, the idle handoff to the stronger Pilot is prohibited and the mobile must continue to use the weaker Pilot until the access is successful. Near the cell edge, and in the soft handoff region, the mobile receives additional power with respect to the serving Pilot, and the mobile overestimates the received power, which causes it to underestimate the path loss back to the Base Station. The low transmit power estimate, however, commonly results in failure of the first several probes.

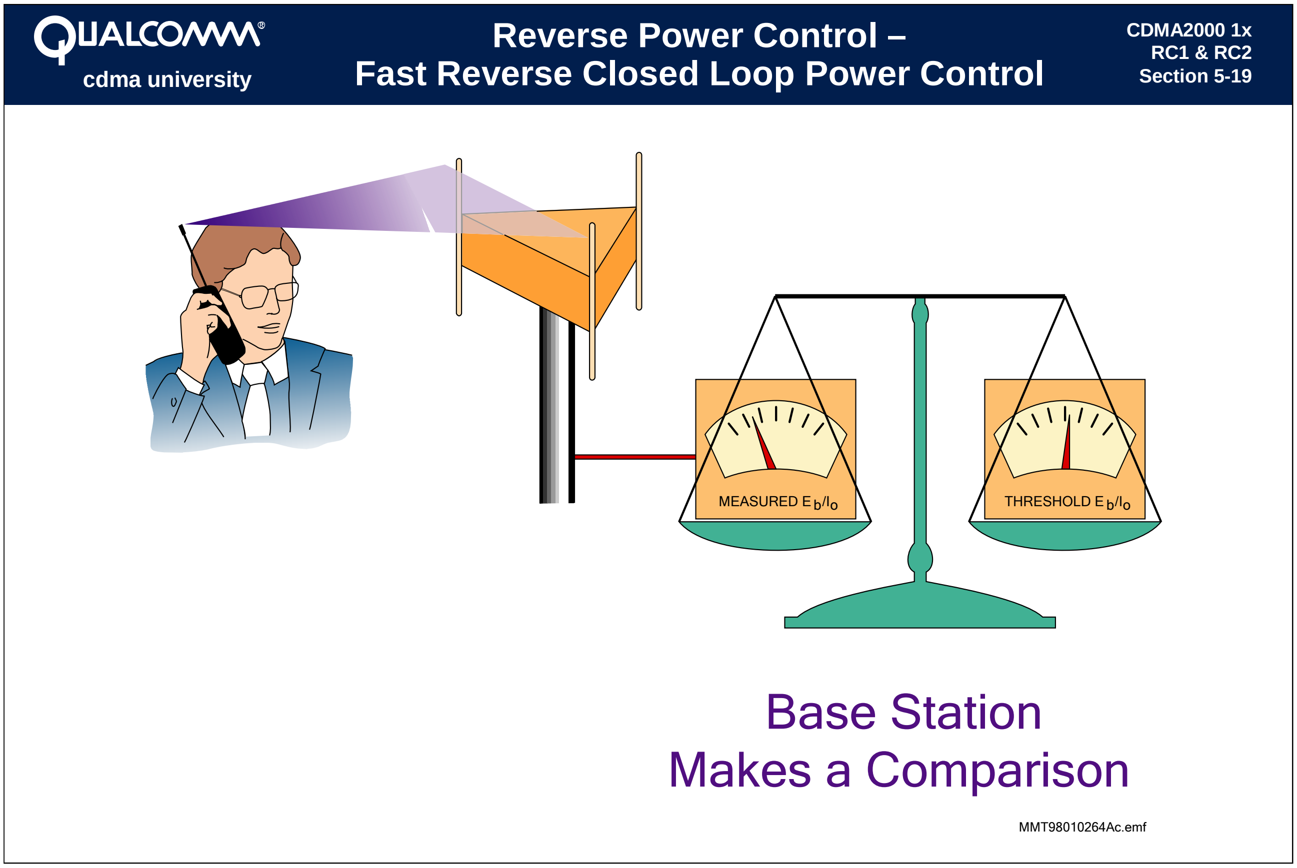
TIA/EIA-95 adds an *interference correction* into the Open Loop Estimate. The magnitude of the interference correction is a function of the strength of the serving Pilot. The interference correction is defined as follows:

$$\text{Interference Correction} = \min \{ \max (- 7 - E_c / I_o), 0], 7 \}$$



Open Loop Interference Correction

In this figure, the interference correction is shown to be a constant +7 dB when the serving Pilot E_c/I_o is -14 dB or lower. The interference correction is 0 dB when the serving Pilot is -7 dB or higher.

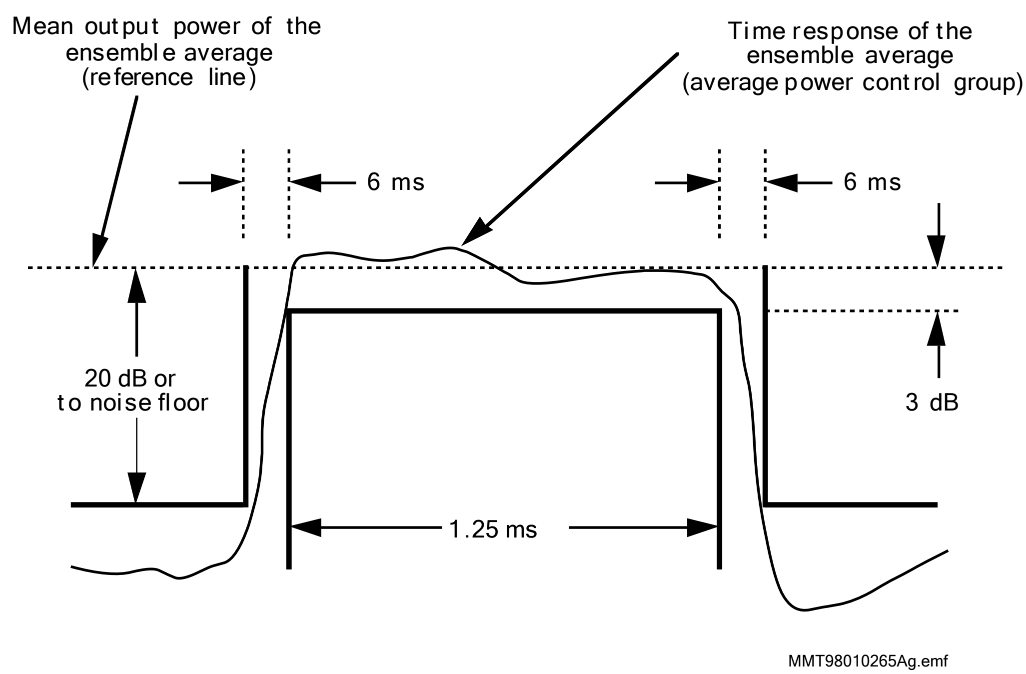


The Reverse Closed Loop Process

In Reverse Closed Loop Power Control, the Base Station measures the signal level received from each mobile and then provides feedback to the mobile to adjust the unit's transmit power. The goal of Reverse Power Control is to adjust each mobile's transmit power to cause the signals from all mobiles to arrive at the Base Station at the minimum level of power required for each unit.

When the mobile transmits on a Traffic Channel, the Base Station measures the received signal-to-interference ratio (E_b/I_0) and compares the measured value to an adjustable threshold. If the measured E_b/I_0 is above the threshold, the Base Station will send a 1-bit command to the mobile directing it to reduce power by a fixed amount. This fixed amount is defined in the CDMA standards to be 1 dB. If the measured value of E_b/I_0 is below the threshold, a 1-bit command is sent to tell the subscriber unit to increase power by 1 dB. This measurement and comparison occurs every 1.25 ms (800 times per second). The 800 bps that result are referred to as the *Power Control Subchannel*. These power control bits are sent to the mobile directly on the Traffic Channel by *puncturing* the Traffic Channel data (overwriting the data).

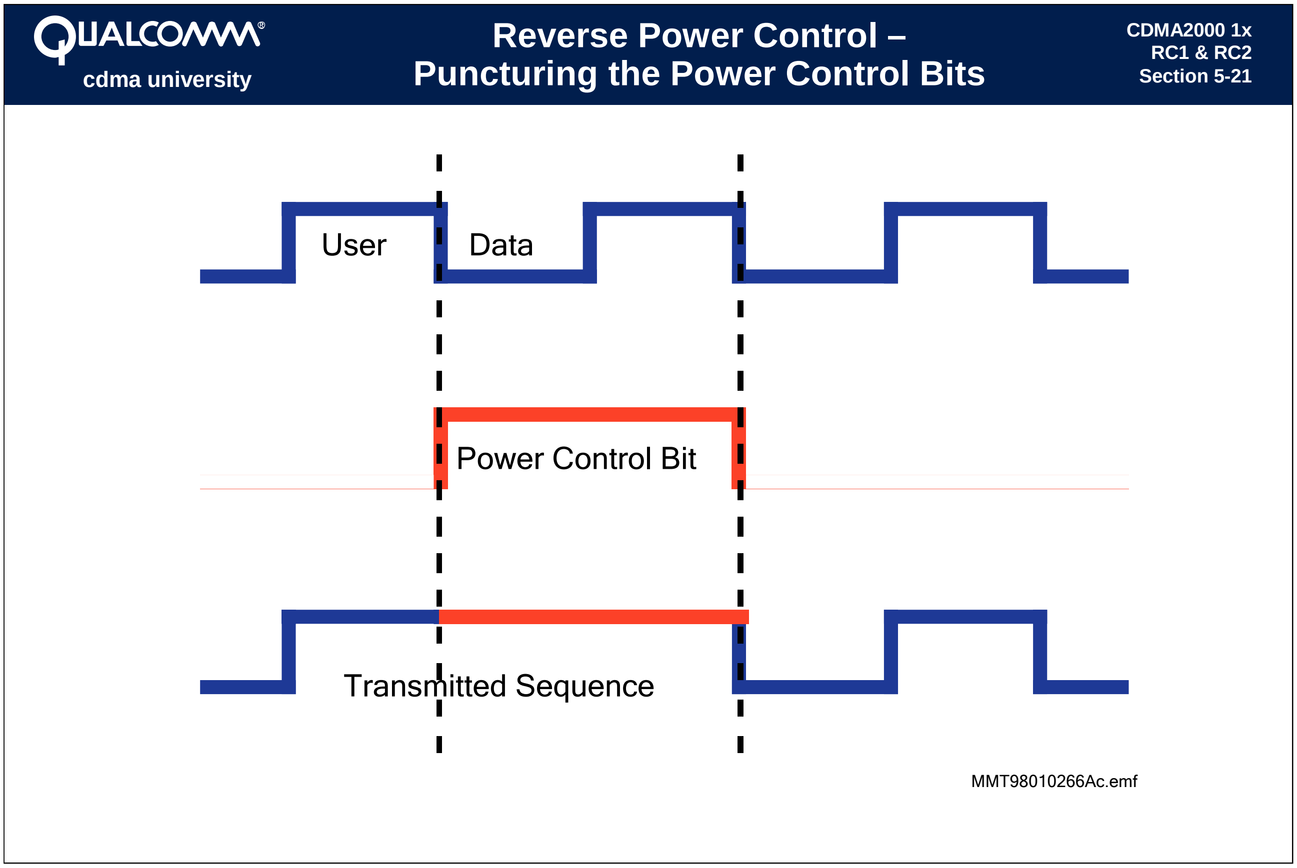
Reverse Power Control – Mobile Transmits Bursts



Mobile Transmits Bursts

A limitation of conventional wireless systems was an inability to rapidly re-allocate resources when a mobile was temporarily not using them. A primary goal of a CDMA system is to take advantage of periods of reduced speech activity. This can be done by reducing average transmit power when the speaker reduces speech activity or stops talking altogether.

On the Reverse link, this reduction in average transmit power is accomplished by turning off the transmitter for a fraction of the time during periods when speaker activity is low. The transmitter is turned off in increments of 1.25 ms. These increments are called *power control groups*.



Puncturing the Power Control Bits

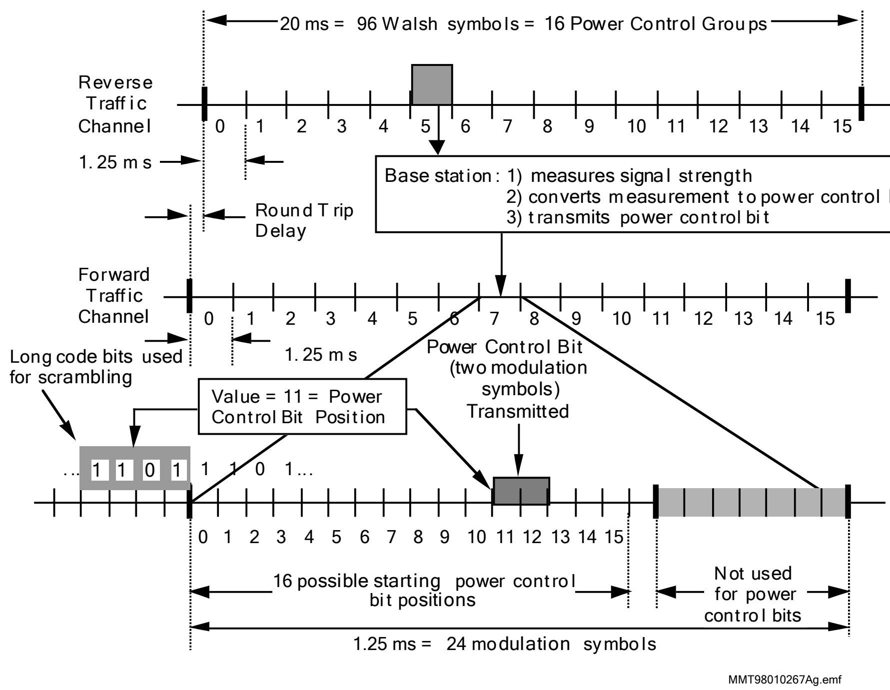
It was previously identified that Reverse power control had to be fast. To meet this requirement for speed, it was decided that power control feedback from the Base Station to the mobile would be *punctured* directly into the Forward Traffic Channel.

The Power Control Bits are punctured into the data traffic 800 times per second. The Power Control Bits are defined to have a duration of two symbol periods when Rate Set 1 is used (9600 bps variable rate speech option, as shown here), but only one symbol period when Rate Set 2 is used (14,400 bps variable rate speech option). The exact timing of each Power Control Bit is pseudorandomly determined by several digits taken from the Long Pseudorandom Noise (PN) code.

QUALCOMM®
cdma university

Reverse Power Control – Pseudorandom Bit Placement

CDMA2000 1x
RC1 & RC2
Section 5-22



Pseudorandom Bit Placement

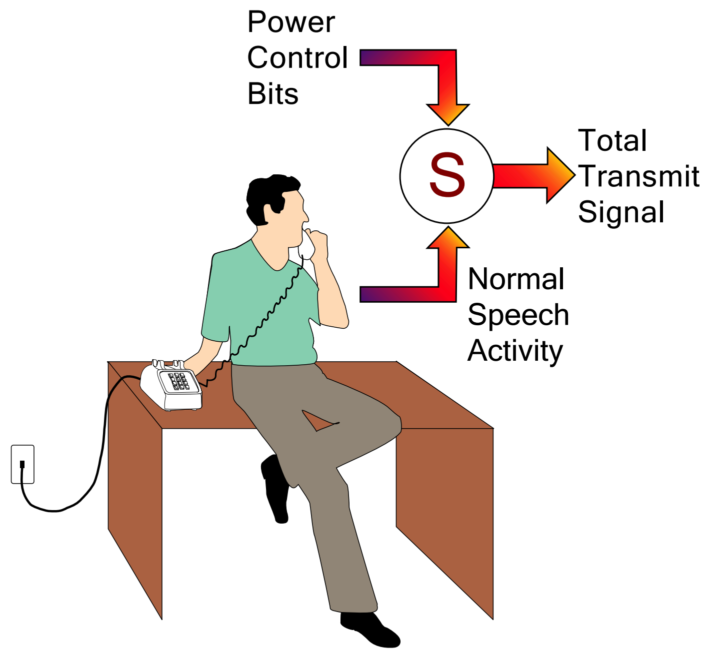
The Power Control Bits are punctured into the Forward Traffic Channel in a pseudorandom manner. Each Traffic Channel frame is divided into 16 segments, each 1.25 ms in duration. These segments are called *Power Control Groups*.

A Power Control Bit is pseudorandomly punctured into each Power Control Group. The location of the Power Control Bit is determined by using the last four chips of the PN sequence that were used to scramble the last four symbols (21, 22, 23, 24) of the previous Power Control Group. These last four chips determine the location of the first symbol to be punctured.

QUALCOMM cdma university

Reverse Power Control – Impact on Apparent Voice Activity

CDMA2000 1x RC1 & RC2 Section 5-23



Impact on Apparent Voice Activity

Power Control Bits are punctured in at Full Rate Power.

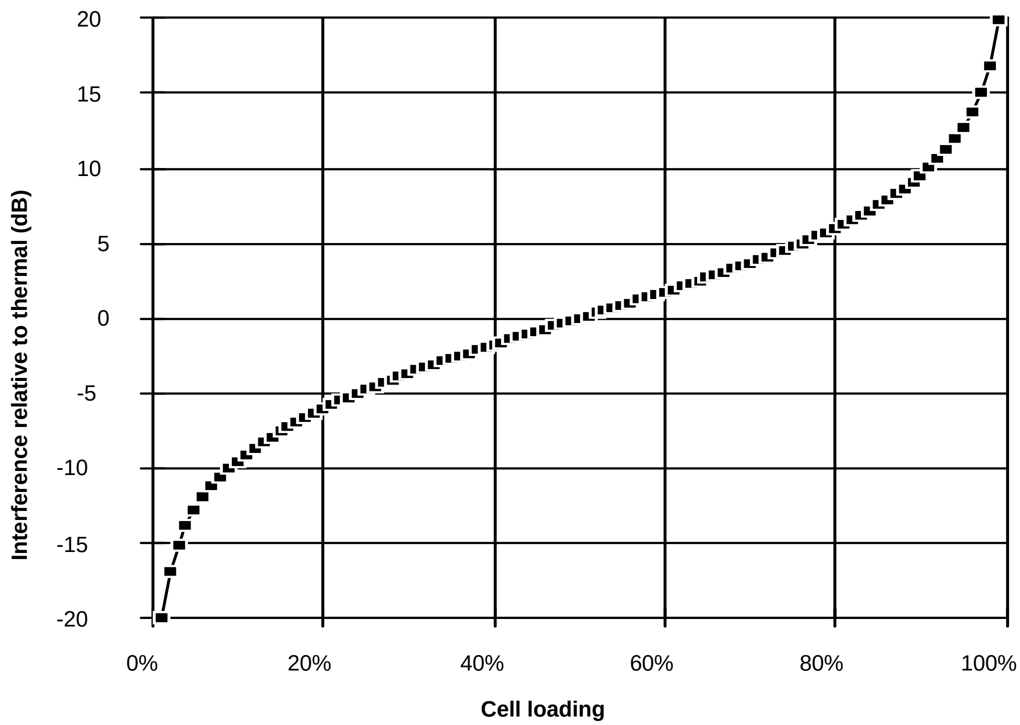
This results in an apparent increase in voice activity on the Forward CDMA Channel:

- Rate Set 1: (40% activity)(11/12) + (100% activity)(1/12) = 45%
- Rate Set 2: (40% activity)(23/24) + (100% activity)(1/24) = 42%

QUALCOMM cdma university

Reverse Power Control – Reverse Link Interference

CDMA2000 1x
RC1 & RC2
Section 5-24



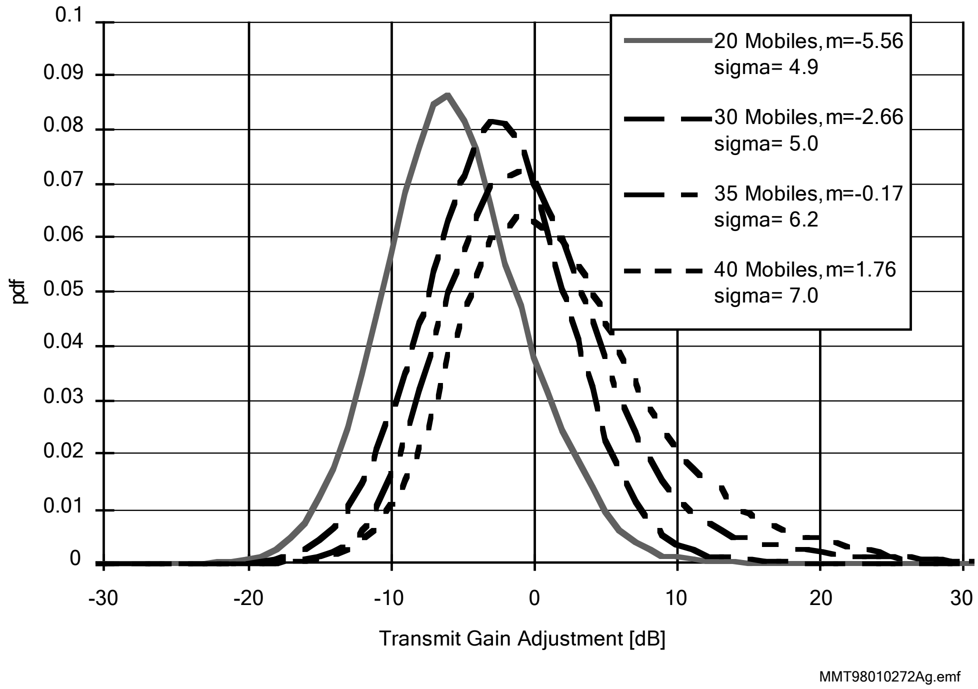
Reverse Link Interference

On the Reverse Link, the cell suffers interference from mobiles in the same cell as well as from mobiles outside the cell. Hence the variation with the cell load, or the ratio between the number of active users and the maximum allowable number of users.

QUALCOMM cdma university

Reverse Power Control – Typical Closed Loop Histogram

CDMA2000 1x RC1 & RC2 Section 5-25



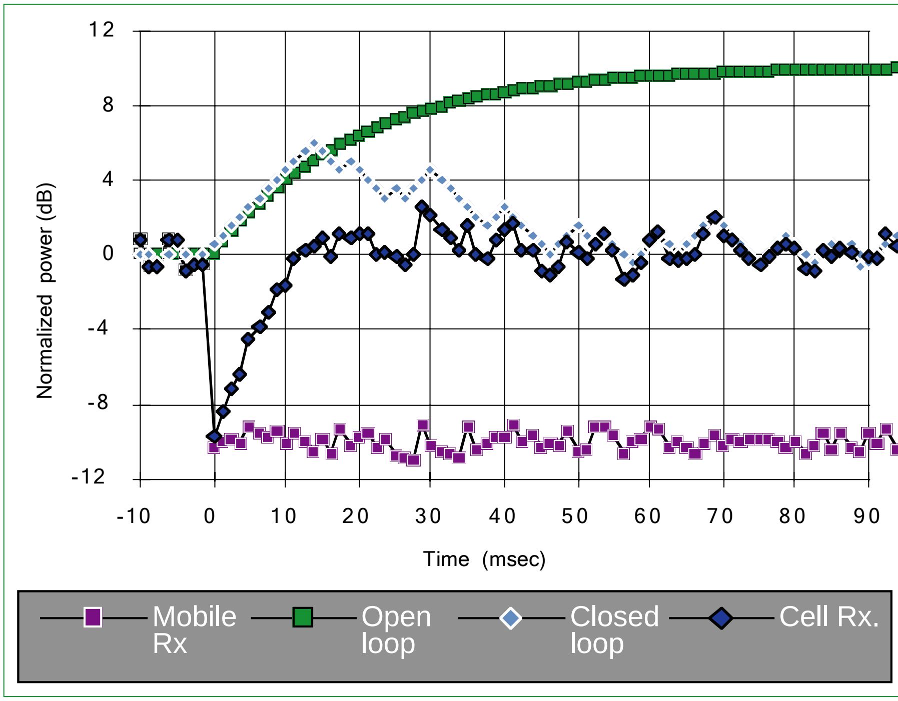
Typical Closed Loop Histogram

The figure illustrates an example of closed loop gain adjustments during field trials in San Diego, California. The histogram shows that the mobile on average slightly overestimated required transmit power when the cell was lightly loaded. As a result, the closed loop process must reduce the mobile's transmit power. This is expected behavior. The mobile's open loop estimate is based on a turnaround constant that assumes a nominal level of cell loading (i.e., 50%).

QUALCOMM cdma university

Reverse Power Control – Power Control Response

CDMA2000 1x RC1 & RC2 Section 5-26



MMT98010642Ac.emf

The Complete Power Control Response

The graph illustrates the overall Power Control response to a sudden degradation in the received power at both the mobile and the cell. This type of degradation is typical when the mobile suddenly moves into the shadow of a building or is driven under a bridge. The graph represents a situation where both the mobile and the cell are initially receiving a satisfactory level of power. At approximately the 0 ms point on the time scale, there is a sudden 10 dB degradation in both mobile receive and cell receive. When the mobile measures this drop in receive power, the Open Loop Power Control process responds with an estimate that causes a 10 dB increase in mobile transmit power. The open loop response is intentionally slowed, however, so that it takes nearly 100 ms to complete the increase.

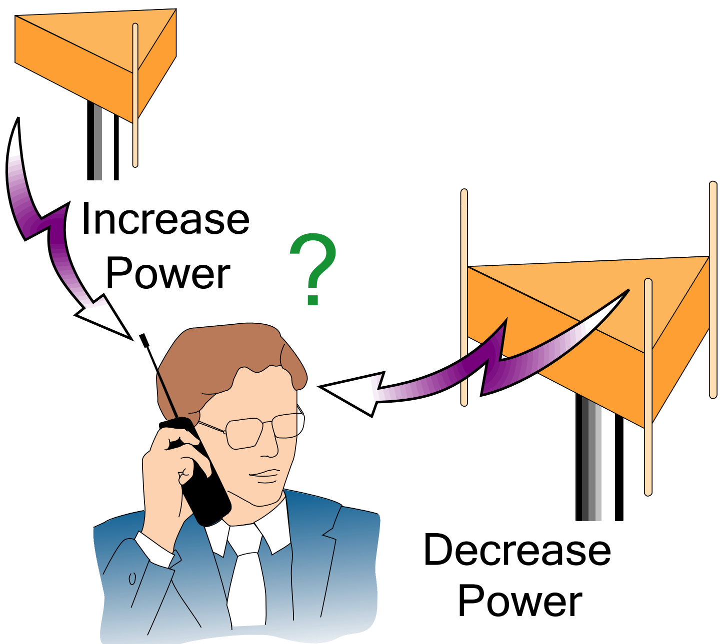
While this is happening, the Base Station (the cell) is measuring receive power also and making a determination that the mobile should increase power. The cell commands the mobile to increase power by sending power control bits every 1.25 ms. Both the open loop and the closed loop processes increase the mobile's transmitted power. This causes the mobile transmit power (and therefore cell receive power) to increase more rapidly than with the open loop alone. Cell receive power returns to a nominal level in just 10 ms. Since Forward power control typically works relatively slowly, mobile receive power has not yet been adjusted in this short time span.

[Note: This illustration was based on an analysis done using a closed loop increment of 0.5 dB. The standard was eventually defined to be 1 dB.]

QUALCOMM cdma university

Reverse Power Control – Power Control During Soft Handoff

CDMA2000 1x RC1 & RC2 Section 5-27



MMT98010271Ac.emf

Closed Loop Control During a Soft Handoff

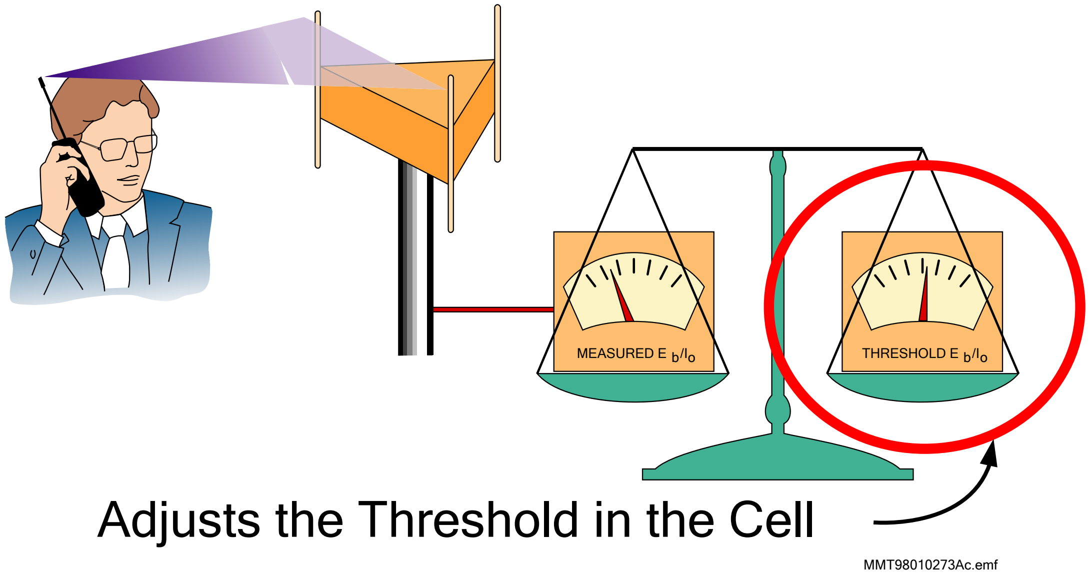
When a mobile is involved in a soft handoff, it can receive conflicting power control commands from the different cells. The mobile must resolve this conflict using a simple rule: if any Base Station commands the mobile to reduce power, it will reduce power.

In the event of a multi-sector handoff, the mobile should receive identical commands from the two sectors. Knowing this, the mobile can *soft combine* the bits before making a decision on the value of the bit.

QUALCOMM cdma university

Reverse Power Control – Reverse Outer Loop Power Control

CDMA2000 1x RC1 & RC2 Section 5-28

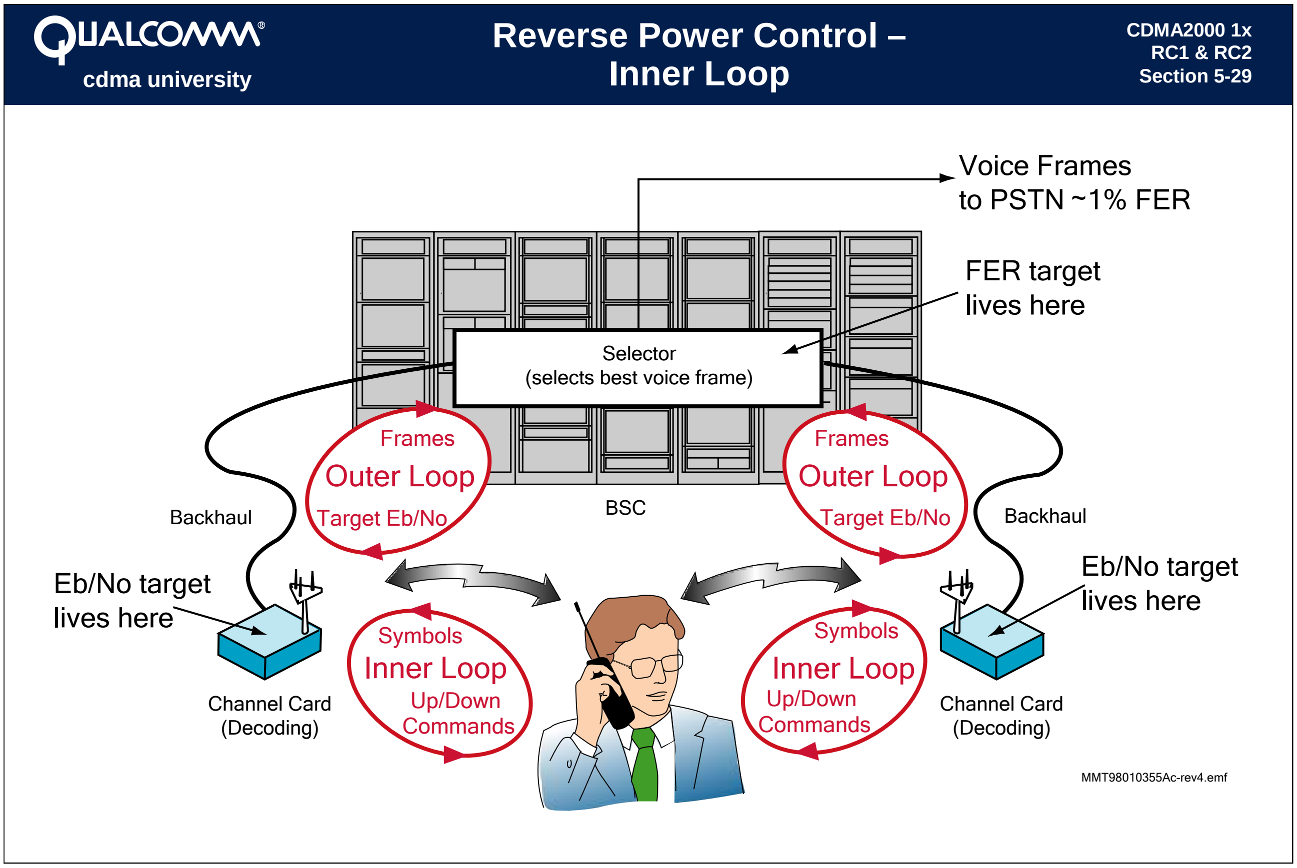


The Reverse Outer Loop Process

In the Closed Loop Power Control process, the E_b/I_0 measured at the cell is compared to an adjustable threshold. The threshold determines the *Frame Error Rate* (FER). Increasing the threshold reduces the FER, thereby improving the quality of the speech. Reducing the threshold tends to increase the FER. Typically, a system would attempt to maintain a FER of 1%. Adjusting this threshold is referred to as *Outer Loop Power Control*. There is no standardized process for Outer Loop Power Control. Infrastructure manufacturers are free to implement their own proprietary algorithms.

A single threshold can be used for every mobile in the cell or each mobile can have its own threshold. Individual thresholds are not expected to vary over a range of more than a few dB. Individual thresholds will be beneficial since this allows mobiles in extremely advantageous circumstances to have a lower threshold, while providing a higher threshold to disadvantaged users. The use of individual thresholds significantly increases capacity. Typically, the sectors involved in a call (there may be several due to soft handoff) all deliver frames to the selector (at the MSC). The selector selects the frames that are not in error and delivers these to the PSTN. The output of the selector is used to determine the FER.

Reverse Power Control – Inner Loop



Inner Loop

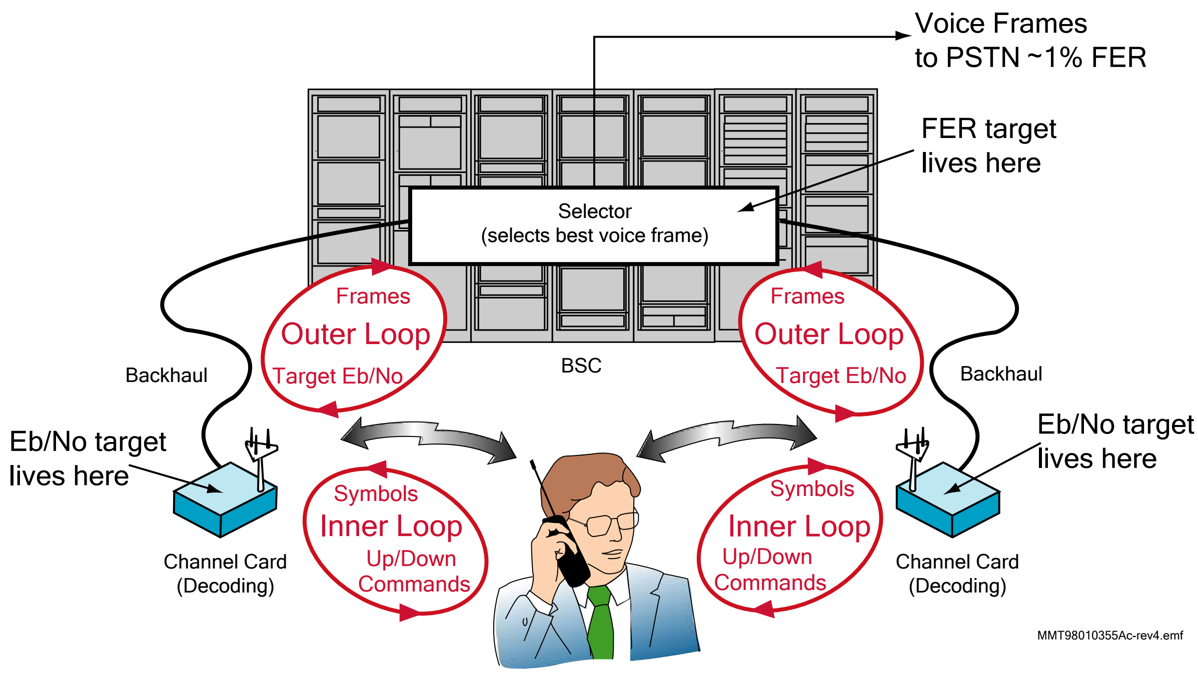
The Inner Loop is the power control loop between the Base Station and the mobile.

The Base Station compares the local Base Station target to the signal received from the mobile, and makes the 1 bit up/down command to send to the mobile 800 times each second.

QUALCOMM cdma university

Reverse Power Control – Outer Loop

CDMA2000 1x
RC1 & RC2
Section 5-30



Outer Loop

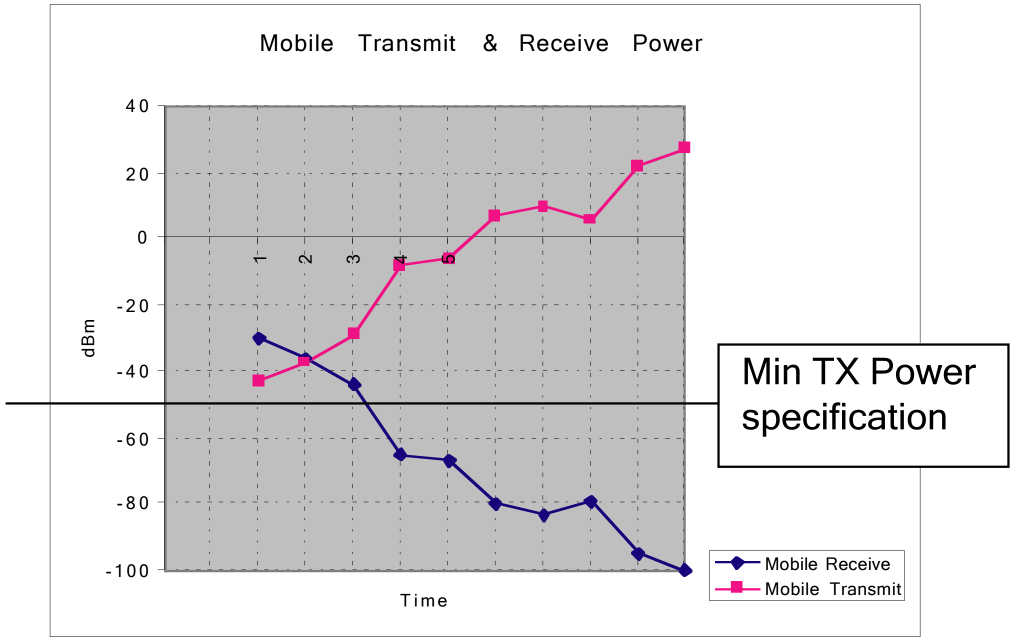
The Selector (usually located in the MSC) is the entity that receives frames from all Base Stations that are involved with this user's call. Soft handoff involves multiple Base Stations, with each Base Station sending frames over the backhaul to the Selector. The Mobile transmits the frames over-the-air to the Base Stations involved in soft handoff for this user; the Base Station time-tags each frame and sends it to the Selector. The Selector has the job of selecting the frames that are correct, based upon the CRC bits in the frame.

The frames being sent to the PSTN are used to calculate the FER. The FER for each Base Station will be different, because the channel between the mobile and each Base Station is unique. The FER between each Base Station and mobile changes with time, because the channel changes due to mobile movement or other changes in the local fading environment. Thus the Selector is the only network element that knows the FER going to the PSTN, making the Selector the correct network element to determine the required user Eb/No target.

This target changes slowly with time (slower than the 800 bit per second of the inner loop) and is broadcast over the backhaul to the Base Stations involved in the user's call. Each user can have a separate target Eb/No, because the FER target typically requires a different Eb/No for each user due to the different user environments. A static (non-moving) user typically requires a smaller Eb/No target than a moving user. A user in a difficult fading/multipath environment requires a higher Eb/No target than a user that has line-of-sight to the Base Station.

Reverse Power Control – Minimum Transmit Power

CDMA2000 1x RC1 & RC2 Section 5-31



MMT98010276Ac.emf

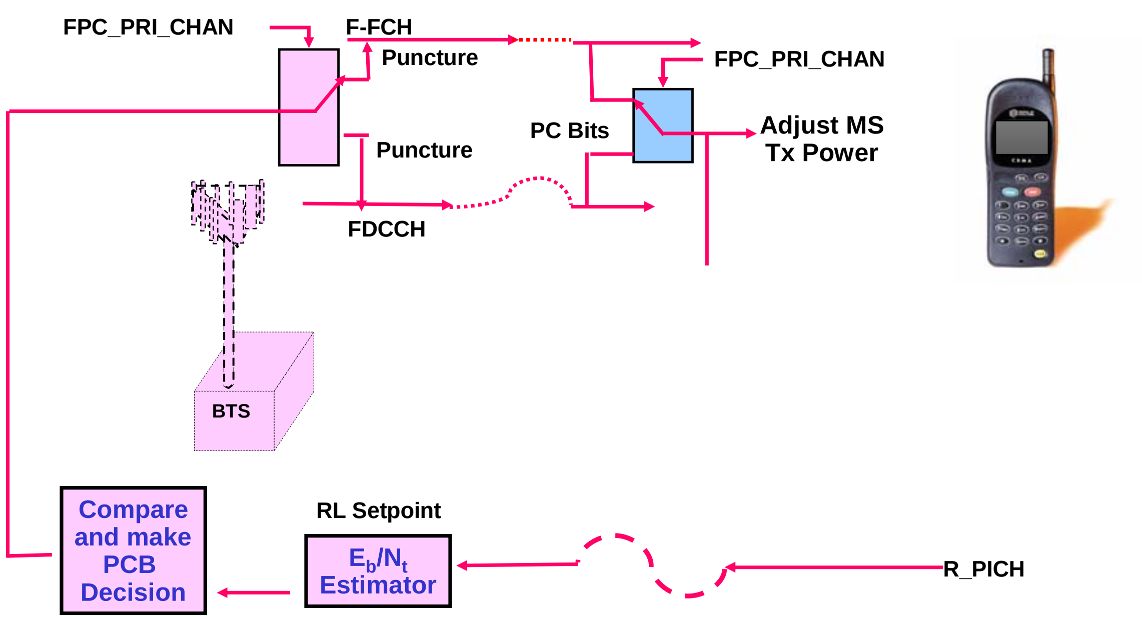
Minimum Transmit Power: Mobiles

- The minimum transmit power is specified at -50 dBm for both cellular and PCS systems.
- The dynamic range required for Reverse Power control is 80 dB (from –50 dBm to around 30 dBm).

QUALCOMM cdma university

Reverse Power Control – CDMA2000 Data Flow

CDMA2000 1x RC1 & RC2 Section 5-32



Power Control on Dedicated Channels

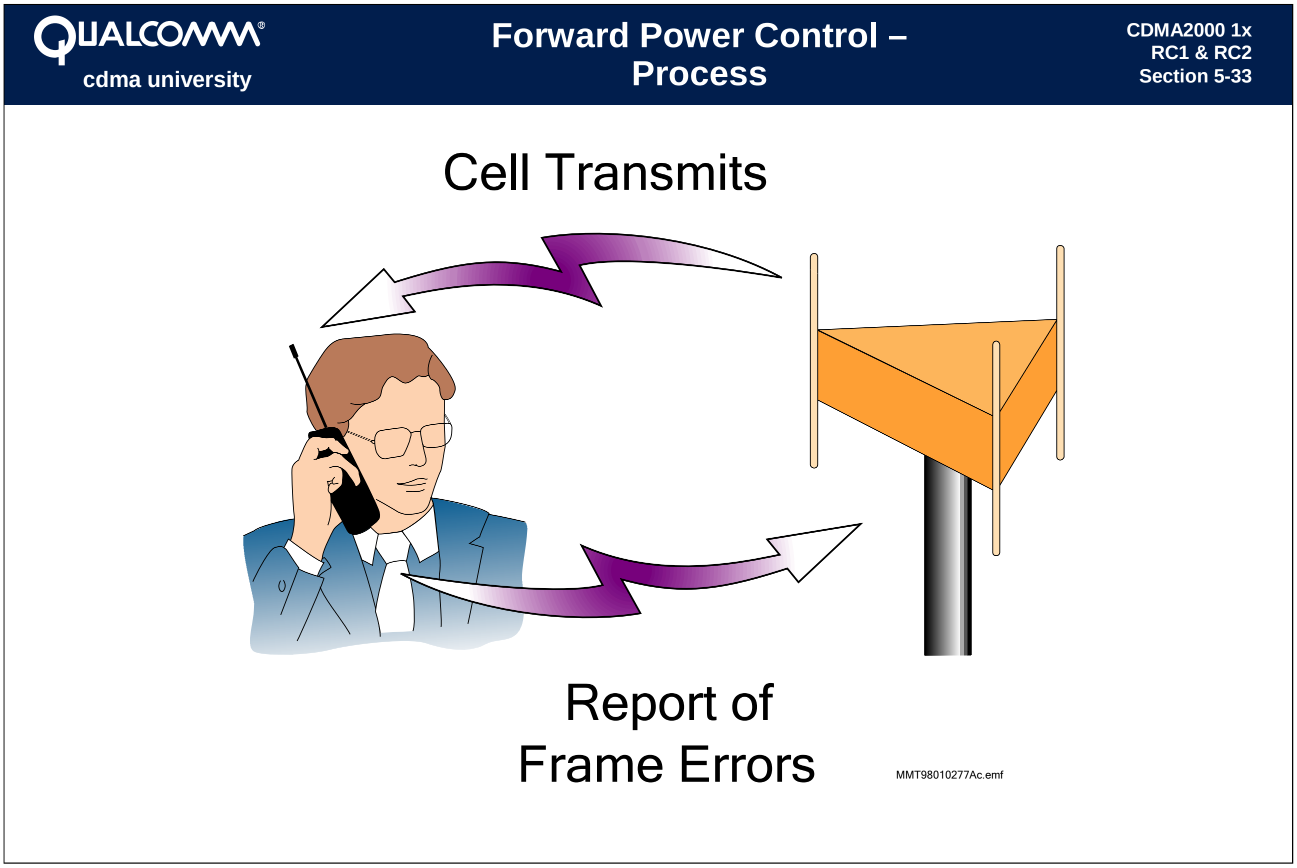
The Reverse Link Power Control procedure at the mobile consists of open loop power control, closed loop power control, and output power adjustment. The output power adjustment is introduced in order to properly distribute the transmitter power among multiple Reverse link traffic channels supported by an CDMA2000 mobile.

The output power adjustments are defined in two ways:

- Use the transmitter power on the R-PICH as the reference and introduce a power offset for the particular Reverse link traffic channel. Such parameters are RLGAIN_TRAFFIC_PILOT and RLGAIN_SUPPL_PILOT.
- Adjust the transmit power based on the channel configuration parameters, such as the rate, frame size, and so on. This type adjustment is called *Attribute Adjustment Gain*.

When determining the transmit power of certain Reverse link traffic channels, the mobile combines the gain adjustments specified by both of the above methods.

The mobile supports a power control step size of 0.5 dB on R-SCH for the purpose of the closed loop power control.



The Forward Power Control Process

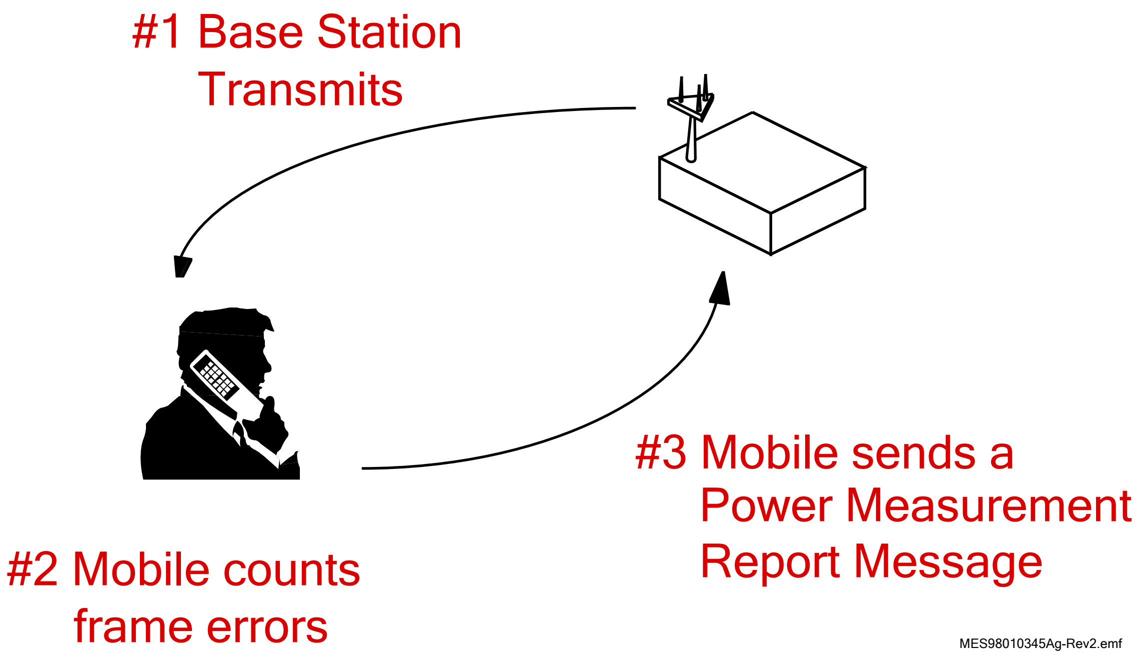
The Forward CDMA Channel power is shared by the Pilot Channel, the Synchronization Channel, the Paging Channels, and the Forward Traffic Channels. Since some mobiles may be in disadvantaged locations (e.g., locations having extreme multipath, a large background noise, or large path attenuation), transmission loss from the Base Station to mobiles varies from unit to unit. It can be beneficial to control the allocation of power to each Forward Channel. The expected range of variation is small (+/- 4 dB).

The Forward power control algorithm, however, is not standardized. Infrastructure manufacturers may implement different processes to control the allocation of the cell's radiated power. The standard does specify that the mobile must monitor the quality of the Forward Traffic Channel and report this information back to the Base Station if told to do so. This is a *closed loop* process similar to the Reverse power control process. In the Reverse direction, however, the closed loop was based on maintaining the signal-to-noise metric at the proper level. The Forward power control process monitors frame error rate. As a result, the Forward power control process is substantially slower.

cdma university

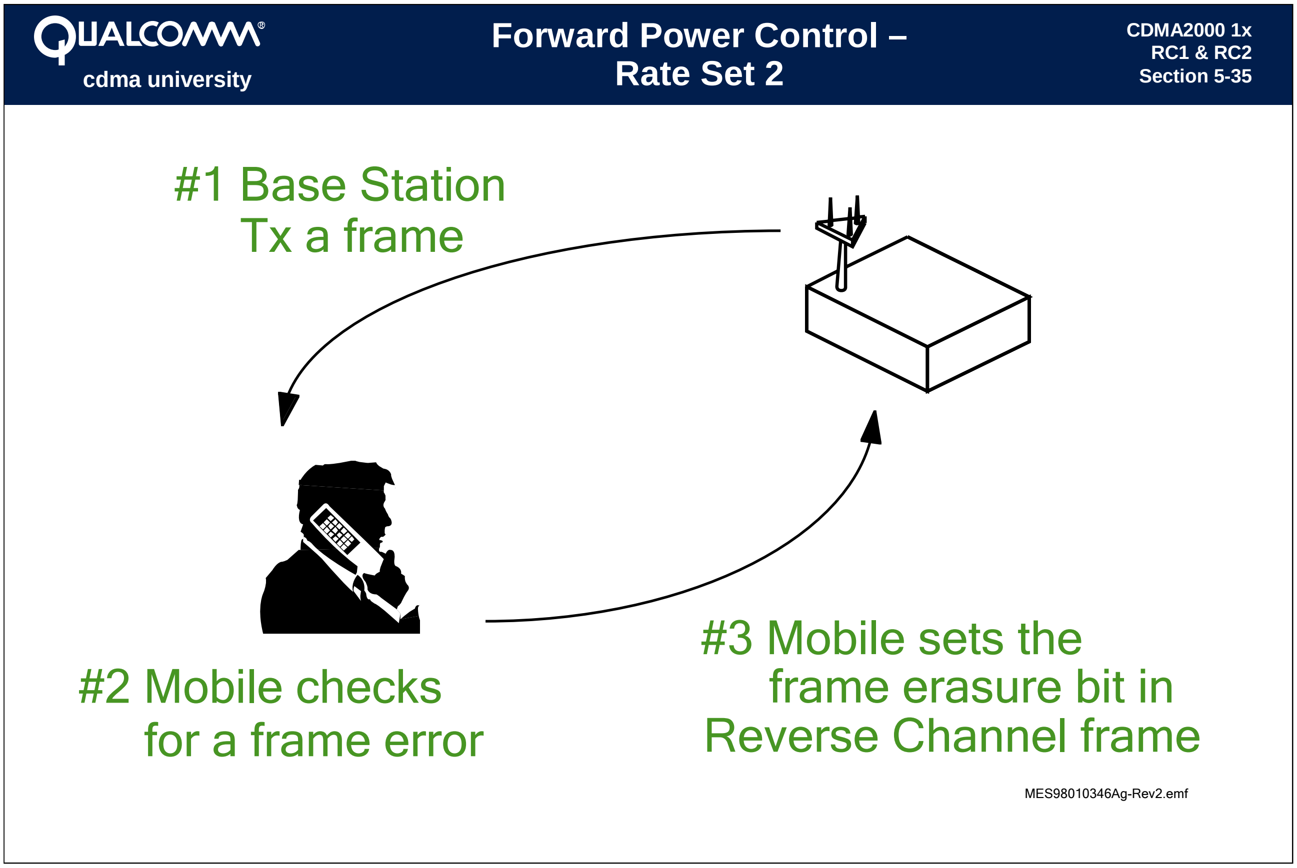
Forward Power Control – Rate Set 1

CDMA2000 1x
RC1 & RC2
Section 5-34



Rate Set 1: 9600 bps Transmission Rate

When the 9600 bps transmission rate is used, the mobile must inform the Base Station of the frame error count using a message defined in the standard. This message is called the Power Measurement Report Message. The mobile provides these reports as directed by the Base Station. Reports can be triggered based on a threshold or periodically.



Rate Set 2: 14.4 kbps Transmission Rate

The 14,400 bps transmission rate allows for a faster Forward power control process. In this rate, a single bit has been set aside in every frame to be used as a *Frame Erasure* bit. This bit is set by the mobile to indicate an erasure (an error) in the Forward Traffic Channel frame.

QUALCOMM cdma university

Forward Power Control – Forward Link Closed Loop Methods

CDMA2000 1x RC1 & RC2 Section 5-36

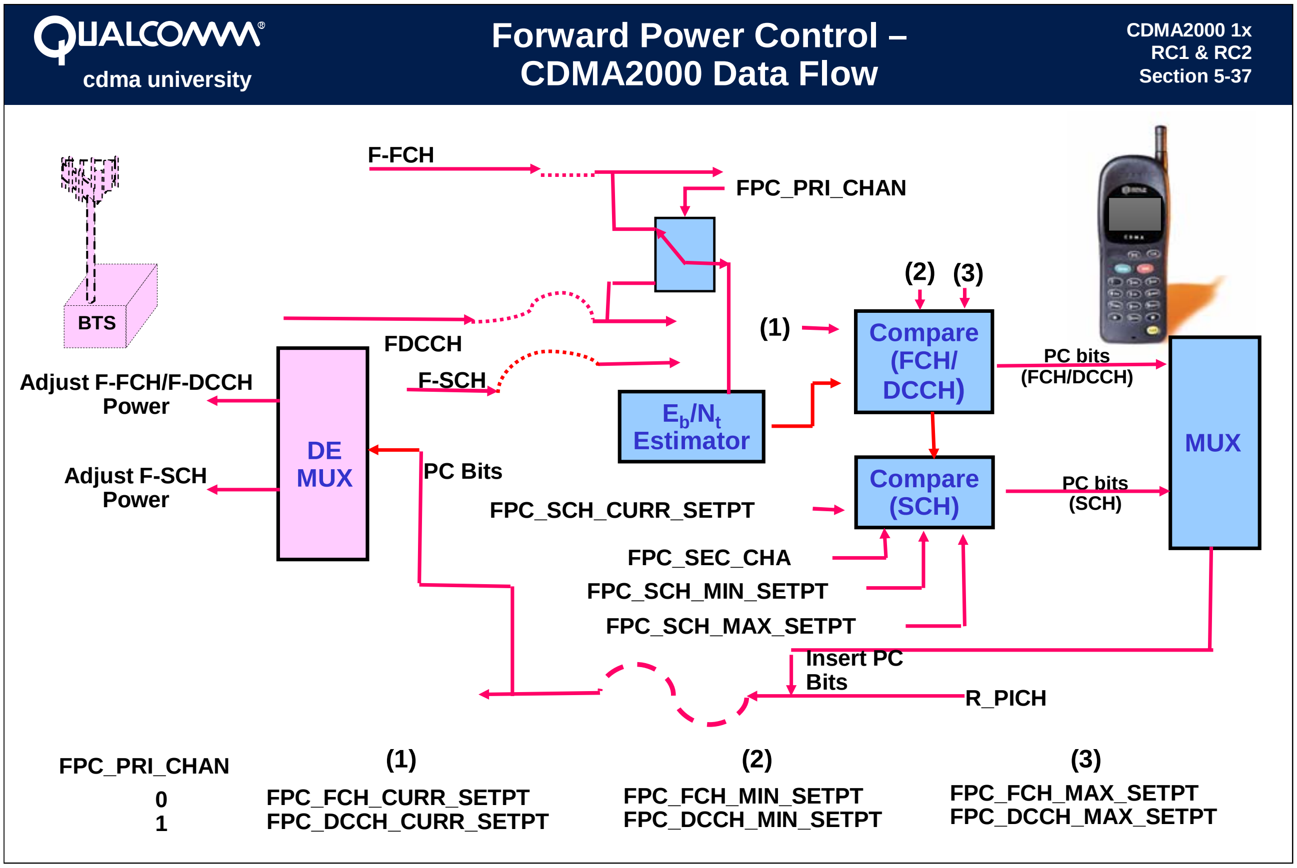
CDMA2000 Forward Link Power Control Summary

- **Seven different modes**
  - Different rates of sending power control bits
  - Different combinations of Forward link channels monitored
  - Different methods for determining power control bits
  - Applicable only to RC 3 through 9
- **Primary and secondary Power Control Subchannels**
  - Sent as a subchannel of the R-PICH
  - Primary based on either F-FCH or F-DCCH
  - Secondary based on one of the F-SCHs
- **Outer Loop setpoints sent by Base Station in a signaling message**
  - Target FER
  - Maximum and minimum setpoints

Forward Link Closed Loop Methods

The rate of Forward link power control depends on the mode (FPC_MODE) selected by the Base Station. Valid rates are 50, 200, 400, 600, and 800 bps.

Power control bits are sent on a subchannel of the R-PICH. As on the Forward link, there are 16 power control groups per 20 ms frame.



Forward Power Control CDMA2000 Data Flow

In the inner loop power control, the mobile sends the Power Control (PC) bits on the Reverse Power Control Subchannel upon comparing the received Eb/It with the setpoint adjusted by the outer loop.

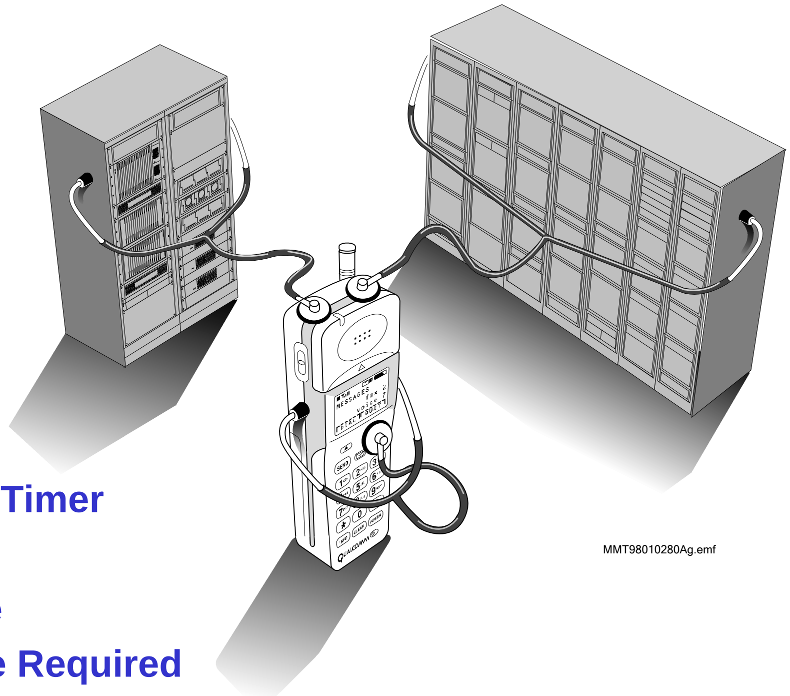
The Power Control Subchannel is time-multiplexed with the R-PICH. The Power Control Subchannel may be divided into the primary and secondary Power Control Subchannels. In such a case, the primary Power Control Subchannel controls the F-FCH, F-DCCH, or both, and the secondary Power Control Subchannel controls the F-SCH.

The Base Station and mobile support all of the Forward Power Control modes involving the primary and secondary to support the fast Forward Power Control. New parameters are added to the Extended Channel Assignment Message, Service Connect Message, Power Control Message, and Extended Supplemental Channel Assignment Message.

To extend the capability of the existing message-based Forward Power Control method, changes have also been made to the Power Measurement Report Message (PMRM), enabling the collection of frame statistics on F-DCCH and F-SCH. In particular, the Base Station may order the mobile to collect the F-SCH within the duration of its assignment by setting FOR_SCH_FER_REP to 1 in the Extended Supplemental Channel Assignment Message.

QUALCOMM cdma university

Malfunction Control



- Malfunction Timer
- Lock Orders
- Power Cycle
- Maintenance Required

Malfunction Control is Specified

In every communications system, mobiles that malfunction can interfere with other users of the system. The CDMA standards define several procedures for mitigating the impact of these malfunctions.

Malfunction Timer

A *malfunction timer* must be implemented in the mobile. This timer has a maximum length of 60 seconds. The timer should be reset periodically during the normal functioning of the unit. If the unit fails to function properly and does not execute instructions in the proper order, the malfunction timer resets will not be executed and the timer will run down as a result. When the timer runs down, the mobile must disable its transmitter.

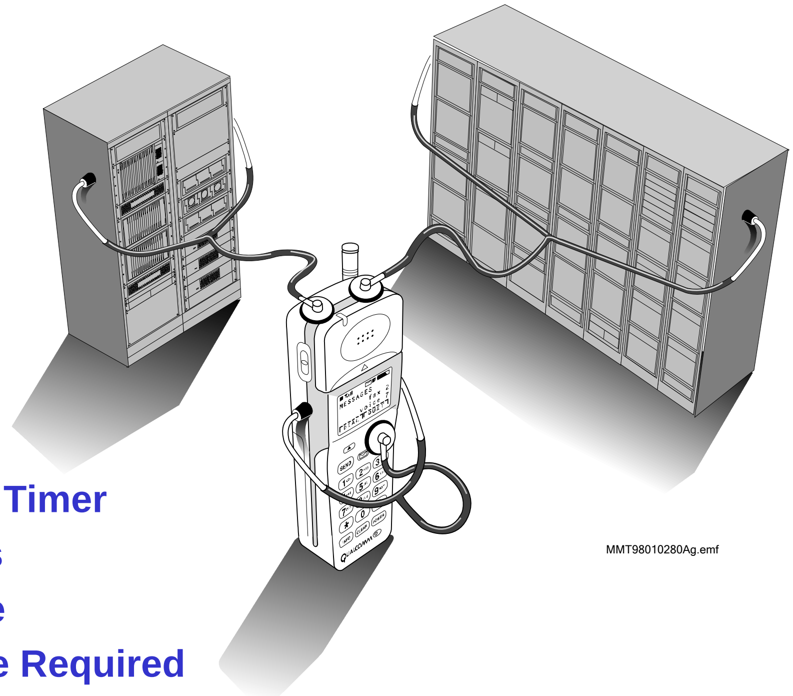
Lock Orders

The standards also define messages that can be used to order the mobile to disable its transmitter. These messages are called *lock orders*.

QUALCOMM cdma university

Malfunction Control (continued)

CDMA2000 1x RC1 & RC2 Section 5-39



- Malfunction Timer
- Lock Orders
- Power Cycle
- Maintenance Required

Lock Until Power Cycled Order

The mobile disables its transmitter, records the reason for the lock order in non-volatile memory, goes to the system determination state with a lock indication, and informs the user of the locked condition. The mobile must stay locked until it receives an unlock order, or until it has been power cycled.

Maintenance Required Order

The *maintenance required order* requires the mobile to record the reason for the maintenance required order in non-volatile memory, and inform the user of the maintenance required condition.

Closed Loop Power Control

Lastly, Closed Loop Power Control can be used to control the mobile's transmit power in the event that an amplifier malfunctions, but the phone still responds appropriately to power control commands.

QUALCOMM cdma university

What We Learned in This Section

CDMA2000 1x
RC1 & RC2
Section 5-40

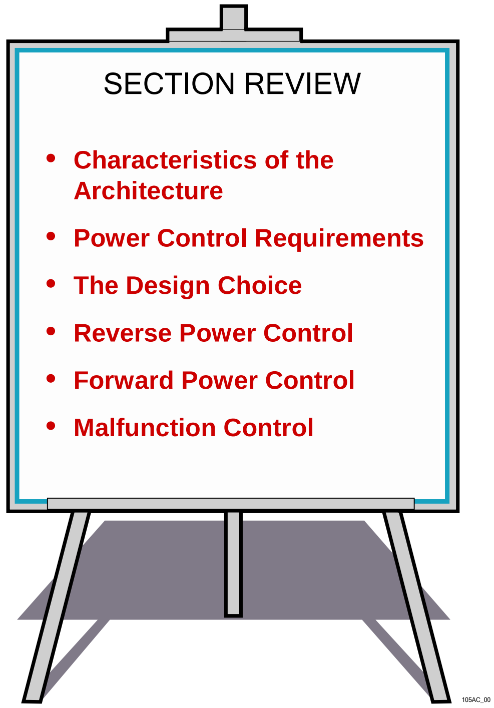
- ✓ The power control processes used in a CDMA system and the rationale for them.
- ✓ The requirements for Power Control.
- ✓ How to calculate an Open Loop Power Estimate.
- ✓ The Closed Loop Power Control process.
- ✓ Outer Loop Power Control.
- ✓ Forward Power Control.
- ✓ The use of a Power Measurement Report Message.

Notes

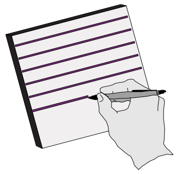
QUALCOMM cdma university

Power Control – Review

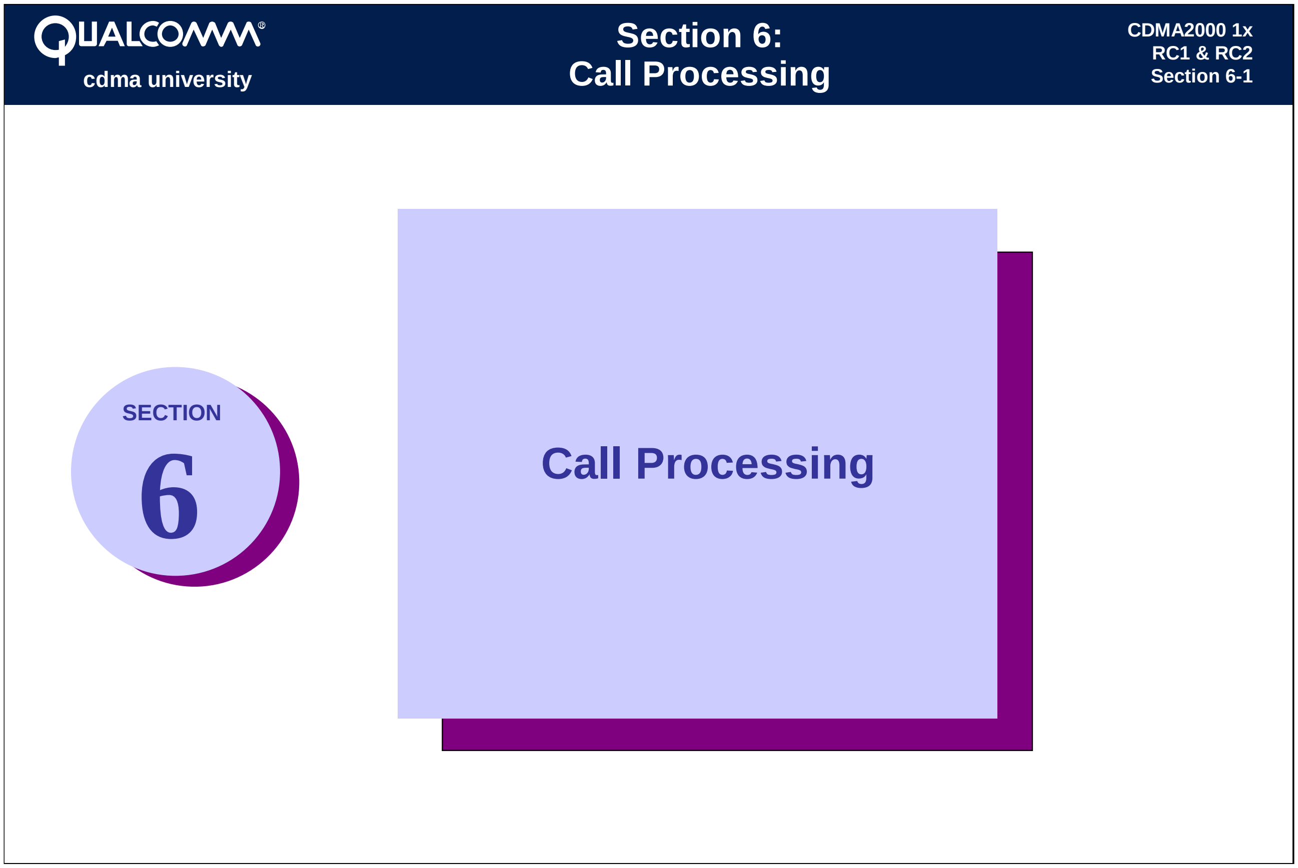
CDMA2000 1x
RC1 & RC2
Section 5-41



Notes



Comments/Notes

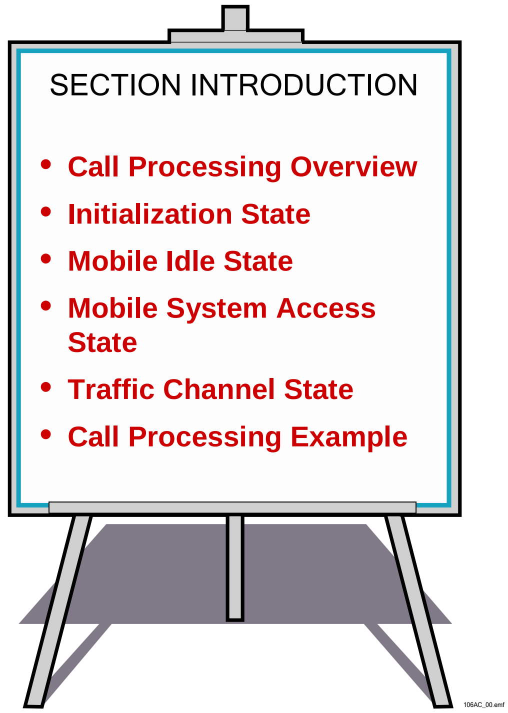

QUALCOMM
cdma university
Section 6:
Call Processing
CDMA2000 1x
RC1 & RC2
Section 6-1
SECTION
6
Call Processing

Notes

QUALCOMM cdma university

Section Introduction

CDMA2000 1x RC1 & RC2 Section 6-2



Notes

Section Learning Objectives

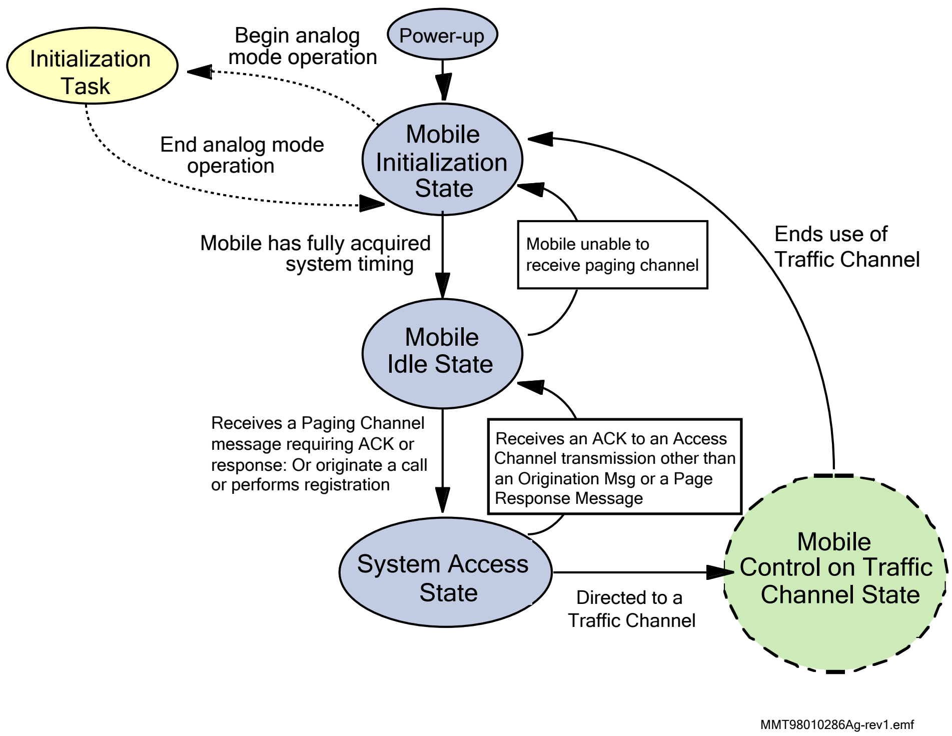
- Describe the call control signaling processes specified in the CDMA standards.
- Explain system determination, synchronization, and timing in CDMA systems.
- Describe the functioning of the Paging Channels.
- Describe the functioning of the Access Channels.
- Describe the Forward and Reverse Traffic Channel Signaling Structures.

Notes

QUALCOMM cdma university

Call Processing Overview – States

CDMA2000 1x RC1 & RC2 Section 6-4



Call Processing States

Pilot and Sync Channel Processing - During Pilot and Sync Channel processing, the mobile uses the Pilot Channel and Sync Channel to acquire and synchronize to the CDMA system. This is the Mobile Initialization state.

Paging Channel Processing - In the Idle state, the mobile monitors the Paging Channel to receive messages.

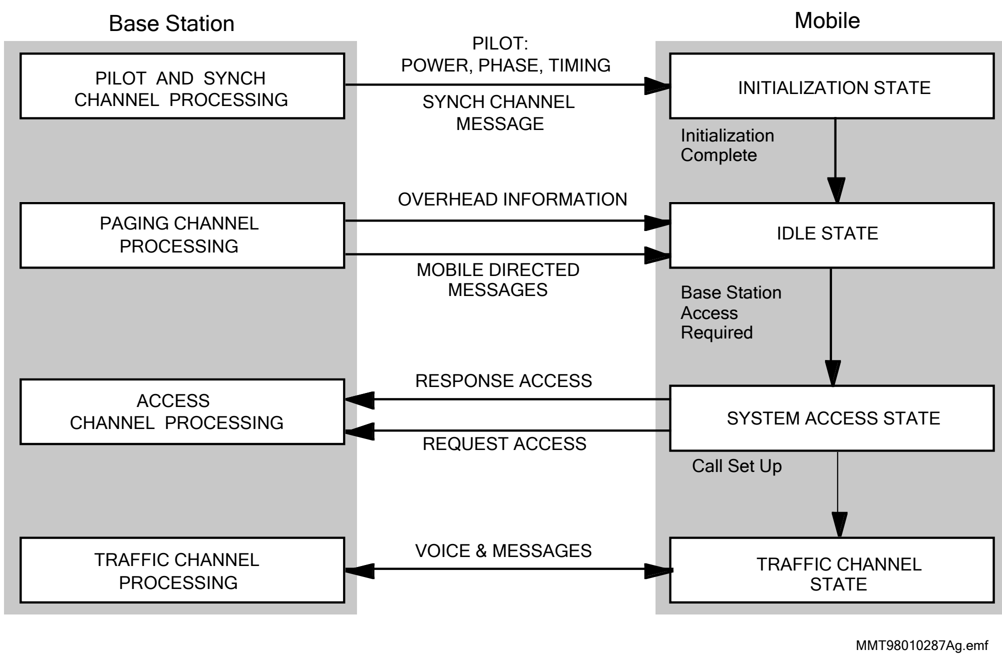
Access Channel Processing - During Access Channel processing, the Base Station monitors the Access Channel to receive messages that the mobile sends while the mobile is in the System Access state. The mobile listens to the Paging Channel for acknowledgments and responses.

Traffic Channel Processing - During Traffic Channel processing, the Base Station uses the Forward and Reverse Traffic Channels to communicate with the mobile while it is in the Mobile Station Control state.

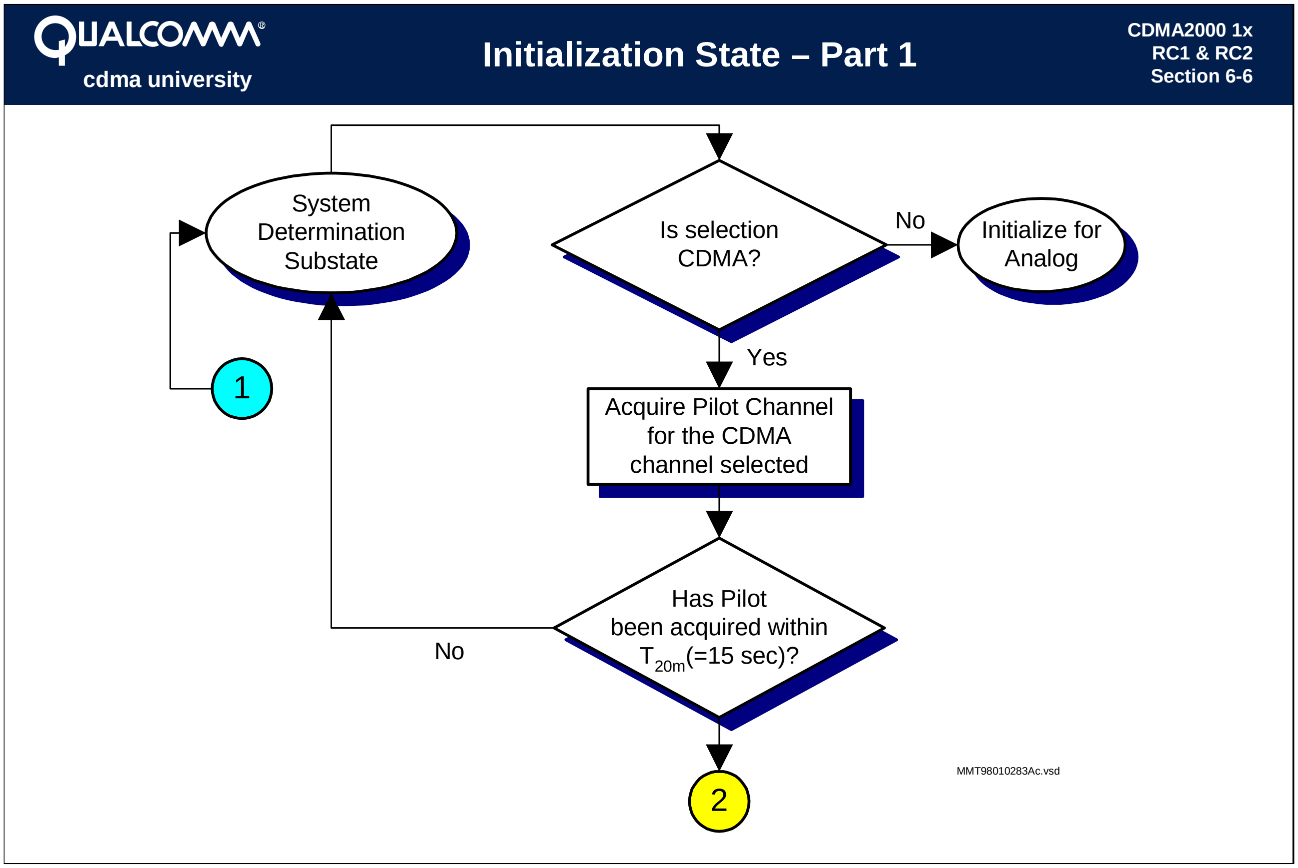
cdma university

Call Processing Overview – Block Diagram of Call Processing

CDMA2000 1x
RC1 & RC2
Section 6-5



Notes

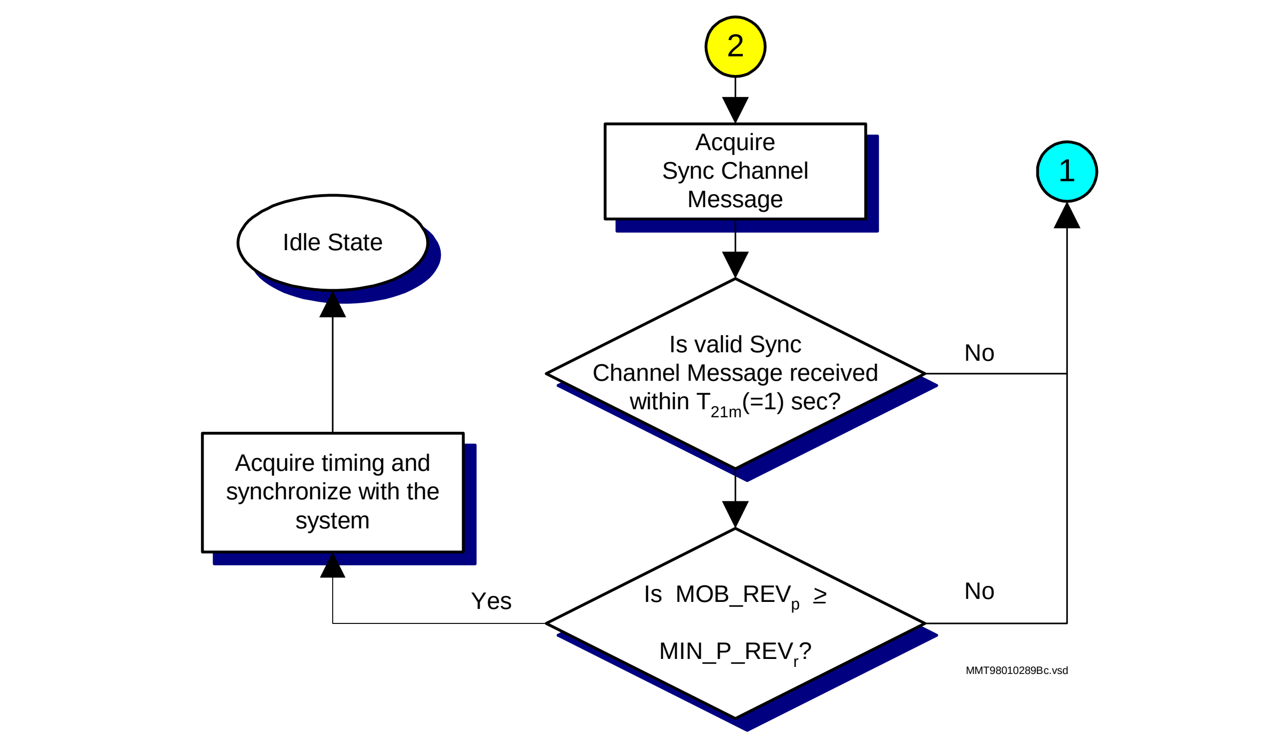

QUALCOMM
cdma university
Initialization State – Part 1
CDMA2000 1x
RC1 & RC2
Section 6-6
System Determination Substate
Is selection CDMA?
No
Initialize for Analog
Yes
1
Acquire Pilot Channel for the CDMA channel selected
Has Pilot been acquired within T20m(=15 sec)?
No
2
MMT98010283Ac.vsd

Notes

cdma university

Initialization State – Part 2

CDMA2000 1x
RC1 & RC2
Section 6-7

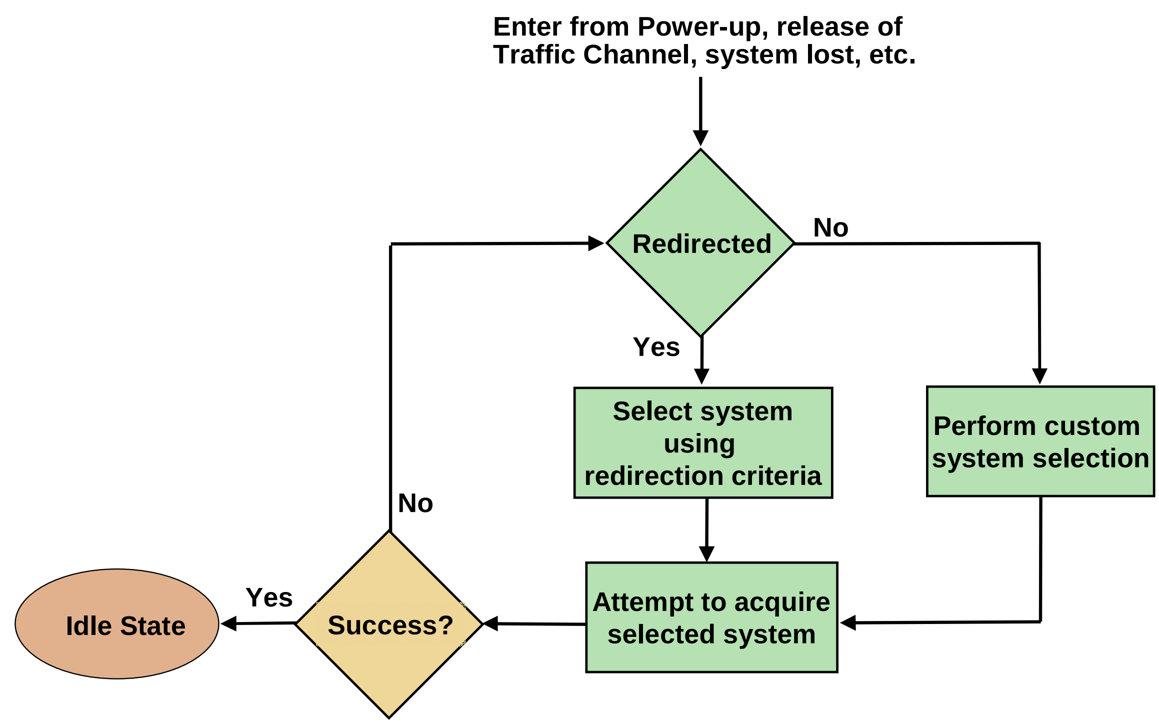


Notes

QUALCOMM cdma university

Initialization State – System Determination

CDMA2000 1x RC1 & RC2 Section 6-8



System Determination

System determination is a process by which the mobile decides what system it will try to obtain service from. Depending on the phone model, this could include decisions such as analog versus digital, cellular versus Personal Communications System (PCS), and A carrier versus B carrier.

System determination may be controlled by a Custom Selection Process. The details of this process are not specified in the standard, but are left to the mobile manufacturer. It is typically influenced by user preferences.

System determination may also be controlled by a service provider using the Redirection Process. This occurs when a mobile acquires a system, but that system sends it a message redirecting it to another system.

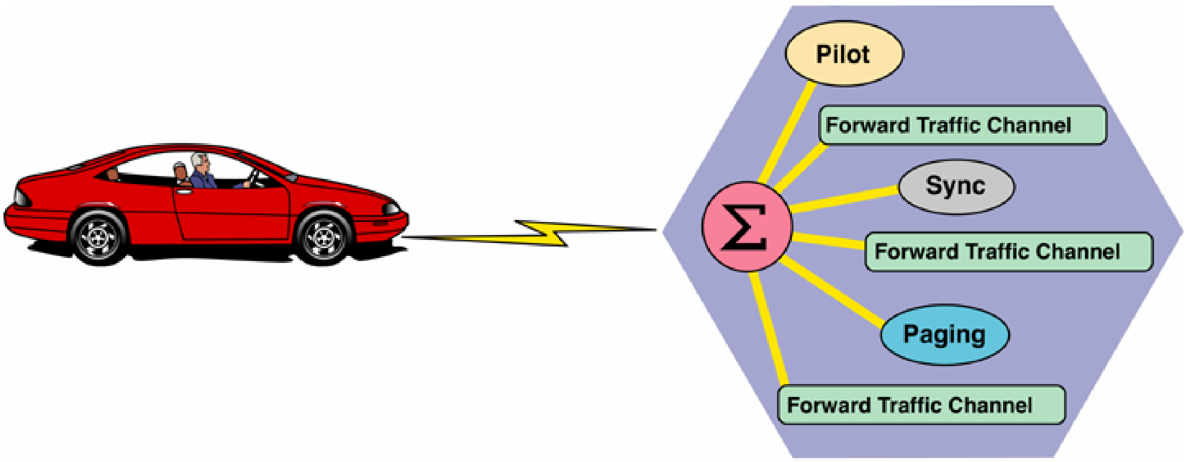
Selection of CDMA Channel

After the mobile selects a system, it must determine on which channel within that system to search for service. For CDMA2000 systems, primary and secondary channels are specified for Spreading Rate 1 in the cellular band, for backward compatibility with CDMAOne systems. A preferred channel list is specified for the PCS band and for Spreading Rate 3 in the cellular band. Selection from this list is manufacturer-dependent.

QUALCOMM cdma university

Initialization State – Pilot Channel Processing

CDMA2000 1x
RC1 & RC2
Section 6-9



680AB_00

Pilot Channel Processing

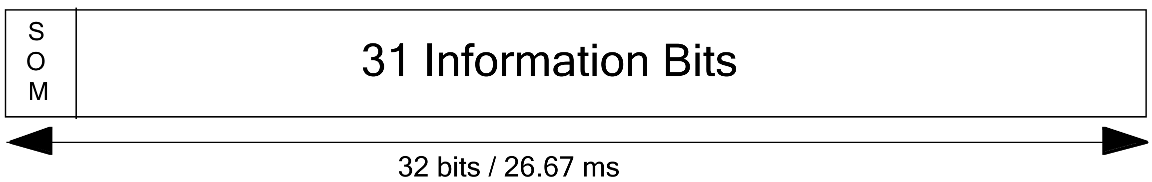
The mobile first gains some idea of system timing by searching for usable Pilot signals. The Pilot has no information, but the mobile can align its own timing by correlating with the Pilot. Once this correlation has been found, the mobile has synchronization with the Synchronization Channel and can read the Sync Channel Message to refine its timing further.

The mobile is permitted to search for up to 15 seconds on a single CDMA channel before it declares failure and returns to System Determination to select either another channel or another system.

It is important to state that the searching process is not standardized. The time to acquire the system depends on the implementation.

In CDMA2000, there may be many Pilot channels on a single CDMA channel (Orthogonal Transmit Diversity [OTD] Pilots, Space Time Spreading [STS] Pilots, auxiliary Pilots, etc.). During system acquisition, the mobile will not find any of these Pilots, because they are on different Walsh codes (the mobile is searching only for Walsh0).

Initialization State – Sync Channel Frame



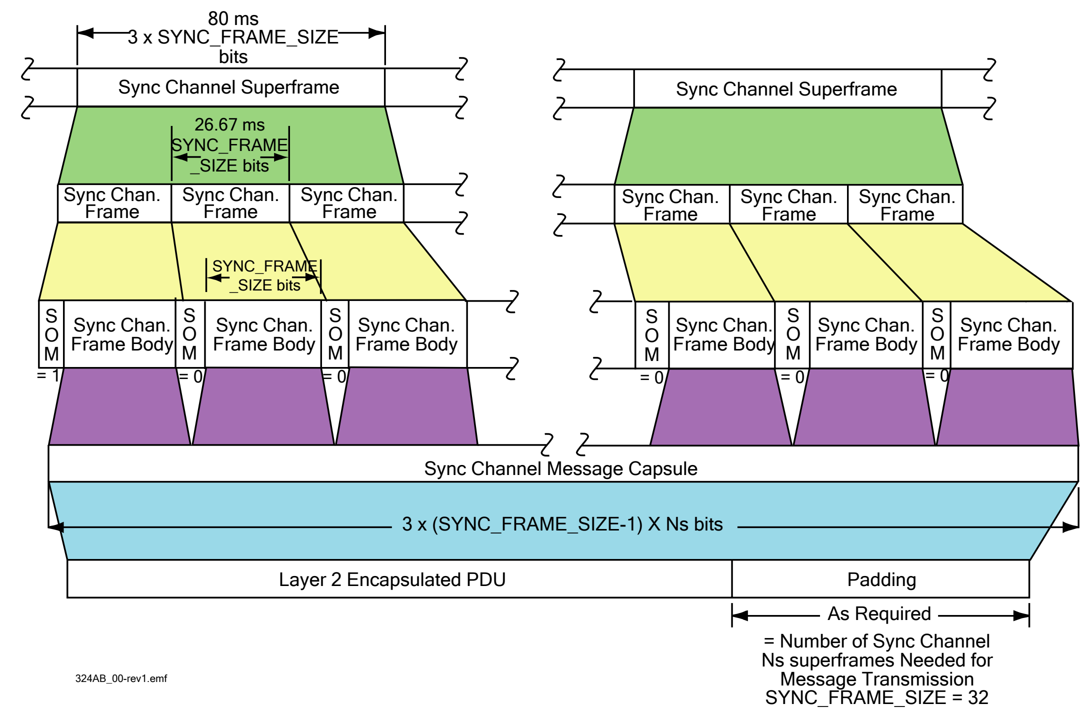
Sync Channel Frame

The Sync Channel is divided into 80 ms superframes. Each superframe is divided into three 26.666... ms frames. The first bit of each frame is a SOM (start of message) Bit, and the remaining bits in the frame comprise the Sync Channel frame body.

QUALCOMM cdma university

Initialization State – Sync Channel (F-SYNCH) Structure

CDMA2000 1x RC1 & RC2 Section 6-11



Sync Channel Characteristics

The structure of the Sync Channel is unchanged from TIA/EIA-95 A/B. Characteristics include:

- 26.67 ms frame duration
- 32 bits per frame
- 80 ms superframe consisting of 3 sync frames
- Start of Message (SOM) bit is the first bit of each frame. The SOM bit is set to 1 to indicate that the frame contains the first bit of a Sync Channel Message, and set to 0 to indicate that the frame contains a continuation of a Sync Channel Message.
- The Sync Channel Message (Layer 2 Encapsulated PDU) may span multiple frames and superframes.
- Message is padded with 0's to fill out the superframe, so that a new message always starts on a superframe boundary.
- The Sync Channel Message for CDMA2000 contains many new fields. New fields appear at the end of the message, so that an older mobile (TIA/EIA-95 A/B compatible) can parse only those fields that it understands.

QUALCOMM cdma university

Initialization State – Sync Channel Message

CDMA2000 1x RC1 & RC2 Section 6-12

Field	Length (bits)
MSG_TYPE (‘00000001’)	8
P_REV	8
MIN_P_REV	8
SID	15
NID	16
PILOT_PN	9
LC_STATE	42
SYS_TIME	36
LP_SEC	8
LTM_OFF	6
DAYLT	1
PRAT	2
CDMA_FREQ	11

MMT98010296Ag.emf

Sync Channel Message

The Sync Channel message is continuously transmitted on the Sync Channel. This message provides the mobile with the information it needs to refine its timing and read the Paging Channel.

MSG_TYPE-Message Type

The Base Station shall set this field to ‘00000001’.

P_REV-Protocol Revision Level

The Base Station shall set this field to ‘‘00000XXX’, according to the maximum P_Rev that the network will support. Legal values are 1 through 5 for TIA/EIA-95.

MIN_P_REV-Minimum Protocol Revision Level

Only mobiles that support revision numbers greater than or equal to this field access the system. The Base Station shall set this field to the minimum protocol revision level that it supports.

QUALCOMM cdma university

Initialization State – Sync Channel Message (continued)

Field	Length (bits)
MSG_TYPE (‘00000001’)	8
P_REV	8
MIN_P_REV	8
SID	15
NID	16
PILOT_PN	9
LC_STATE	42
SYS_TIME	36
LP_SEC	8
LTM_OFF	6
DAYLT	1
PRAT	2
CDMA_FREQ	11

MMT98010296Ag.emf

SID-System Identification

The Base Station shall set this field to the System Identification Number (SID) for this cellular system (see TIA/EIA-95 section 6.6.5.2).

NID-Network Identification

This field serves as a sub-identifier of a system as defined by the owner of the SID. The Base Station shall set this field to the Network Identification Number (NID) for this network (see TIA/EIA-95 section 6.6.5.2)

PILOT_PN-Pilot PN Sequence Offset Index

The Base Station shall set this field to the Pilot PN sequence offset for this Base Station, in units of 64 PN chips.

LC_STATE-Long Code State

The Base Station shall set this field to the long code state at the time given by the SYS_TIME field of this message.

QUALCOMM cdma university

Initialization State – Sync Channel Message (continued)

CDMA2000 1x RC1 & RC2 Section 6-14

Field	Length (bits)
MSG_TYPE ('00000001')	8
P_REV	8
MIN_P_REV	8
SID	15
NID	16
PILOT_PN	9
LC_STATE	42
SYS_TIME	36
LP_SEC	8
LTM_OFF	6
DAYLT	1
PRAT	2
CDMA_FREQ	11

MMT98010296Ag.emf

SYS_TIME-System Time

The Base Station shall set this field to the System Time as of four Sync Channel superframes (320 ms) after the end of the last superframe containing any part of this Sync Channel Message, minus the Pilot PN sequence offset, in units of 80 ms (see TIA/EIA-95 section 1.2).

LP_SEC-Leap Seconds

The number of leap seconds that have occurred since the start of System Time. The Base Station shall set this field to the number of leap seconds that have occurred since the start of System Time, as of the time given by the SYS_TIME field of this message.

LTM_OFF-Offset of Local Time from System Time

The current local time of day is equal to SYS_TIME - LP_SEC + LTM_OFF. The Base Station shall set this field to the two's complement offset of local time from System Time, in units of 30 minutes.

DAYLT-Daylight Savings Time Indicator

If the daylight savings time is in effect, the Base Station shall set this field to '1'. Otherwise, the Base Station shall set this field to '0'.

QUALCOMM cdma university

Initialization State – Sync Channel Message (continued)

CDMA2000 1x RC1 & RC2 Section 6-15

Field	Length (bits)
MSG_TYPE ('00000001')	8
P_REV	8
MIN_P_REV	8
SID	15
NID	16
PILOT_PN	9
LC_STATE	42
SYS_TIME	36
LP_SEC	8
LTM_OFF	6
DAYLT	1
PRAT	2
CDMA_FREQ	11

MMT98010296Ag.emf

PRAT-Paging Channel Data Rate

The Base Station shall set this field to the PRAT field value shown in TIA/EIA-95 Table 7.7.1.3-1 corresponding to the data rate used by the Paging Channels in the system.

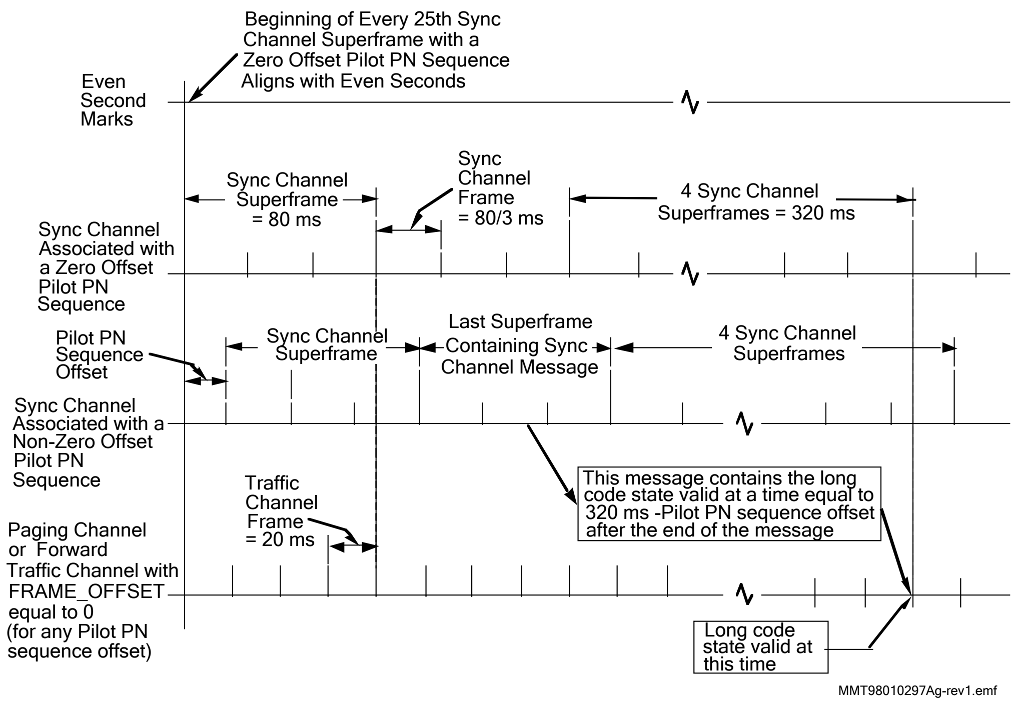
CDMA_FREQ-Frequency Assignment

The Base Station shall set this field to the CDMA Channel Number, in the specific CDMA band class, corresponding to the CDMA frequency assignment for the CDMA Channel containing a Primary Paging Channel.

QUALCOMM cdma university

Initialization State – Sync Channel Timing

CDMA2000 1x RC1 & RC2 Section 6-16



Sync Channel Timing

The Sync Channel frames are always aligned with the Short PN codes. The Paging Channel Frames, however, are always aligned with System Time, as shown. The mobile must shift its timing in order to read the Paging Channel.

QUALCOMM cdma university

Initialization State – Sync Channel Example

CDMA2000 1x RC1 & RC2 Section 6-17

05/05/2000 01:48:27.730 [02] SYNC CAI	
Sync Channel Message	When released from Traffic, we go back to Init
p_rev 3	p_rev=3 is the highest protocol revision
min_p_rev 1	Minimum p_rev this Base Station will talk to is one
sid 99	This is System ID=99
nid 1	Network ID=1
pilot_pn 0x012c = 300 (300)	Listening in Idle mode to PN300
lc_state 35FF5D2FDE5	42 bits of long code state
sys_time 1DDF97888 (05/05/2000 01:48:28.160)	GPS time
lp_sec 13	13 leap seconds since Jan13 1980
ltm_off 0x34 (-6.0 hours)	Local time offset from GPS in Denver is 6 hours
daylt 1	We are using daylight savings time
prat 0	9600 bps Paging Channel
cdma_freq 384	384 has the primary Paging channel

Sync Channel Example

This is an example of a Sync Channel message gathered from a log file in an operating system.

QUALCOMM cdma university

Initialization State – Sync Channel Message for Release 0

CDMA2000 1x RC1 & RC2 Section 6-18

Release 0 adds the following field:

- Extended frequency assignment
- Base Station sets the channel number that has a primary Paging Channel to support RC>2 or the QPCH.

Sync Channel Message for Release 0

For Release 0 the Sync Channel Message gets one additional field, the Extended Frequency Assignment field. This tells the mobile where to find the primary Paging Channel that supports Radio Configurations greater than 2, and the Quick Paging Channel.

This field may be set to the same channel as supports TIA/EIA-95 (RC1 and RC2), or it could be different, depending on how the carrier wants to design their system. If the extended frequency is different than the IS-95 channel, this has the effect of moving all 1x phones to the new extended frequency.

Sync Channel Rel A

In Release A, many new physical channels are available, and 3x spreading may be available. Many new fields are added to the Sync channel message to specify system operation in Release A.

Walsh channels must be specified for many of the new physical channels, and if they use Transmit Diversity then Walsh channels and FEC rates need to be specified.

Parameters for the Broadcast Channel and the Quick Paging Channel need to be specified.

For 3x systems, the Broadcast and Quick Paging parameters need to be specified, and also channel assignments, Pilot powers, and primary Pilots.

QUALCOMM cdma university

Mobile Idle State – Idle State Functions

CDMA2000 1x RC1 & RC2 Section 6-20

Idle State Functions perform the following:

- Paging Channel monitoring
- Message acknowledgment
- Registration procedures
- Idle handoff procedures
- Response to Overhead Information Operation (in response to a System parameters Message, Neighbor List Message, CDMA Channel List Message, Access Parameters Message)
- Mobile Station Page Match Operation
- Mobile Station Order and Message Processing Operation
- Mobile Station Origination Operation
- Mobile Station Message Transmission Operation, if directed by the user to transmit a message
- Mobile Station Power-Down Operation

Idle State Functions

The term *Idle state* is somewhat of a misnomer. The mobile can be very busy in the Idle state.

In general, the mobile is receiving the Paging Channel and processing the messages on that channel. Overhead or configuration messages are compared to the stored sequence numbers to ensure the mobile has the most current parameters. Mobile-directed messages are checked to determine the intended subscriber.

Protocol Revisions

1. IS-95 / J-STD-008
2. IS-95A
3. IS-95A + TSB-74
4. TIA/EIA-95B minimum required features
5. TIA/EIA-95B all required features
6. CDMA2000 Release 0
7. CDMA2000 Release A

Protocol Revisions in the Cellular & PCS Bands

CDMA standards are continually evolving to add new features. Each time the CDMA standards are revised, a new protocol revision number is assigned.

Within the PCS band, the protocol revisions are:

1. IS-95/J-STD-008

4. IS-95B minimum required features

5. IS-95B all required features

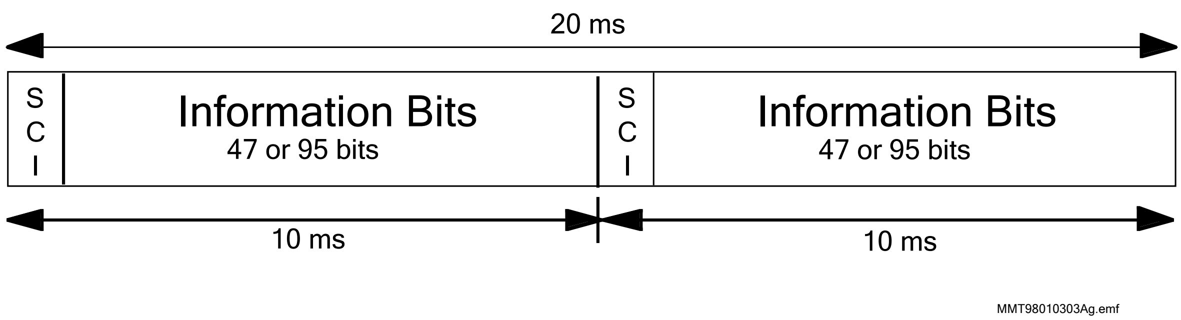
6. CDMA2000 Release 0

7. CDMA2000 Release A

QUALCOMM cdma university

Mobile Idle State – Paging Channel Frames

CDMA2000 1x RC1 & RC2 Section 6-22



Paging Channel Frames

Each 80 ms slot is composed of four Paging Channel frames, each 20 ms in length. A 20-ms-long Paging Channel frame is divided into 10-ms-long Paging Channel half frames. The first bit in any Paging Channel half frame is an SCI (Synchronized Capsule Indicator) Bit.

Mobile Idle State – Paging Channel Overhead Messages

- System Parameters Message
- Extended System Parameters Message
- Access Parameters Message
- Neighbors List Message
- Extended Neighbors List Message
- CDMA Channel List Message
- Global Service Redirection Message

Paging Channel Overhead Messages

For P_rev of 6 or less, Overhead Messages are transmitted on the Paging Channel. The mobile uses the information in these messages to configure itself for proper operation in the serving system.

Cellular and PCS systems have slightly different configuration messages.

QUALCOMM cdma university

Mobile Idle State – CDMA2000 Overhead Messages

CDMA2000 1x RC1 & RC2 Section 6-24

New Overhead Messages on F-PCH and F-BCCH:

- User Zone Identification Message
- Private Neighbor List Message
- Extended Global Service Redirection Message
- Extended CDMA Channel List Message

CDMA2000 Overhead Messages

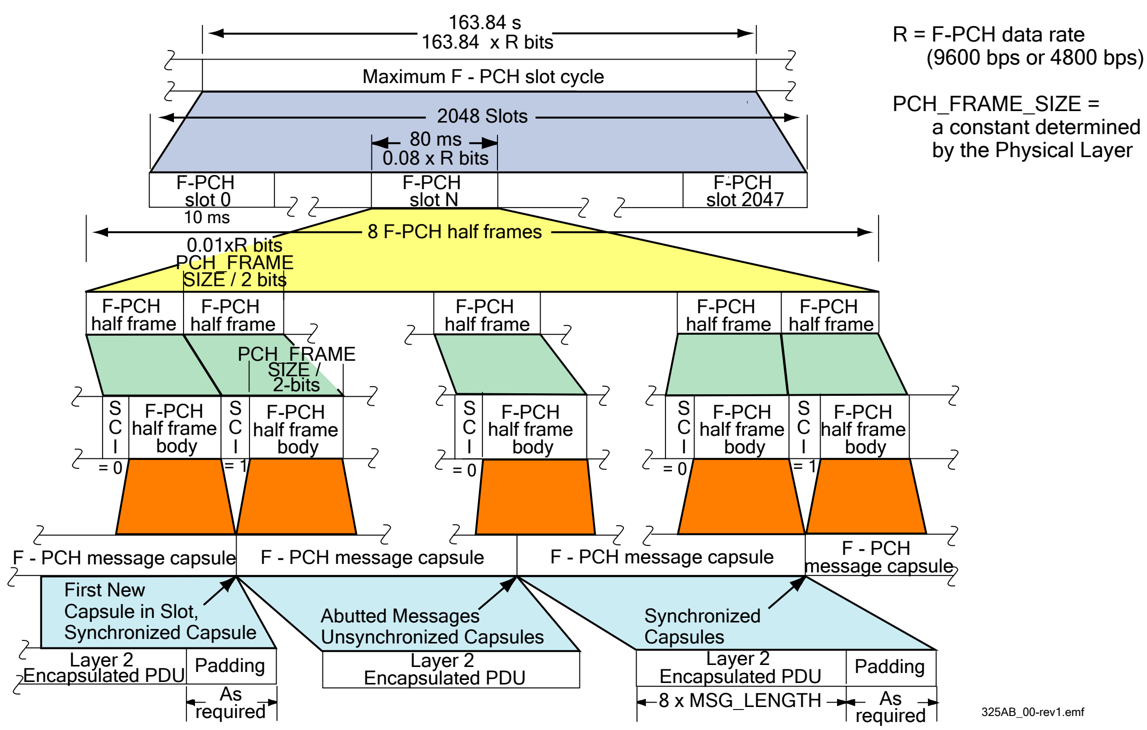
For P_rev=6 and P_rev=7 systems, new overhead messages have been defined in CDMA2000 that may be transmitted on the Paging Channel and the Broadcast Control Channel.

- The *User Zone Identification Message* and *Private Neighbor List Message* are used to support CDMA tiered services, which will be discussed later in this section.
- The *Extended Global Service Redirection Message* serves the same purpose as the Global Service Redirection Message, which is to redirect mobiles to another system. The extended form of the message includes the ability to redirect a mobile as a function of its protocol revision.
- The *Extended CDMA Channel List Message* serves the same purpose as the CDMA Channel List Message, which is to provide mobiles with the list of CDMA channels used by the system. The extended form of the message includes information about the availability of Quick Paging Channels, and whether transmit diversity is supported on the available CDMA channels.

cdma university

Mobile Idle State – Paging Channel Structure

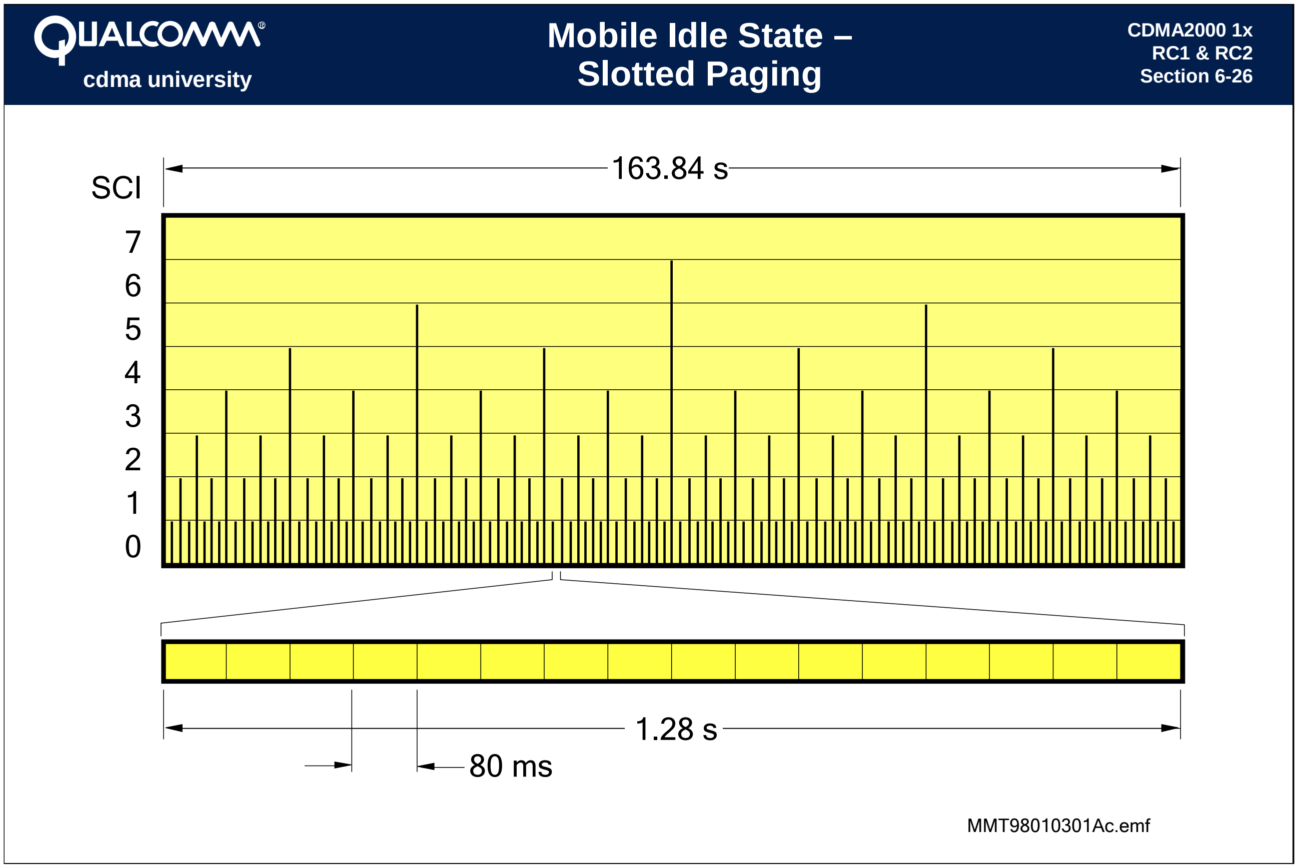
CDMA2000 1x RC1 & RC2 Section 6-25



Paging Channel Structure

The structure of the Paging Channel (F-PCH) is unchanged from TIA/EIA-95 A/B. Characteristics include:

- 9600 bps or 4800 bps data rate.
- Each frame is divided into two half frames.
- 80 ms slots containing eight half frames.
- 2048 slots constitute a maximum slot cycle (163.84 seconds).
- Synchronized Capsule Indicator (SCI) bit is the first bit of every half frame. The SCI bit is set to 1 to indicate that the frame contains the first bit of a Paging Channel Message, and set to 0 to indicate that the frame contains a continuation of a Paging Channel Message. Paging Channel Messages are not required to start on half frame boundaries, except for the first new message in a paging channel slot.
- A Paging Channel Message (Layer 2 Encapsulated PDU) may span multiple frames and half frames.
- A message is padded with 0’s only when the next message will be transmitted on a half frame boundary (with SCI = 1).
- All of the TIA/EIA-95 A/B compatible messages are transmitted on the Paging Channel, along with some new messages defined in CDMA2000.



Slotted Paging

The main purpose of slotted paging is to conserve battery power in mobiles. Both the mobile and the Base Station can agree on which slots the mobile will be paged in. The mobile can power down some of its processing circuitry during unassigned slots.

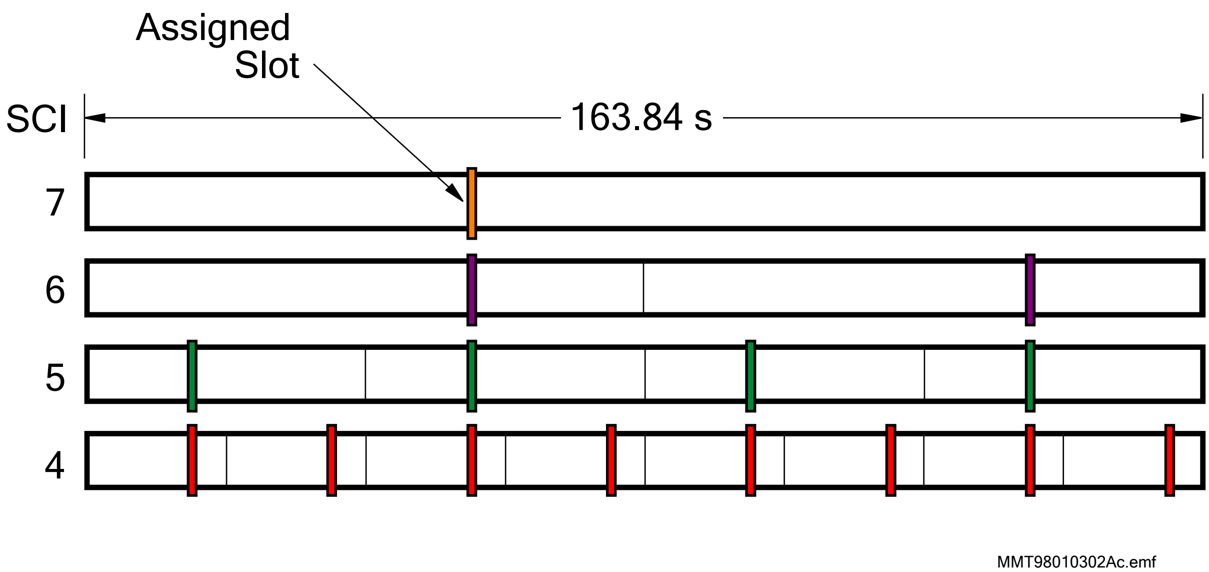
The Slot Time is a function of the Slot Cycle Index (SCI), which can take on the values of 0 through 7.

The Slot Time is equal to 1.28 seconds * $2^{\wedge SCI}$

cdma university

Mobile Idle State – Paging Slot Determination

CDMA2000 1x
RC1 & RC2
Section 6-27



Paging Slot Determination

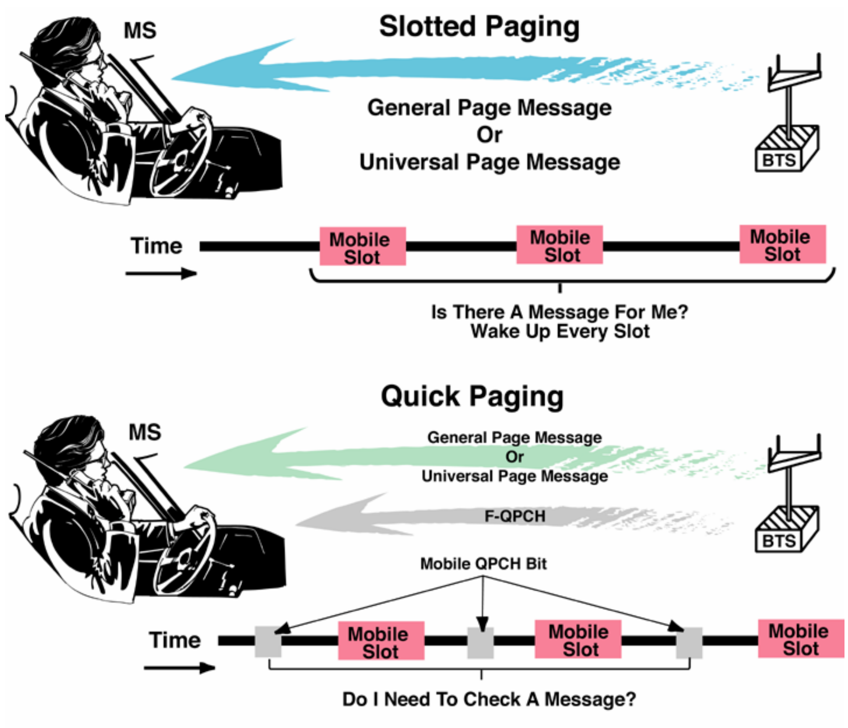
To determine the assigned Paging Channel slots for a mobile with a given slot cycle index, the Base Station shall select a number PGSLOT using a hash function with the following inputs:

1. Mobile's MIN.
2. Maximum number of Paging Channel slots (2048).

QUALCOMM cdma university

Mobile Idle State – Slotted and Quick Paging

CDMA2000 1x RC1 & RC2 Section 6-28



073AC_00

Slotted Paging and Quick Paging

The CDMA2000 technology supports slotted paging using a Slot Cycle Index (SCI) on the Paging Channel and on the F-CCCH. On the F-CCCH, either the General Page Message or the Universal Page Message may be used to page the mobile.

The CDMA2000 technology (P_Rev 6 or higher) also supports a Quick Paging Channel that allows the mobile to power up for a shorter period of time than is possible using only slotted paging on the F-PCH or F-CCCH.

Mobile Idle State – System Parameters Message

Field	Length (bits)
MSG_TYPE ('00000001')	8
PILOT_PN	9
CONFIG_MSG_SEQ	6
SID	15
NID	16
REG_ZONE	12
TOTAL_ZONES	3
ZONE_TIMER	3
MULT_SIDS	1
MULT_NIDS	1
BASE_ID	16
BASE_CLASS	4
PAGE_CHAN	3
MAX_SLOT_CYCLE_INDEX	3
HOME_REG	1
FOR_SID_REG	1
FOR_NID_REG	1
POWER_UP_REG	1
POWER_DOWN_REG	1
PARAMETER_REG	1
REG_PRD	7
BASE_LAT	22
BASE_LONG	23
REG_DIST	11
SRCH_WIN_A	4

Field	Length (bits)
SRCH_WIN_N	4
SRCH_WIN_R	4
NGHBR_MAX_AGE	4
PWR_REP_THRESH	5
PWR_REP_FRAMES	4
PWR_THRESH_ENABLE	1
PWR_PERIOD_ENABLE	1
PWR_REP_DELAY	5
RESCAN	1
T_ADD	6
T_DROP	6
T_COMP	4
T_TDROP	4
EXT_SYS_PARAMETER	1
EXT_NGHBR_LIST	1
GLOBAL_REDIRECT	1
RESERVED	1

MMT98010305Ag.emf

System Parameters Message

The System Parameters Message is an overhead message used to communicate general system parameters to the mobile.

The Pilot_PN field indicates which sector this message is coming from.

SID and NID indicate the System and Network ID numbers.

Registration is controlled by the Reg-Zone, Total_Zones, Zone_Timer, Mult_SIDS, Mult_NIDS, Home_Reg, For_SID_Reg, For_NID_Reg, Power_Up_Reg, Power_Down, Reg, Parameter_Reg, Reg_Prd, and Reg_Dist fields.

Mobile searching is controlled by specifying the search window size for Active, Neighbor and Remainder sets by using the Srch_Win_A, Srch_Win_N, and Srch_Win_R fields.

Forward power control is controlled by the Pwr_Rep_Thresh, Pwr_Rep_Frames, Pwr_Thresh_Enable, Pwr_Period_Enable, and Pwr_Rep_Delay fields.

Soft handoff parameters are specified by T_Add, T_Drop, T_Comp and the drop timer parameter, T_Tdrop.

The last three fields tell the mobile if an Extended Systems Parameter Message, Extended Neighbor List, or General Redirection Message can be expected on this Paging Channel.

QUALCOMM cdma university

Mobile Idle State – System Parameters Example

CDMA2000 1x RC1 & RC2 Section 6-30

05/05/2000 01:47:21.503 [06] PAGING CAI
System Parameter Message

pilot_pn 0x0158 = 344 (344)	System message from PN344
config_msg_seq 1	Message sequence 1
sid 58, nid 1	System ID=58 (Verizon) NID=1
reg_zone 4, total_zones 0, zone_timer 0	We are in Registration zone 4, don't remember any old zones
mult_sids 0, mult_nids 0	Don't remember multiple SIDs or NIDs
base_id 3243	Hex BTS number 3243
base_class 0	800Mhz Cellular band
page_chan 1	There is 1 paging channel
max_slot_cycle_index 0	Please use a SCI of 0
home_reg 1	Register if this is your home network
for_sid_reg 1	Register if this is a foreign SID
for_nid_reg 1	Register if this is a foreign NID
power_up_reg 1	Register on Power up
power_down_reg 0	Don't Register when you power down
parameter_reg 1	Register when system parameters change
reg_prd 54 (926.82 sec = 15 min 27 sec)	Register Periodically every 15 minutes
base_lat 575892, base_lon -1514224 39ø59'33.00"N x 105ø9'16.00"W	
reg_dist 0	Don't Register based on distance
srch_win_a 6, srch_win_n 13, srch_win_r 13	Active search window of 28 chips, Neighbor and Remainder of 226
nghbr_max_age 0	Don't remember old neighbors
pwr_rep_thresh 2 erasures in pwr_rep_frames 0x9 (113 frames), Enabled	Measure forward FER over 113 frames
pwr_period_enable 0	Don't report FER periodically
pwr_rep_delay 1 (4 frames)	If you complain about FER, wait 4 frames to start counting
rescan 0	Don't re-initialize and re-acquire
t_add 28, t_drop 32, t_comp 8, t_tdrop 2	t_add of –14 dB, t_drop of –16 dB, t_comp of 4 dB, drop timer of 2 sec
Ext Sys-Param:1, Ext Nghbr List:0, Gen Nghbr List:0, Gbl Redir:1	Expect Ext Sys Param and Glb redirection on paging ch

System Parameters Example

This is an example of a real System Parameters Message, obtained from a log file on an operational system.

Mobile Idle State – Extended System Parameters Message

The Extended System Parameters Message adds the following parameters:

- Dynamic Soft Handoff
- Packet Zone ID
- Candidate Frequency Search
- Access Handoff Parameters

Extended System Parameters Message

The Extended System Parameters Message contains information to control the following:

- **Dynamic Soft Handoff** – Several new parameters to make the Add and Drop thresholds for soft handoff to be a function of the received Ec/Io and total Pilot strength. This is used to reduce the percentage of soft handoff.
- **Packet Zone ID** – Used by the Mobile to indicate when Packet Data services are available.
- **Candidate Frequency Search Parameters** – To control the mobile when it goes off the serving frequency to search for viable Pilot signals on a new frequency.
- **Access Handoff Parameters** – Many new parameters are required to control Access Entry Handoff, Access Probe Handoff, and Access Handoff.

QUALCOMM cdma university

Mobile Idle State – Access Parameters Message

CDMA2000 1x RC1 & RC2 Section 6-32

Field	Length (bits)
MSG_TYPE('00000010')	8
PILOT_PN	9
ACC_MSG_SEQ	6
ACC_CHAN	5
NOM_PWR	4
INIT_PWR	5
PWR_STEP	3
NUM_STEP	4
MAX_CAP_SZ	3
PAM_SZ	4
PSIST(0-9)	6
PSIST(10)	3
PSIST(11)	3
PSIST(12)	3
PSIST(13)	3
PSIST(14)	3
PSIST(15)	3
MSG_PSIST	3
REG_PSIST	3
PROBE_PN_RAN	4
ACC_TMO	4
PROBE_BKOFF	4
BKOFF	4

Field	Length (bits)
MAX_REQ_SEQ	4
MAX_RSP_SEQ	4
AUTH	2
RAND	0 or 32
NOM_PWR_EXT	1
RESERVED	6

MMT98010307Ag.emf

The **Access Parameters Message** contains the information required by the Mobile to use the Access Channel.

- Pilot_PN indicates the sector sending this message.
- Nom_Pwr, Init_Pwr and Pwr_Step indicate the Base Station Pilot level, the initial power to use for the first probe relative to the Open Loop Estimate, and the power increase for each successive Access Probe.
- Max_Cap_Sz and Pam_Sz indicate the length of the Access Preamble and the number of frames in the message.
- The PSIST parameters are the Persistence values to control the use of the Access channel by the various groups.
- Probe_PN_Ran is a parameter to control the time randomization for the Access Probe.
- Acc_Tmo is how long the mobile waits for a response from an Access probe before sending the next probe.
- Probe_Bkoff is the number of slots the mobile should delay between consecutive Access Probes.
- Bkoff is the number of slots to delay between Access sequences.
- Max_Req_Seq and Max_Rsp_Seq are the number of probe sequences for requests and responses.
- Auth indicates if the mobile is to perform Authentication, using the value Rand.
- Nom_Pwr_Ext offsets the open loop estimate for pico cell operation.

QUALCOMM cdma university

Mobile Idle State – Access Parameters Example

CDMA2000 1x RC1 & RC2 Section 6-33

05/05/2000 01:47:21.203 [03] PAGING CAI

Access Parameters Message

pilot_pn 0x0158 = 344 (344)	From Sector PN Offset = 344 (*64) chips
acc_msg_seq 1	Message sequence number is 1
acc_chan 0	# of Access Channels is 1 more than this number
nom_pwr 3, (nom_pwr_ext=0)	This cell is 3dB louder Pilot than the normal assumption
init_pwr –3	Start Access Probes 3 dB below the Open Loop estimate
pwr_step 5	Use 5dB steps on Access Probes
num_step 3	Access Probes can have up to 4 steps
max_cap_sz 3	Max Access frames is 3+2
pam_sz 3	3 frames of preamble on the Access probe
psist_0_9:0, 10:0, 11:0, 12:0, 13:0, 14:0, 15:0	Don't use persistence test
msg_psist 0	No message persistence test
reg_psist 0	No registration persistence test
probe_pn_ran 0	Don't bother to add random delay PN chips to probe
acc_tmo 1	Access timeout is 2+1 = 3 80 ms wait units
probe_bkoff 0	Don't bother to do backoff timing on probes
bkoff 0	No backoff between sequences
max_req_seq 3, max_rsp_seq 3	Max of 3 Access sequences for request or response
auth 0	No authentication

Notes

QUALCOMM cdma university

Mobile Idle State – Neighbor List Message

CDMA2000 1x RC1 & RC2 Section 6-34

Field	Length (bits)
MSG_TYPE ;('00000011')	8
PILOT_PN	9
CONFIG_MSG_SEQ	6
PILOT_INC	4

Zero or more occurrences of the following record:

NGHBR_CONFIG	3
NGHBR_PN	9

RESERVED	0 - 7 (as needed)

MMT98010308Ag.emf

Neighbor List Message

The Neighbor List Message is sent by a sector:

- Pilot_PN identifies the sector that sent the message.
- Pilot _Inc indicates the PN spacing between neighbors.
- The Neighbor List includes the neighbors of this sector and how they are configured. The configuration information informs the mobile if the neighbors have the same frequency channels available, if the Neighbors have a Paging Channel on the current frequency assignment, or if the configuration is unknown.

Mobile Idle State – Neighbor List Example


```
05/05/2000 01:47:21.443 [06] PAGING CAI
  Neighbor List Message
    pilot_pn 0x0158 =  344 (  344 )
    config_msg_seq 1
    pilot_inc 4
    num_nghbrs 20
     nghbr_config 0, pn 0x0018 =   24 (   24 )
     nghbr_config 0, pn 0x00b8 =  184 (  184 )
     nghbr_config 0, pn 0x016c =  364 (  364 )
     nghbr_config 0, pn 0x00cc =  204 (  204 )
     nghbr_config 0, pn 0x012c =  300 (  300 )
     nghbr_config 0, pn 0x0198 =  408 (  408 )
     nghbr_config 0, pn 0x01a8 =  424 (  424 )
     nghbr_config 0, pn 0x0108 =  264 (  264 )
     nghbr_config 0, pn 0x018c =  396 (  396 )
     nghbr_config 0, pn 0x0040 =   64 (   64 )
     nghbr_config 0, pn 0x0058 =   88 (   88 )
     nghbr_config 0, pn 0x0180 =  384 (  384 )
     nghbr_config 0, pn 0x01cc =  460 (  460 )
     nghbr_config 0, pn 0x01c4 =  452 (  452 )
     nghbr_config 0, pn 0x0148 =  328 (  328 )
     nghbr_config 0, pn 0x002c =   44 (   44 )
     nghbr_config 0, pn 0x0060 =   96 (   96 )
     nghbr_config 0, pn 0x01b0 =  432 (  432 )
     nghbr_config 0, pn 0x00ec =  236 (  236 )
     nghbr_config 0, pn 0x01ec =  492 (  492 )
```

These are the PN offsets of the neighbors of PN344
They are all modulo 4
All Neighbors have the same Freq and Paging as PN344

Neighbor List Example

The Neighbor List Message contains the Pilot Increment, the number of Neighbors, the configuration of each Neighbor, and the Neighbors of this sector.

QUALCOMM cdma university

Mobile Idle State – Extended Neighbor List

CDMA2000 1x RC1 & RC2 Section 6-36

Field	Length (bits)
MSG_TYPE ('00001110')	8
PILOT_PN	9
CONFIG_MSG_SEQ	6
PILOT_INC	4

Zero or more occurrences of the following record:

Field	Length (bits)
NGHBR_CONFIG	3
NGHBR_PN	9
SEARCH_PRIORITY	2
FREQ_INCL	1
NGHBR_BAND	0 or 5
NGHBR_FREQ	0 or 11

RESERVED	0 - 7 (as needed)

MMT98010309Ag.emf

Extended Neighbor List

The Extended Neighbor List allows for neighbors that are on different frequencies and different bands, and contains a Search Priority field.

QUALCOMM cdma university

Mobile Idle State – CDMA Channel List Message

CDMA2000 1x RC1 & RC2 Section 6-37

Field	Length (bits)
MSG_TYPE (‘00000100’)	8
PILOT_PN	9
CONFIG_MSG_SEQ	6

One or more occurrences of the following field:

CDMA_FREQ	11

RESERVED	0 - 7 (as needed)

MMT98010310Ag.emf

CDMA Channel List Message

The CDMA Channel List Message contains a list of frequencies that contain a valid Paging Channel. The Mobile performs a hash to determine which Paging Channel to monitor.

Mobile Idle State – Channel List Example

05/05/2000 01:47:21.206 [03] PAGING CAI

Channel List Message

pilot_pn 0x0158 = 344 (344)

config_msg_seq 1

num_channels 1 **There is one channel with a Paging Channel in this system**

Channel 384

Notes

QUALCOMM cdma university

Mobile Idle State – Paging Channel Messages

CDMA2000 1x RC1 & RC2 Section 6-39

Message Name	Message Type (binary)
System Parameters Message	00000001
Access Parameters Message	00000010
Reserved for obsolete Neighbor List Message	00000011
CDMA Channel List Message	00000100
Reserved for Obsolete Slotted Page Message	00000101
Reserved for Obsolete Page Message	00000110
Order Message	00000111
Channel Assignment Message	00001000
Data Burst Message	00001001
Authentication Challenge Message	00001010
SSD Update Message	00001011
Feature Notification Message	00001100
Extended System Parameters Message	00001101
Extended Neighbor List Message	00001110
Status Request Message	00001111
Service Redirection Message	00010000
General Page Message	00010001
Global Service Redirection message	00010010
TMSI Assignment Message	00010011
Null Message	--

MMT98010312Ag.emf

Paging Channel Messages

In addition to the overhead messages, the Base Station also sends messages on the Paging Channel directed to a particular mobile. The figure lists all of the messages that can be sent on the Paging Channel.

QUALCOMM cdma university

Mobile Idle State – Channel Assignment Message

CDMA2000 1x RC1 & RC2 Section 6-40

Field	Length (bits)
MSG_TYPE ('00001 000')	8

One or more occurrences of the following record:

ACK_SEQ	3
MSG_SEQ	3
ACK_REQ	1
VALID_ACK	1
ADDR_TYPE	3
ADDR_LEN	4
ADDRESS	8 ´ ADDR_LEN
ASSIGN_MODE	3
ADD_RECORD_LEN	3

If ASSIGN_MODE = '010', the record also includes the following fields:

RESPOND	1
ANALOG_SYS	1
RESERVED	6

If ASSIGN_MODE = '011', the record also includes the following fields:

SID	15
VMAC	3
ANALOG_CHAN	11
SCC	2
MEM	1
AN_CHAN_TYPE	2
DSCC_MSB	1
RESERVED	5

If ASSIGN_MODE = '100', the record also includes the following fields:

FREQ_INCL	1
RESERVED	7
GRANTED_MODE	2
CODE_CHAN	8
FRAME_OFFSET	4
ENCRYPT_MODE	2
BAND_CLASS	0 or 5
CDMA_FREQ	0 or 11

If ASSIGN_MODE = '101', the record also includes the following fields:

RESPOND	1
FREQ_INCL	1
BAND_CLASS	0 or 5
CDMA_FREQ	0 or 11

One or more occurrences of the following field:

PILOT_PN	9

RESERVED	0 - 7 (as needed to make the record an integer number of octets)

RESERVED	0 - 7 (as needed to make the message an integer number of octets)

MMT98010313Ag.emf

Channel Assignment Message

A Channel Assignment Message is an example of a mobile-directed message. The message contains fields that identify the intended mobile. The Channel Assignment Message can be used for many purposes. The intent of the message is conveyed in the field called *Assignment Mode* (ASSIGN_MODE).

QUALCOMM cdma university

Traffic Channel State – ASSIGN_MODE Variations

Channel Assignment Message

Value (binary)	Assignment Mode	IS-95A	J-008	TIA/EIA/95-B	CDMA2000
000	Traffic Channel Assignment (Band Class 0 only)	Yes	No	Yes	Yes
001	Paging Channel Assignment (Band Class 0 only)	Yes	No	Yes	Yes
010	Acquire Analog System	Yes	Yes	Yes	Yes
011	Analog Voice Channel Assignment	Yes	Yes	Yes	Yes
100	**Extended** Traffic Channel Assignment	No	Yes	Yes	Yes
101	**Extended** Paging Channel Assignment	No	Yes	Yes	Yes

Extended Channel Assignment Message

Value (binary)	Assignment Mode	TIA/EIA/95-B	CDMA2000
000	Traffic Channel Assignment	Yes	Yes
001	Paging Channel Assignment	Yes	Yes
010	Acquire Analog System	Yes	Yes
011	Analog Voice Channel Assignment	Yes	Yes
100	**Enhanced** Traffic Channel Assignment	No	Yes

ASSIGN_MODE Variations

The Channel Assignment Message and the Extended Channel Assignment Message each contain a field called ASSIGN_MODE. The value of this field then determines the format and contents of remaining fields of the message. As the CDMA standards have evolved and new features have been required, the ASSIGN_MODE field takes on new values to represent those changes.

In CDMA2000, some new fields have been added to all variations of this message that pertain to Traffic Channel assignment. For the Channel Assignment Message, fields have been added to both the basic and extended Traffic Channel assignment to specify signaling encryption.

The Extended Channel Assignment Message is used whenever other new CDMA2000 features are required, such as:

- Radio Configuration greater than 2
- Dedicated Control Channel (F/R-DCCH)
- New Forward link power control mechanisms
- 3x Forward link used with 1x Reverse link
- Auxiliary or transmit diversity Pilots

QUALCOMM cdma university

Mobile Idle State – Assignment Example

CDMA2000 1x RC1 & RC2 Section 6-42

05/05/2000 01:47:22.492 [21] PAGING CAI

Channel Assignment Message

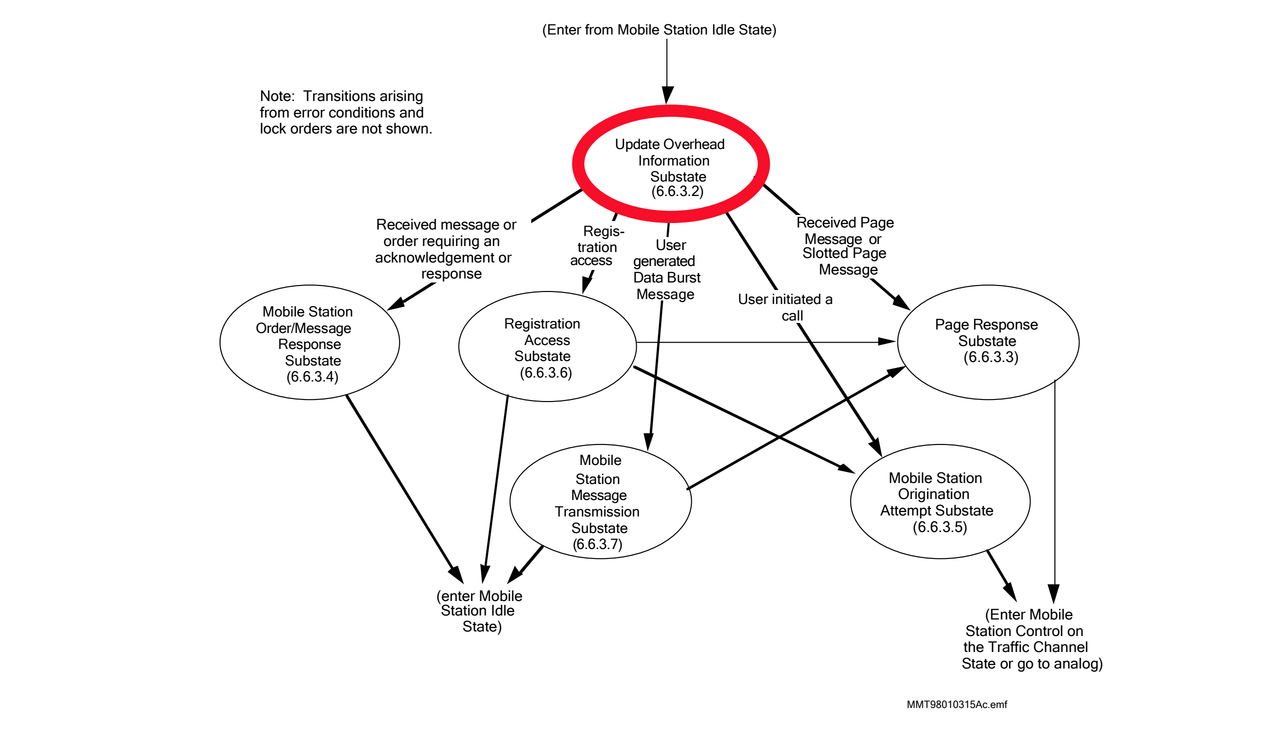
num_assigns 1	Traffic Channel Assignment for the phone
ack_seq 0, msg_seq 1, ack_req 0, valid_ack 1	
imsi {0,0} imsi_s=124d12a7c=(303) 555-0747	
assign_mode 4, Extended CDMA Traffic Channel Assignment	
freq_incl 1	RF frequency is included in this message
granted_mode 2, Svc Connect at default rate-set for service option	Connect with Rate Set 2
code_chan 28	Use Walsh 28
frame_offset 0	Zero frame offset
encrypt_mode 0	No encryption
band_class 0	Cellular band
cdma_freq 384	Ch 384

Notes

QUALCOMM cdma university

Mobile System Access State – Flow Diagram

CDMA2000 1x RC1 & RC2 Section 6-43

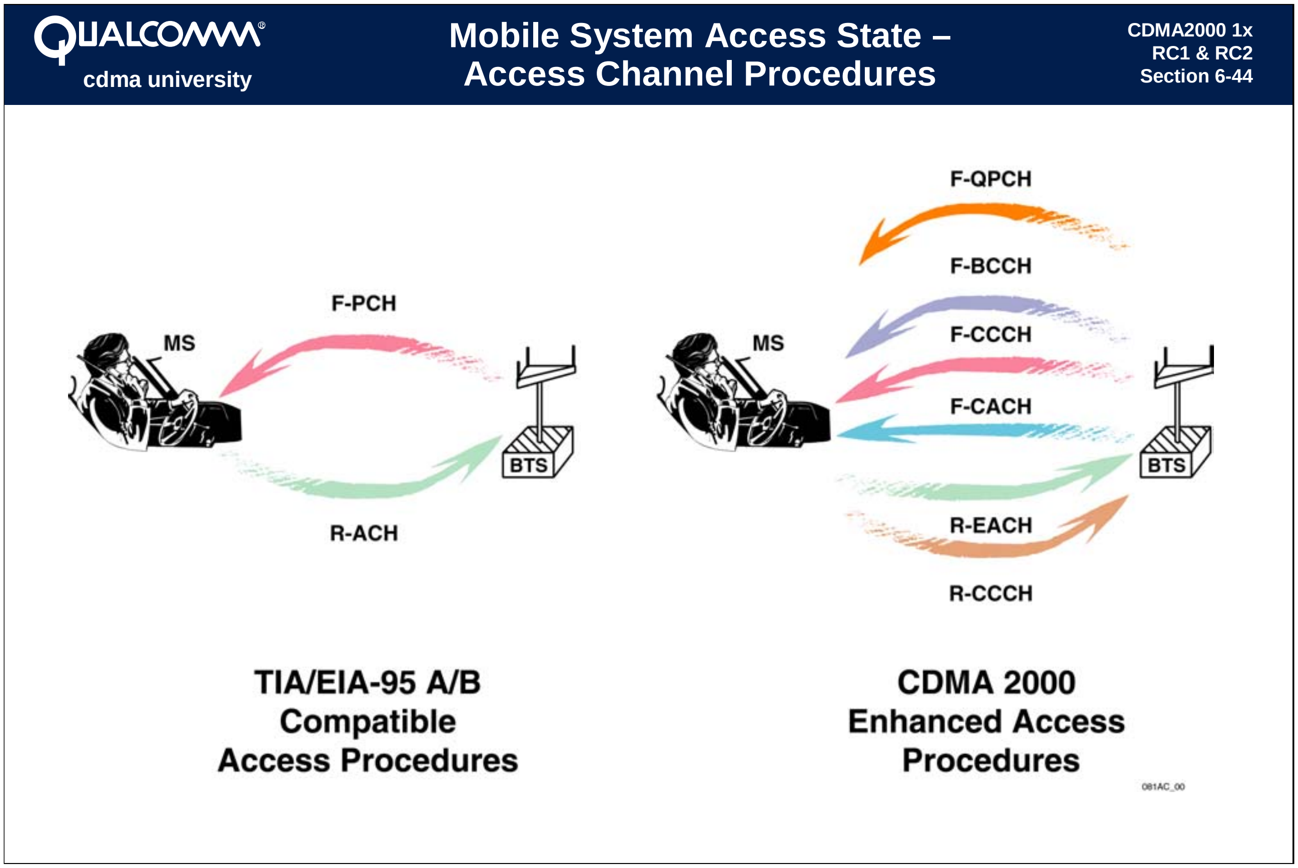


System Access State Flow

The figure illustrates the Access State flow diagram. It is important to note that the first step in the Access process is to update overhead information.

Mobiles will randomly select an Access Channel and transmit without coordination with the Base Station or other mobiles. This kind of random access procedure can result in collisions. Several steps can be taken to reduce the likelihood of collision:

- Use a slotted structure.
- Evenly distribute the mobiles across the slots.
- Use multiple Access Channels.
- Transmit at random start times.
- Employ congestion control (e.g., overload classes).



Access Channel Procedures

TIA/EIA-95 A/B Compatible Access Channel Procedures

If the mobile monitors the Paging Channel (F-PCH), then its Access attempts are made on the Access Channel (R-ACH). These procedures are identical to TIA/EIA-95 A/B Access procedures. P_rev of 6 or less use the Paging and Access Channel.

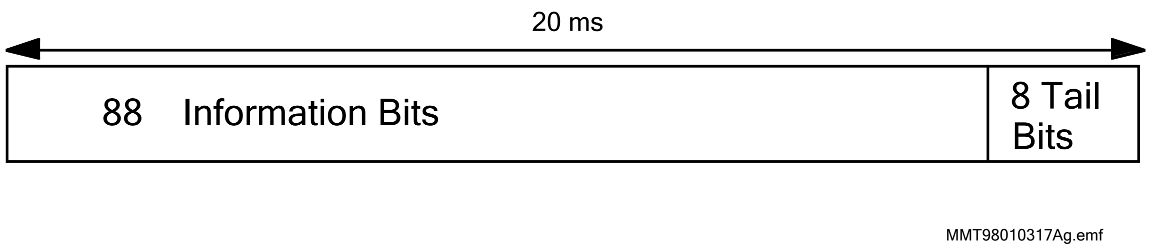
CDMA2000 Enhanced Access Channel Procedures

If the mobile monitors the Forward Common Control Channel (F-CCCH) and Broadcast Control Channel (F-BCCH), then its Access attempts are made on the Enhanced Access Channel (R-EACH) using the CDMA2000 enhanced Access procedure. P_rev of 7 or greater use the enhanced Access procedures.

cdma university

Mobile System Access State – Access Channel Frames

CDMA2000 1x RC1 & RC2 Section 6-45



Access Channel Frames

The Access Channel is formatted in a slotted structure. The length of the slot is configurable. Slots are accessed at random by the mobiles. It is not efficient to reserve a channel or a slot.

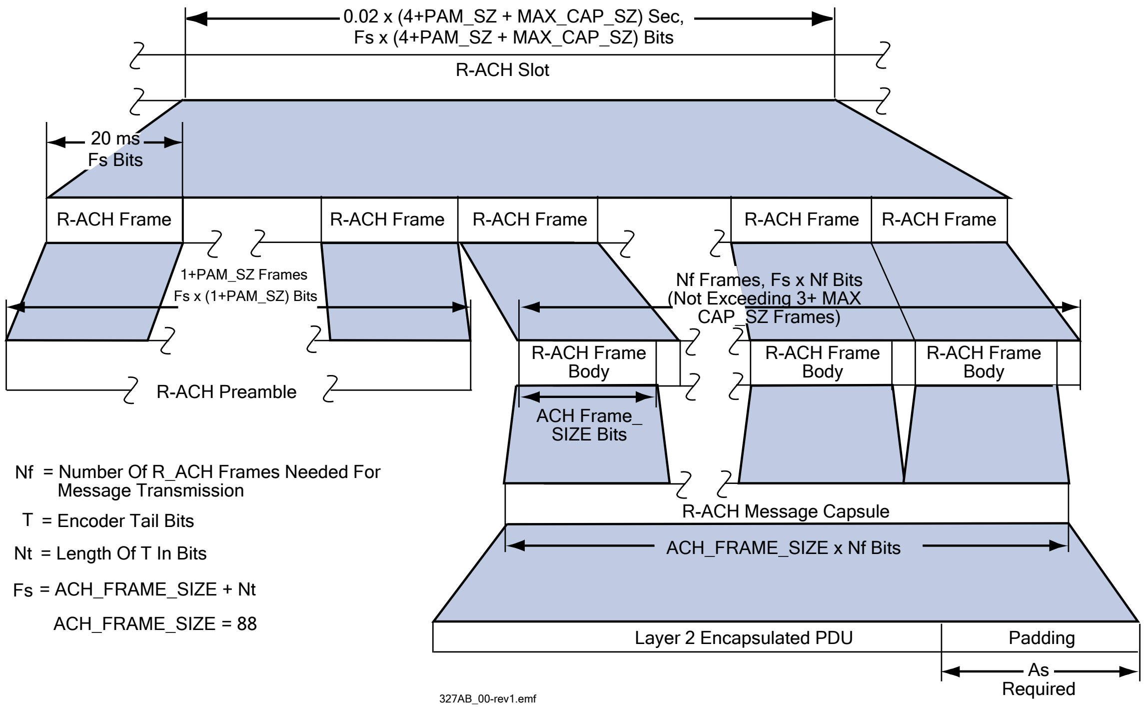
The beginning of every slot is reserved for a preamble of variable length. The preamble is followed by a message capsule. Access Channel messages are entirely contained within the slot.

The Access Channel is transmitted at 4800 bps. The frames are 20 ms in duration and contain 88 information bits and 8 tail bits. No CRC is used at frame level. The message itself will have CRC bits appended.

cdma university

Mobile System Access State – Access Channel Structure

CDMA2000 1x
RC1 & RC2
Section 6-46



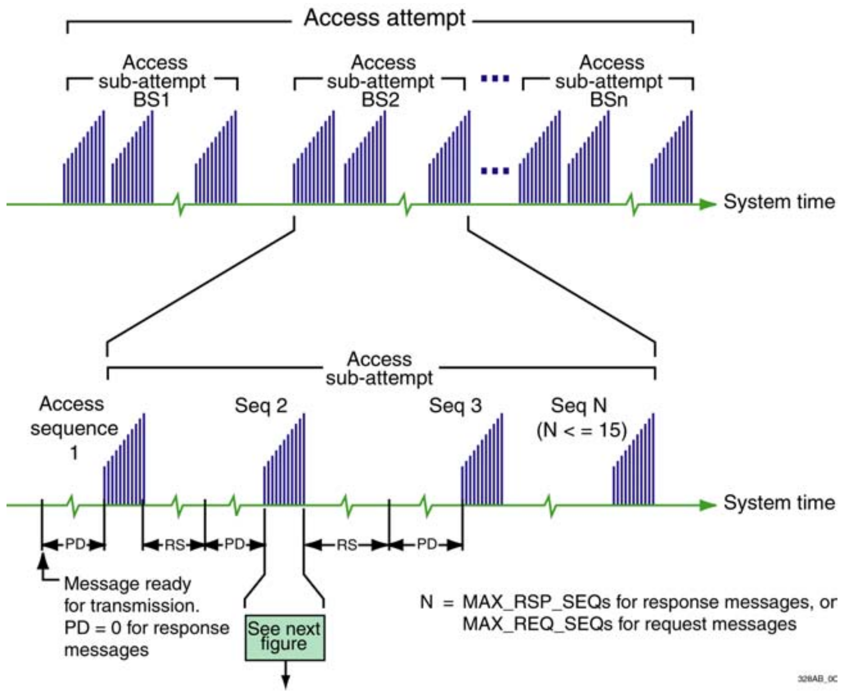
Access Channel Structure

The structure of the Access Channel (ACH) is unchanged from TIA/EIA-95 A/B. Characteristics include:

- 4800 bps data rate
- 20 ms frame duration
- Slot size is derived from parameters in the Access Parameters Message (PAM_SZ and MAX_CAP_SZ).
- Each message is preceded by a preamble, whose length is determined by a parameter in the Access Parameters Message.
- Messages may span multiple frames, not to exceed MAX_CAP_SZ + 3 frames.
- Messages are padded if necessary to fill the last frame.
- All of the TIA/EIA-95 A/B compatible messages may be transmitted on the Access Channel, along with 2 new messages defined in CDMA2000. Some messages have new fields, which are included only by CDMA2000 mobiles and are omitted by TIA/EIA-95 A/B mobiles.

Mobile System Access State – Access Channel (R-ACH) Procedures

CDMA2000 1x RC1 & RC2 Section 6-47



Access Attempt

An Access attempt is the entire process of sending one Access Channel Message, and receiving or failing to receive an acknowledgment from the Base Station.

Access Subattempt

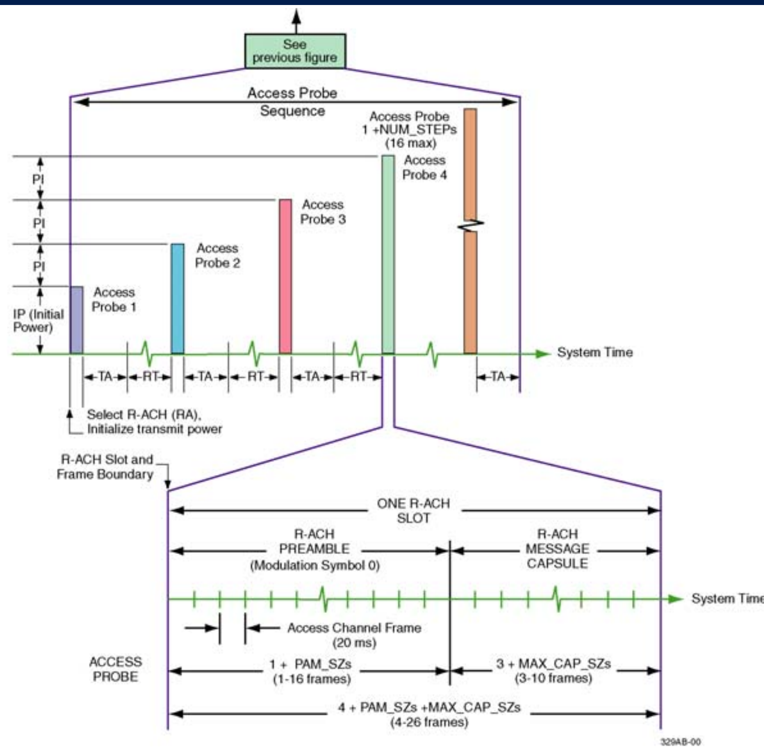
An Access subattempt consists of a collection of Access sequences, all transmitted to the same Base Station. If an Access Channel handoff occurs, a new access subattempt is started. Sequences within a subattempt are separated by a random backoff interval (RS), and a Persistence Delay (PD).

The PD applies only to Access Channel requests, not Access Channel responses. For example, an Origination Message is a request, while a Page Response Message is a response.

QUALCOMM cdma university

Mobile System Access State – Access Channel (R-ACH) Procedures (cont.)

CDMA2000 1x RC1 & RC2 Section 6-48



Access Sequence

An Access sequence is a collection of Access probes, each of which is transmitted at increasing power levels. Probes are separated by a delay period in which the mobile waits for an acknowledgment (TA) and a random backoff interval (RT).

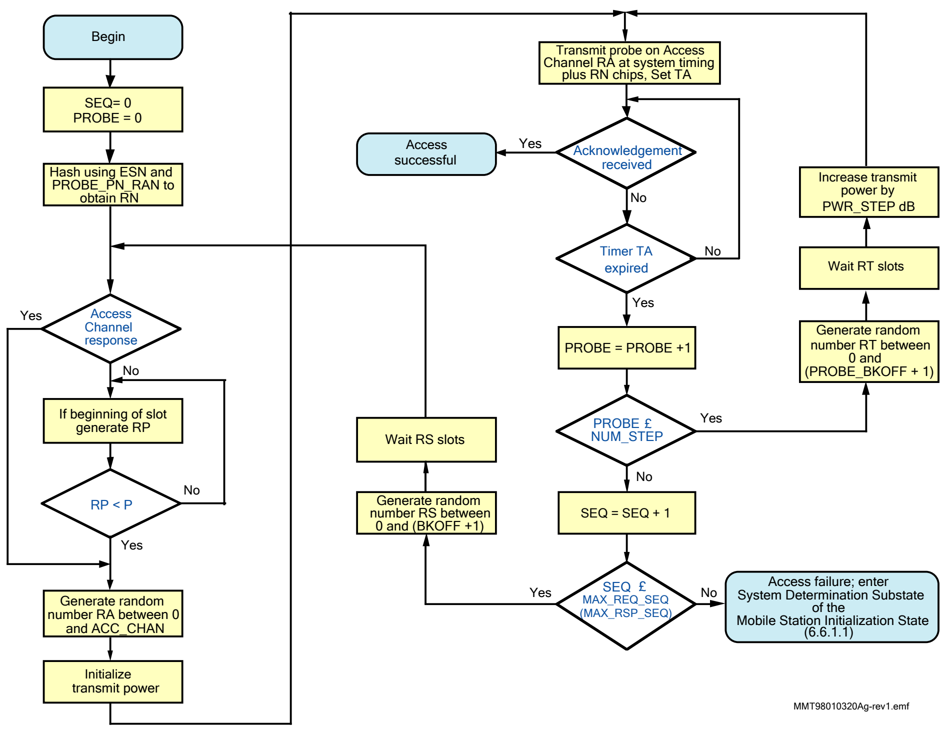
Access Probe

An Access probe consists of the transmission of the Access Channel preamble, followed by the Access Channel Message. The maximum duration of a single probe is called an Access Channel slot. A probe always begins on a slot boundary, plus a small random delay (0 to 511 chips).

cdma university

Mobile System Access State – Access Procedure

CDMA2000 1x
RC1 & RC2
Section 6-49



Access Procedure

The Mobile calculates several parameters for each new Access Probe that it sends. Open Loop power control is operating to estimate the required probe transmit power. The Persistence test must be passed before the Access Probe can be sent.

The Mobile then chooses an Access Channel to use, and transmits the probe with the correct random PN offset.

If the Mobile does not receive an acknowledgement within the TA timer period, and if the number of probes is less than Num_Step, then another probe is sent.

Probes continue to be sent until an acknowledgment is received on the Paging Channel or the number of probes is greater than Num_Step.

If the number of probes is greater than Num_Step, a new sequence is started, up to the maximum number of sequences.

QUALCOMM cdma university

Mobile System Access State – Access Channel Parameters

CDMA2000 1x RC1 & RC2 Section 6-50

Vari-able	Name	Generation	Range	Units
IP	Initial Open-Loop Power	IP = -73 -Mean Input Power (dBm) + NOM_PWR + INIT_PWR	See 6.1.2.1 6.1.2.2.1	dBm
PD	Persistence Delay	Delay continues slot-by-slot until persistence test (run every slot) passes.	–	slots
PI	Power Increment	PI = PWR_STEP	0 to 7	dB
RA	Access Channel Number	Random between 0 and ACC_CHAN; generated before every sequence.	0 to 31	–
RN	PN Randomization Delay	Hash using ESN between 0 and $2^{PROBE\_PN\_RAN}-1$; generated once at beginning of attempt.	0 to 511	chips
RS	Sequence Backoff	Random between 0 and 1 + BKOFF; generated before every sequence (except the first sequence).	0 to 16	slots
RT	Probe Backoff	Random between 0 and 1 + PROBE_BKOFF; generated before subsequent probes.	0 to 16	slots
TA	Ack Response Timeout	TA = 80 ´ (2 + ACC_TMO); timeout from end of slot	160 to 1360	ms

MMT98010321Ag-rev1.emf

Notes

Mobile System Access State – Access Channel Failure Mechanisms

- **Power Related**
- **Size Related**
- **Timing Related**
- **Base Station Related**

Access Channel Failure Mechanisms

Power Related:

- NOM_PWR
- INIT_PWR
- PWR_STEP

Size Related:

- PAM_SIZE
- MAX_CAP_SIZE

Timing Related:

- PROBE_PN_RAND
- Persistence
- ACC_TMO
- Probe backoff

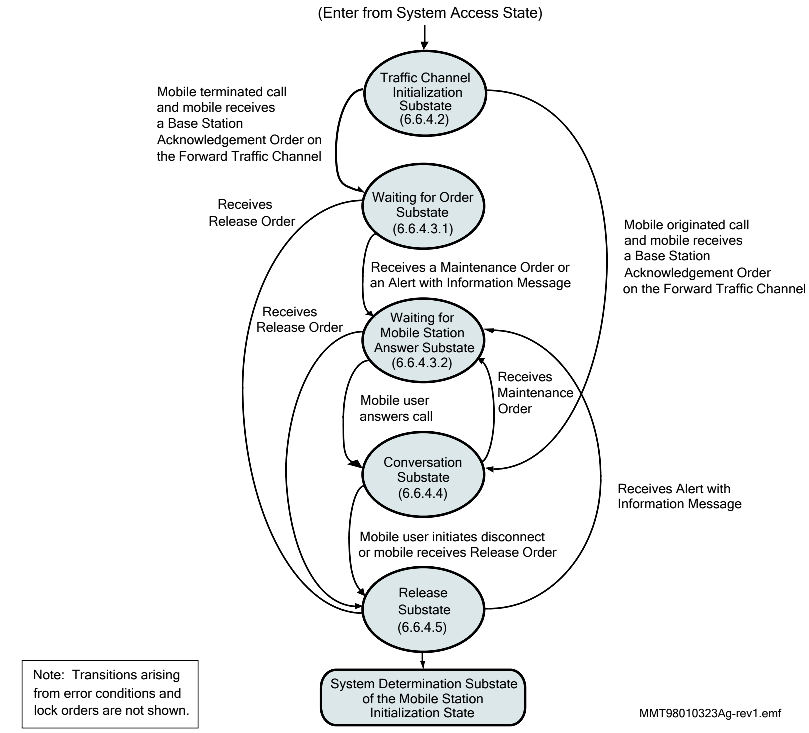
Base Station Related:

- Number of Access Channels supported
- Size of Access Channel search windows used at the BS

cdma university

Traffic Channel State – Substates

CDMA2000 1x
RC1 & RC2
Section 6-52



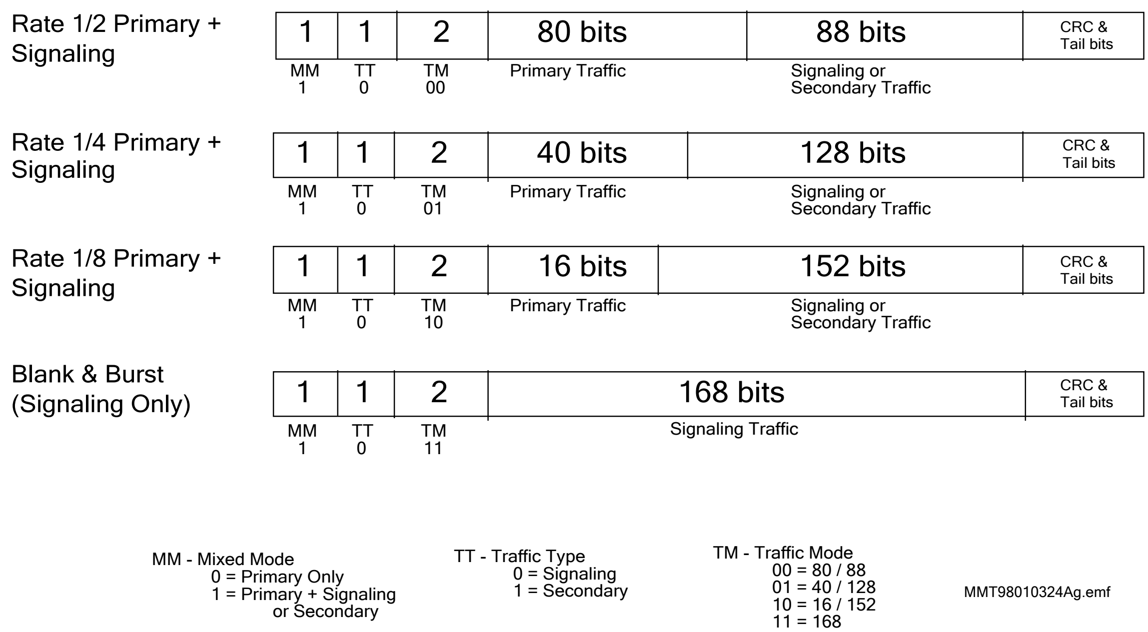
Mobile Traffic Channel Substates

The figure illustrates the processing flow while the mobile is in the Traffic Channel state. It is important to note that the mobile returns to the Initialization State on release.

QUALCOMM cdma university

Traffic Channel State – Traffic Channel Message Structure

CDMA2000 1x RC1 & RC2 Section 6-53



Traffic Channel Message Structure

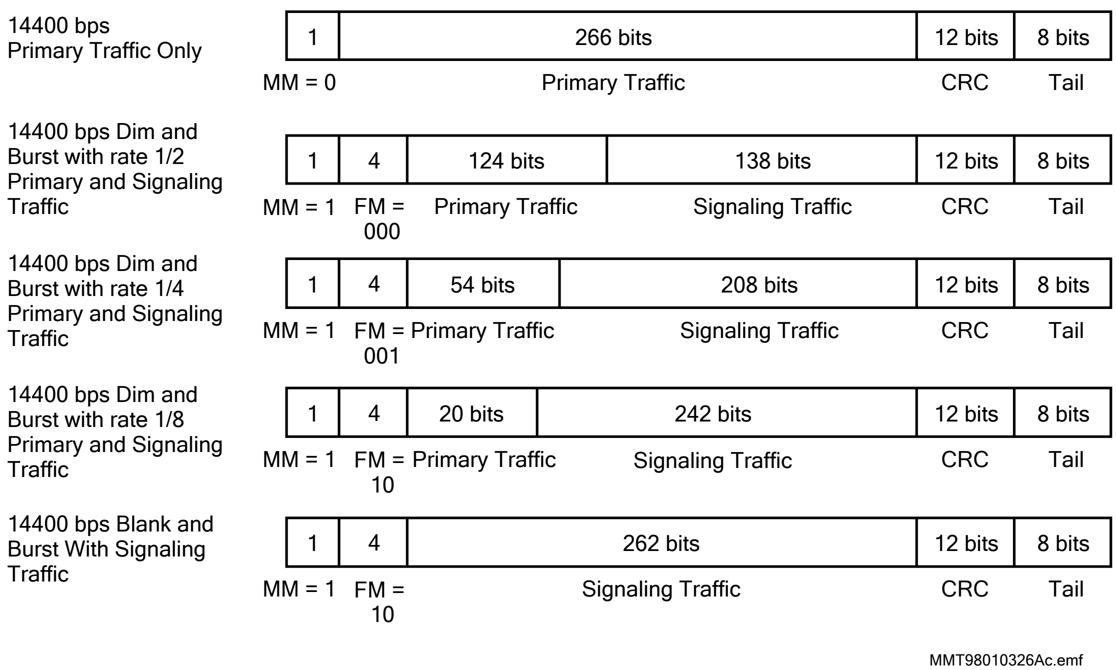
Signaling messages are transmitted on the Traffic Channels right along with the voice and user data. This is accomplished using a multiplex option. Multiplex Option 1 is shown here.

The signaling message is broken down into packets and placed into several frames in the portion of the frame that is allocated for signaling. The first bit of the Signaling payload in every multiplex option frame is reserved for the Start of Message flag (SOM). This bit is set to indicate that the message starts with this frame. Note that multiplexing is allowed for every frame rate in Rate Set 2 vocoder.

QUALCOMM cdma university

Traffic Channel State – Multiplex Option 2

CDMA2000 1x RC1 & RC2 Section 6-54



Multiplex Option 2

Multiplex Option 2 is shown here. Note that multiplexing is allowed for every frame rate in Rate Set 2 vocoder.

QUALCOMM cdma university

Traffic Channel State – Forward Traffic Channel Messages

Message Name	Message type (binary)
Order Message	00000001
Authentication Challenge Message	00000010
Alert With Information Message	00000011
Data Burst Message	00000100
Reserved for obsolete Handoff Direction Message	00000101
Analog Handoff Direction Message	00000110
In-Traffic System Parameters Message	00000111
Neighbor List Update Message	00001000
Send Burst DTMF Message	00001001
Power Control Parameters Message	00001010
Retrieve Parameters Message	00001011
Set Parameters Message	00001100
SSD Update Message	00001101
Flash With Information Message	00001110
Mobile Station Registered Message	00001111
Status Request Message	00010000
Extended Handoff Direction Message	00010001
Service Request Message	00010010
Service Response Message	00010011
Service Connect Message	00010100
Service Option Control Message	00010101
TMSI Assignment Message	00010110

MMT98010327Ag.emf

Notes

QUALCOMM cdma university

Traffic Channel State – Reverse Traffic Channel Messages

CDMA2000 1x RC1 & RC2 Section 6-56

Message Name	Message Type (binary)
Order Message	00000001
Authentication Challenge Response Message	00000010
Flash With Information Message	00000011
Data Burst Message	00000100
Pilot Strength Measurement Message	00000101
Power Measurement Report Message	00000110
Send Burst DTMF Message	00000111
Reserved for obsolete Status Message	00001000
Origination Continuation Message	00001001
Handoff Completion Message	00001010
Parameters Response Message	00001011
Service Request Message	00001100
Service Response Message	00001101
Service Connect Completion Message	00001110
Service Option Control Message	00001111
Status Response Message	00010000
TMSI Assignment Completion Message	00010001

MMT98010328Ag.emf

Notes

QUALCOMM cdma university

Traffic Channel State – Mobile Station Origination Example

CDMA2000 1x RC1 & RC2 Section 6-57

Mobile				
• Detects user-initiated call				
• Sends Origination Message	>	Access Channel	>	• Sets up Traffic Channel
				• Begins sending null Traffic Channel data
• Sets up Traffic Channel	<	Paging Channel	<	• Sends Channel Assignment Message
• Receives N_{5m} consecutive valid frames				
• Begins sending the Traffic Channel preamble	>	Reverse Traffic Channel	>	• Acquires the Reverse Traffic Channel
• Begins transmitting null Traffic Channel data	<	Forward Traffic Channel	<	• Sends Base Station Acknowledgment Order
• Begins processing primary traffic in accordance with Service Option 1	<	Forward Traffic Channel	<	• Sends Service Option Response Order
Optional				Optional
• Sends Origination Continuation Message	>	Reverse Traffic Channel	>	
Optional				Optional
• Applies ring back in audio path	<	Forward Traffic Channel	<	• Sends Alert With Information Message (ring back tone)
Optional				Optional
• Removes ring back from audio path	<	Forward Traffic Channel	<	• Sends Alert With Information Message (tones off)
(User conversation)				(User conversation)

MMT98010329Ag-rev1.emf

Mobile Origination

This example assumes that there are no errors during transmission of the signaling messages and that all messages requiring an acknowledgment are properly acknowledged.

QUALCOMM cdma university

Traffic Channel State – Origination Example

05/05/2000 01:47:21.565 [07] ACCESS CAI

Origination Message

ack_seq 7, msg_seq 1, ack_req 1, valid_ack 0, ack_type 0

esn 0xB3CC1DF8	Phone ESN
imsi {0,0} imsi_s=124d12a7c=(303) 555-0747	Phone IMSI
auth_mode 0	No authentication
mob_term 1	Phone will accept incoming calls when roaming
slot_cycle_index 2	Phone likes SCI=2
mob_p_rev 3	Phone is p_rev=3 (IS-95B light)
scm 0x6a	Station Class Mark, indicates dual mode, portable, cellular
request_mode 3	Requesting a CDMA Traffic Channel
special_service 1	Phone wants special vocoder, QCELP 13K
service_option 0x8000	13K voice
pm 0	No privacy mode
digit_mode 0	Digits are binary DTMF
more_fields 0	All the dialed digits fit in this Origination
num_fields 10	Number of dialed digits
chari[]: 3035551234	Dialed number
nar_an_cap 0	This phone does not support NAMPS

Origination Example

This Origination message from the phone to the Base Station requests a 13K vocoder voice call (Rate Set 2) and provides the dialed digits for the call. Other parameters about the phone (ESN, IMSI, Authentication, Slot cycle index, P_Rev) are also provided to the Base Station.

QUALCOMM cdma university

Traffic Channel State – Service Connect Message Example

CDMA2000 1x RC1 & RC2 Section 6-59

05/05/2000 01:47:22.928 [18] FORWARD TC CAI

Service Connect Message

ack_seq 0, msg_seq 1, ack_req 1, encryption 0

implied action time, con_seq 0

Fwd Mux Option 2 {Full Half Qtr 8th} Connect Forward and Reverse with 13K voice

Rev Mux Option 2 {Full Half Qtr 8th}

1: 0x8000 on Fwd Primary and Rev Primary (13K Voice)

Service Connect Message Example

The Base Station responds to the Origination request with the Service Connect message, granting the 13K variable rate voice call.

QUALCOMM cdma university

Traffic Channel State – Failure Mechanisms

CDMA2000 1x RC1 & RC2 Section 6-60

- Mobile ACK Failure
- BS ACK Failure
- Mobile Fade Timer
- Mobile Bad Frames
- BS Bad Frames
- Capacity

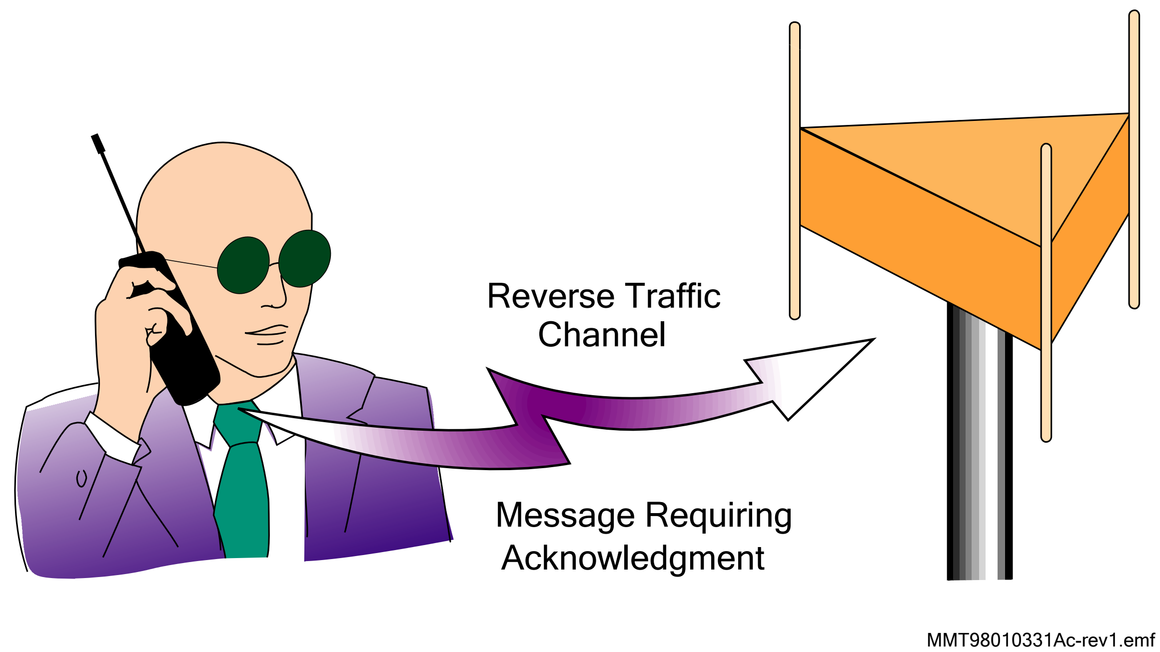
Traffic Channel Failure Mechanisms

Once in the traffic mode, a mobile can experience difficulty maintaining an acceptable level of quality. The CDMA specifications provide guidance on when to drop the call. Calls can fail for many reasons, including those listed in the slide.

QUALCOMM cdma university

Traffic Channel State – Mobile Acknowledgment Failure

CDMA2000 1x RC1 & RC2 Section 6-61



Mobile ACK Failure

Certain messages require acknowledgment. The mobile may retransmit a message if it is not acknowledged within a specified time (400 ms). The specifications limit the number of retries to a maximum of three. If the third retransmission is not acknowledged, the mobile must drop the call. The 95B standard extends the retry limit to nine.

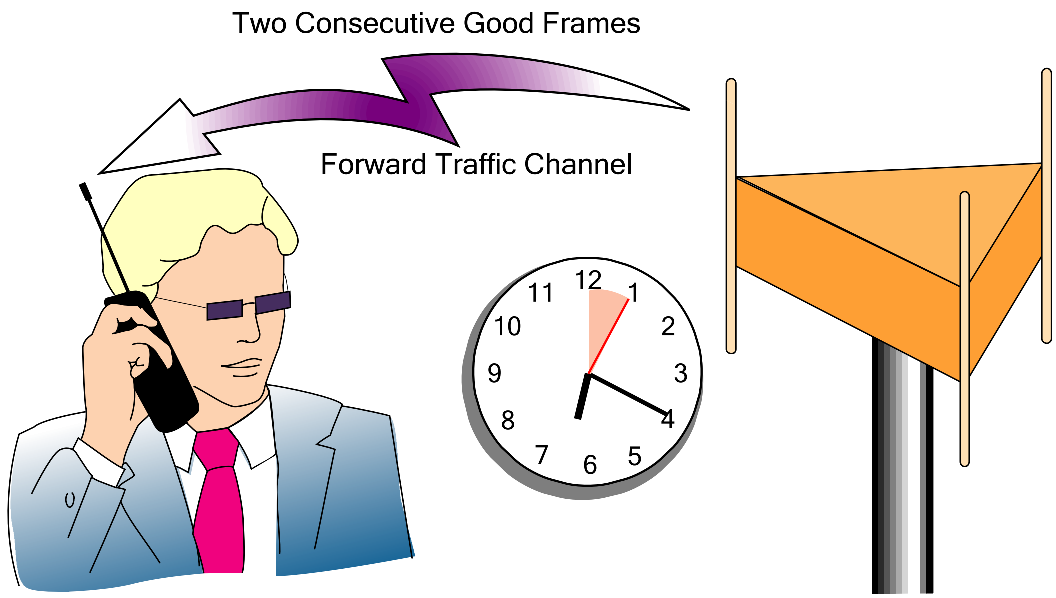
Base Station ACK Failure

Base Station acknowledgment failure is not standardized. A Base Station might typically retransmit a message requiring acknowledgment 5-15 times. The period between retransmissions would be on the order of 400 ms (same as the mobile).

cdma university

Traffic Channel State – Mobile Fade Timer

CDMA2000 1x
RC1 & RC2
Section 6-62



MMT98010332Ac.emf

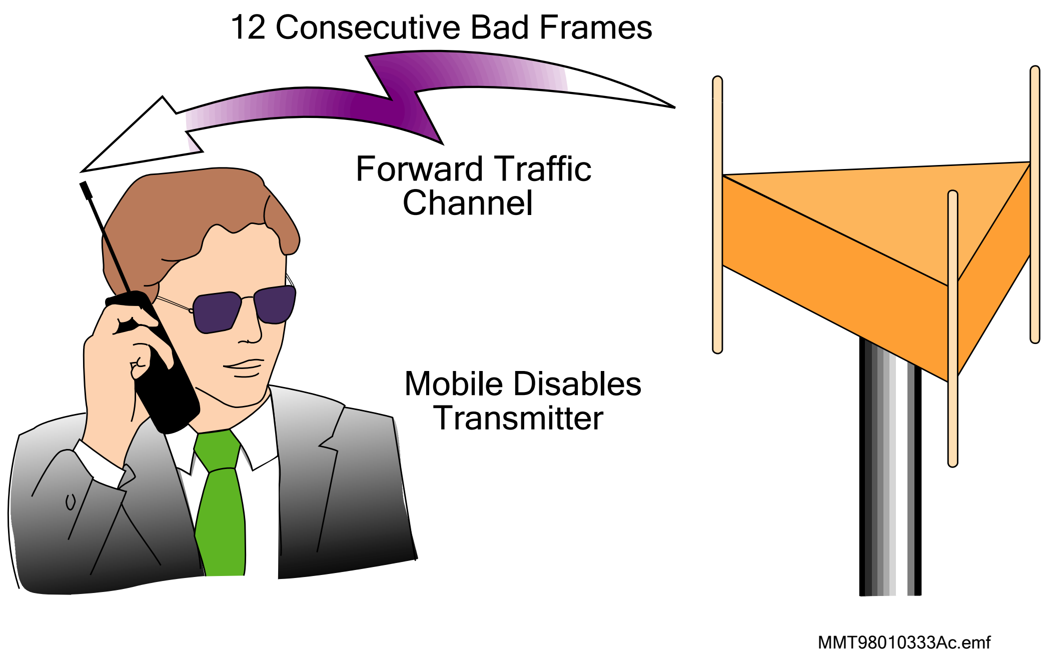
Mobile Fade Timer

The CDMA specifications define a required mobile fade timer. The timer is continuously running down. It is reset to five seconds on every mobile receipt of two consecutive good frames. If the timer expires due to a failure to receive good frames, the mobile must disable its transmitter. From a practical standpoint, this doesn’t happen often.

QUALCOMM cdma university

Traffic Channel State – Mobile Bad Frames

CDMA2000 1x RC1 & RC2 Section 6-63



Mobile Bad Frames

If a sequence of consecutive bad frames is received by the mobile, the specifications require the mobile to disable its transmitter. The number of consecutive bad frames is 12. The mobile can enable the transmitter on receipt of two consecutive good frames.

Base Station Bad Frames

This is also not standardized. A Base Station would be expected to send a release order after receiving a sequence of bad frames for a period of 3-5 seconds.

What We Learned in This Section

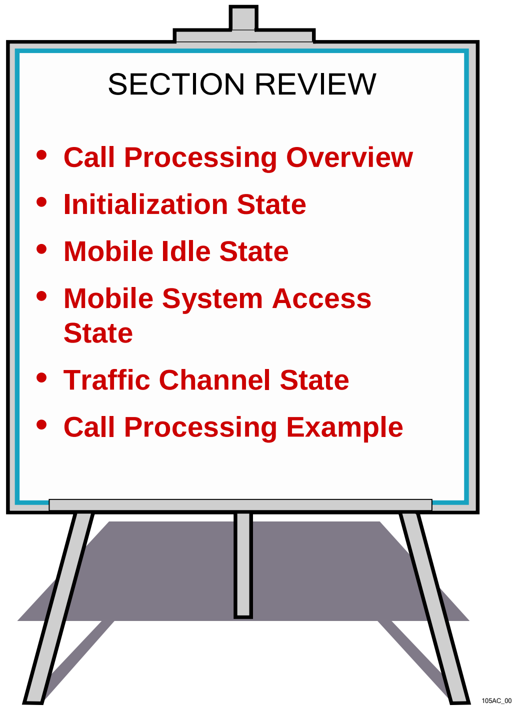
- ✓ The call control signaling processes specified in the CDMA standards.
- ✓ System determination, synchronization, and timing in CDMA systems.
- ✓ The functioning of the Paging Channels.
- ✓ The functioning of the Access Channels.
- ✓ The Forward and Reverse Traffic Channel Signaling Structures.

Notes

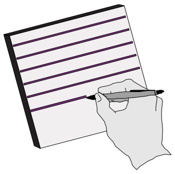
QUALCOMM cdma university

Call Processing – Review

CDMA2000 1x RC1 & RC2 Section 6-65



Notes



Comments/Notes

Call Processing Example (Sample Log File)

The following is a log file of a short voice call, mobile-initiated. The phone sends messages to a laptop PC for the log; a GPS receiver is connected to the PC for position information. QUALCOMM's CAIT tool was used to parse the log file and create this text file.

```
05/05/2000 01:47:19.951 [33] Status Packet
   Version ET1002  , Rev 466, CAI Rev 3, Compiled Apr 14 1999
   MSM 3000-A3 (0x0f), minor version 0x2c                          This phone has a MSM3000
   ESN b3cc1df8, model 31 (QCP_860p), SCM 6a, RF Mode CDMA Cellular
   Orig_min 0:
      MIN (0x124) D12A7C = (303) 555-0747
         (pg slots: 38, 102, 166, ...      [29 more up to 2048])
   SID 78, NID 0, Slot-Cycle-Index 2                               SCI wants to be 2
   Freq chan 349, Code chan 0, Pilot 0x0000 =    0 (    0 )
   log_mask: 0x004889f0, end_time: 05/05/2000 01:48:28

05/05/2000 01:47:20.191 [36] PAGING CAI                            The phone is Idle, listening to the Paging Channel
   General Page Message (slot 1334)
      Config_msg_seq 1, Acc_msg_seq 1
            Done's: class_0: 1, class_1: 1, TMSI: 1, BCast: 1
      Ordered TMSIs: 0

05/05/2000 01:47:20.191 [36] Position And Speed Information Read From GPS Receiver
   Latitude 39ø 59' 12.9"N, Longitude -105ø 10' 31.6"W
   Latitude +39.98692ø,   Longitude -105.17545ø, Speed 0 mph, Heading 182, Time: 01:47:06         At the Stop sign, pointed South

05/05/2000 01:47:21.111 [01] Temporal Analyzer Finger Info Only    Searcher has three fingers, on PN344, two at offset ed28
   Finger #1 PN=0x0158 =  344 (  344 ): pos=0xed28, eng=0          with zero energy, one good finger at offset ed10 with
   Finger #2 PN=0x0158 =  344 (  344 ): pos=0xed10, eng=160 (-8.6) energy of Ec/Io=-8.6 dB
   Finger #3 PN=0x0158 =  344 (  344 ): pos=0xed28, eng=0

05/05/2000 01:47:21.162 [02] PAGING CAI
   General Page Message (slot 1346)
      Config_msg_seq 1, Acc_msg_seq 1                              Paging message with one page message
            Done's: class_0: 1, class_1: 1, TMSI: 1, BCast: 1
      Ordered TMSIs: 0
      Page[0] {0,0} msg_seq 0, imsi_s 1246d5c20=(303) 555-7143, S.O.: 0x8000

05/05/2000 01:47:21.192 [02] Temporal Analyzer Finger Info Only
   Finger #1 PN=0x0158 =  344 (  344 ): pos=0xed28, eng=0          Searcher info, now the strong finger has delayed to ed15,
   Finger #2 PN=0x0158 =  344 (  344 ): pos=0xed15, eng=22 (-17.2) and the strength has fallen to Ec/Io = -17.2 dB
   Finger #3 PN=0x0158 =  344 (  344 ): pos=0xed28, eng=0

05/05/2000 01:47:21.203 [03] PAGING CAI
   Access Parameters Message
      pilot_pn 0x0158 =  344 (  344 )                              From Sector PN Offset = 344 (*64) chips
      acc_msg_seq 1                                                Message sequence number is 1
      acc_chan 0                                                   # of Access Channels is 1 more than this number
      nom_pwr 3, (nom_pwr_ext=0)                                   This cell is 3 dB louder Pilot than the normal assumption
      init_pwr –3                                                  Start Access Probes 3dB below the Open Loop estimate
      pwr_step 5                                                   Use 5 dB steps on Access Probes
      num_step 3                                                   Access Probes can have up to 4 steps
      max_cap_sz 3                                                 Max Access frames is 3+2
      pam_sz 3                                                     3 frames of preamble on the Access probe
      psist_0_9:0,  10:0,  11:0,  12:0,  13:0,  14:0,  15:0        Don't use persistence test
      msg_psist 0                                                  No message persistence test
      reg_psist 0                                                  No registration persistence test
      probe_pn_ran 0                                               Don't bother to add random delay PN chips to probe
      acc_tmo 1                                                    Access timeout is 2+1 = 3     80 ms wait units
```

```
    probe_bkoff 0                                                   Don't bother to do backoff timing on probes
    bkoff 0
    max_req_seq 3, max_rsp_seq 3                                    Max of 3 Access sequences for request or response
    auth 0                                                          No authentication

05/05/2000 01:47:21.206 [03] PAGING CAI
  Channel List Message
    pilot_pn 0x0158 =  344 (  344 )
    config_msg_seq 1
    num_channels 1                                                  There is one channel with a Paging Channel in this system
    Channel 384


05/05/2000 01:47:21.443 [06] PAGING CAI
  Neighbor List Message
    pilot_pn 0x0158 =  344 (  344 )
    config_msg_seq 1
    pilot_inc 4
    num_nghbrs 20
     nghbr_config 0, pn 0x0018 =   24 (   24 )                      These are the PN offsets of the neighbors of PN344
     nghbr_config 0, pn 0x00b8 =  184 (  184 )                      They are all modulo 4
     nghbr_config 0, pn 0x016c =  364 (  364 )
     nghbr_config 0, pn 0x00cc =  204 (  204 )
     nghbr_config 0, pn 0x012c =  300 (  300 )
     nghbr_config 0, pn 0x0198 =  408 (  408 )
     nghbr_config 0, pn 0x01a8 =  424 (  424 )
     nghbr_config 0, pn 0x0108 =  264 (  264 )
     nghbr_config 0, pn 0x018c =  396 (  396 )
     nghbr_config 0, pn 0x0040 =   64 (   64 )
     nghbr_config 0, pn 0x0058 =   88 (   88 )
     nghbr_config 0, pn 0x0180 =  384 (  384 )
     nghbr_config 0, pn 0x01cc =  460 (  460 )
     nghbr_config 0, pn 0x01c4 =  452 (  452 )
     nghbr_config 0, pn 0x0148 =  328 (  328 )
     nghbr_config 0, pn 0x002c =   44 (   44 )
     nghbr_config 0, pn 0x0060 =   96 (   96 )
     nghbr_config 0, pn 0x01b0 =  432 (  432 )
     nghbr_config 0, pn 0x00ec =  236 (  236 )
     nghbr_config 0, pn 0x01ec =  492 (  492 )


05/05/2000 01:47:21.503 [06] PAGING CAI
  System Parameter Message
    pilot_pn 0x0158 =  344 (  344 )                                 System message from PN344
    config_msg_seq 1                                                Message sequence 1
    sid 78, nid 1                                                   System ID=78   NID=1
    reg_zone 4, total_zones 0, zone_timer 0                         We are in Registration zone 4, don't remember any old zones
    mult_sids 0, mult_nids 0                                        Don't remember multiple SIDs or NIDs
    base_id 3243                                                    Hex BTS number 3243
    base_class 0                                                    800 Mhz Cellular band
    page_chan 1                                                     There is 1 Paging Channel
    max_slot_cycle_index 0                                          Please use a SCI of 0
    home_reg 1                                                      Register if this is your home network
    for_sid_reg 1                                                   Register if this is a foreign SID
    for_nid_reg 1                                                   Register if this is a foreign NID
    power_up_reg 1                                                  Register on power up
    power_down_reg 0                                                Don't register when you power down
    parameter_reg 1                                                 Register when system parameters change
    reg_prd 54 (926.82 sec = 15 min 27 sec)                         Register periodically every 15 minutes
    base_lat 575892, base_lon -1514224 39ø59'33.00"N x  105ø9'16.00"W
    reg_dist 0                                                      Don't register based on distance
    srch_win_a 6, srch_win_n 13, srch_win_r 13              Active Set search window of 28 chips, Neighbor and Remainder of 226
    nghbr_max_age 0                                                 Don't remember old neighbors
    pwr_rep_thresh 2 erasures in pwr_rep_frames 0x9 (113 frames), Enabled    Measure forward FER over 113 frames
    pwr_period_enable 0                                             Don't report FER periodically
    pwr_rep_delay 1 (4 frames)                                      If you complain about FER, wait 4 frames to start counting
    rescan 0                                                        Don't re-initialize and re-acquire
    t_add 28, t_drop 32, t_comp 8, t_tdrop 2        t_add of –14 dB, t_drop of –16 dB, t_comp of 4 dB, and drop timer of 2 seconds
```

Ext Sys-Param:1, Ext Nghbr List:0, Gen Nghbr List:0, Gbl Redir:1	Expect Ext Sys Param and Glb redirection on Paging Channel
05/05/2000 01:47:21.565 [07] ACCESS CAI	
Origination Message	
ack_seq 7, msg_seq 1, ack_req 1, valid_ack 0, ack_type 0	
esn 0xB3CC1DF8	Phone ESN
imsi {0,0} imsi_s=124d12a7c=(303) 555-0747	Phone IMSI
auth_mode 0	No authentication
mob_term 1	Phone will accept incoming calls when roaming
slot_cycle_index 2	Phone likes SCI=2
mob_p_rev 3	Phone is p_rev=3 (IS-95B lite)
scm 0x6a	Station Class Mark, indicates dual mode, portable, cellular
request_mode 3	Requesting a CDMA Traffic Channel
special_service 1	Phone wants special vocoder, QCELP 13K
service_option 0x8000	13K voice
pm 0	No privacy mode
digit_mode 0	Digits are binary DTMF
more_fields 0	All the dialed digits fit in this Origination
num_fields 10	Number of dialed digits
chari[]: 3035551234	Dialed number
nar_an_cap 0	This phone does not support NAMPS
05/05/2000 01:47:21.566 [07] PAGING CAI	
Access Parameters Message	
pilot_pn 0x0158 = 344 (344)	
acc_msg_seq 1	
acc_chan 0	
nom_pwr 3, (nom_pwr_ext=0)	
init_pwr -3	
pwr_step 5	
num_step 3	
max_cap_sz 3	
pam_sz 3	
psist_0_9:0, 10:0, 11:0, 12:0, 13:0, 14:0, 15:0	
msg_psist 0	
reg_psist 0	
probe_pn_ran 0	
acc_tmo 1	
probe_bkoff 0	
bkoff 0	
max_req_seq 3, max_rsp_seq 3	
auth 0	
05/05/2000 01:47:21.663 [08] Access Probe Information	
Seq num 1, Probe num 1	
RX AGC 0xbc (-85.915 dBm), TX ADJ 0	Access Probe information logged from phone
Number of psist tests 1, Access channel number 0	
PN Rand delay 0, Sequence backoff delay 0, Probe backoff delay 0	
05/05/2000 01:47:21.843 [0B] PAGING CAI	
Channel List Message	
pilot_pn 0x0158 = 344 (344)	
config_msg_seq 1	
num_channels 1	
Channel 384	
05/05/2000 01:47:21.847 [0B] Temporal Analyzer Finger Info Only	
Finger #1 PN=0x0158 = 344 (344): pos=0xed04, eng=0	
Finger #2 PN=0x0158 = 344 (344): pos=0xed0f, eng=157 (-8.6)	
Finger #3 PN=0x0158 = 344 (344): pos=0xece0, eng=0	

```
05/05/2000 01:47:21.883 [0B] PAGING CAI
  Mobile Station Order Message
    num_ords 1
    ack_seq 1, msg_seq 0, ack_req 0, valid_ack 1
    imsi {0,0} imsi_s=124d12a7c=(303) 555-0774
      Base Station Acknowledgement Order                    Base Station ACKing the Origination

05/05/2000 01:47:21.883 [0B] Position And Speed Information Read From GPS Receiver
  Latitude 39ø 59' 12.8"N, Longitude -105ø 10' 31.6"W
  Latitude +39.98690ø,   Longitude -105.17546ø, Speed 3 mph, Heading 209, Time: 01:47:09

05/05/2000 01:47:09.202 [2D] Sparse AGC Power Control Information   Sparse power information at the PCG rate
  adc_therm     = 0x00cb
  batt_volt     = 0x00d0
  tx_pwr_limit  = 0x00e2
  Rx AGC Average = 0xffbd, Rx Power  =  -85.655 dBm
  ADJ Average   = 0x006b, ADJ      =  -53.975 dB
  TX AGC Average = 0x0022, AGC Power =  -40.830 dBm
  TX Turnaround Power =  -41.320 dBm
   0:  Rx/Tx/Adj =  -87.248,  -49.250,  -63.500          Receive Power / Transmit Power / Closed Loop Power Control
   1:  Rx/Tx/Adj =  -86.915,  -49.250,  -63.500
   2:  Rx/Tx/Adj =  -86.581,  -49.250,  -63.500          Phone in Idle state, not transmitting
   3:  Rx/Tx/Adj =  -86.915,  -49.250,  -63.500
   4:  Rx/Tx/Adj =  -86.915,  -49.250,  -63.500
   5:  Rx/Tx/Adj =  -86.915,  -49.250,  -63.500
   6:  Rx/Tx/Adj =  -87.915,  -48.917,  -63.500
   7:  Rx/Tx/Adj =  -87.581,  -48.917,  -63.500
   ***
  67:  Rx/Tx/Adj =  -84.248,  -52.250,  -63.500
  68:  Rx/Tx/Adj =  -84.248,  -52.250,  -63.500
  69:  Rx/Tx/Adj =  -84.248,  -52.250,  -63.500
  70:  Rx/Tx/Adj =  -83.915,   11.083,    0.000          Access Probe Starts here
  71:  Rx/Tx/Adj =  -85.248,   11.417,    0.000          Phone obeys Open Loop estimate during Access probe
  72:  Rx/Tx/Adj =  -85.581,   12.083,    0.000          -73 –Rx = Tx
  73:  Rx/Tx/Adj =  -85.915,   12.417,    0.000          -73- -85.9 = +12 dBm
  74:  Rx/Tx/Adj =  -83.915,   12.083,    0.000
  75:  Rx/Tx/Adj =  -82.581,   11.417,    0.000
  76:  Rx/Tx/Adj =  -84.248,   10.750,    0.000
  77:  Rx/Tx/Adj =  -85.915,   11.417,    0.000
  78:  Rx/Tx/Adj =  -86.915,   12.417,    0.000
  79:  Rx/Tx/Adj =  -85.248,   12.750,    0.000
  80:  Rx/Tx/Adj =  -83.915,   12.083,    0.000
  81:  Rx/Tx/Adj =  -83.915,   11.417,    0.000
  82:  Rx/Tx/Adj =  -85.915,   11.750,    0.000
  83:  Rx/Tx/Adj =  -86.581,   12.417,    0.000
  84:  Rx/Tx/Adj =  -85.248,   13.083,    0.000
  85:  Rx/Tx/Adj =  -82.248,  -51.917,  -63.500          Access probe done, wait for ACK
  86:  Rx/Tx/Adj =  -81.248,  -52.250,  -63.500
  87:  Rx/Tx/Adj =  -80.915,  -52.250,  -63.500
  88:  Rx/Tx/Adj =  -81.581,  -52.250,  -63.500
  89:  Rx/Tx/Adj =  -80.915,  -52.250,  -63.500
  90:  Rx/Tx/Adj =  -86.248,  -52.250,  -63.500
  91:  Rx/Tx/Adj =  -88.581,  -51.250,  -63.500
  92:  Rx/Tx/Adj =  -87.581,  -49.583,  -63.500
  93:  Rx/Tx/Adj =  -90.248,  -48.583,  -63.500
  94:  Rx/Tx/Adj =  -88.581,  -47.583,  -63.500
  95:  Rx/Tx/Adj =  -88.248,  -47.917,  -63.500
```

05/05/2000 01:47:22.492 [21] PAGING CAI	
Channel Assignment Message	
num_assigns 1	Traffic Channel Assignment for the phone
ack_seq 0, msg_seq 1, ack_req 0, valid_ack 1	
imsi {0,0} imsi_s=124d12a7c=(303) 555-0747	
assign_mode 4, Extended CDMA Traffic Channel Assignment	
freq_incl 1	RF frequency is included in this message
granted_mode 2, Svc Connect at default rate-set for service option	Connect with Rate Set 2
code_chan 28	Use Walsh 28
frame_offset 0	Zero frame offset
encrypt_mode 0	No encryption
band_class 0	Cellular band ch 384
cdma_freq 384	
05/05/2000 01:47:22.687 [15] REVERSE TC CAI	
Pilot Strength Measurement Message	
ack_seq 0, msg_seq 0, ack_req 1, encryption 0	Phone is now on Traffic Channel, and send a PSMM on
ref_pn 0x0158 = 344 (344)	Reverse Traffic Channel
pilot_strength 21 (-10.5 dB)	
keep	
	It likes PN344 and wants to keep it
pilot_pn_phase[0] 0x3317 => 204 + 23 chips (204)	It wants to add PN204 in soft handoff
pilot_strength[0] 19 (-9.5 dB)	
keep	
05/05/2000 01:47:22.888 [18] FORWARD TC CAI	
Base Station Acknowledgement Order	
ack_seq 0, msg_seq 0, ack_req 0, encryption 0	
implied action time	Base Station ACK of PSMM
05/05/2000 01:47:22.928 [18] FORWARD TC CAI	
Service Connect Message	
ack_seq 0, msg_seq 1, ack_req 1, encryption 0	
implied action time, con_seq 0	
Fwd Mux Option 2 {Full Half Qtr 8th}	Connect Forward and Reverse with 13K voice
Rev Mux Option 2 {Full Half Qtr 8th}	Voice is now active both Forward and Reverse
1: 0x8000 on Fwd Primary and Rev Primary (13K Voice)	Messages now muxed with voice traffic
05/05/2000 01:47:22.967 [19] REVERSE TC CAI	
Service Connect Complete Message, serv_con_seq=0	ACK to Base Station for service connect
ack_seq 1, msg_seq 1, ack_req 1, encryption 0	
05/05/2000 01:47:23.168 [1B] FORWARD TC CAI	
Base Station Acknowledgement Order	Base Station ACK to service connect ACK
ack_seq 1, msg_seq 1, ack_req 0, encryption 0	
implied action time	
05/05/2000 01:47:23.208 [1C] FORWARD TC CAI	
Status Request Message	
ack_seq 1, msg_seq 2, ack_req 1, encryption 0	Base Station wants to know status of phone
qual_info_type 2, band class 0, op mode 1	
Service Option Information request	
Multiplex Option Information request	
05/05/2000 01:47:23.307 [1D] REVERSE TC CAI	
Status Response Message	
ack_seq 2, msg_seq 0, ack_req 0, encryption 0	
qualifiers: band_class 0, op mode 1	
Service Option 0x0001 supports fwd & rev (IS-96A 8K Voice)	These are the services that this phone can do
Service Option 0x0003 supports fwd & rev (IS-127 EVRC)	
Service Option 0x8000 supports fwd & rev (13K Voice)	
Service Option 0x8001 supports fwd & rev (IS-96 8K Voice)	
Service Option 0x801E supports fwd & rev (8K Markov)	

```
    Service Option 0x801F supports fwd & rev  (13K Markov)
    Service Option 0x0006 supports fwd & rev  (IS-637 8K SMS)
    Service Option 0x000E supports fwd & rev  (IS-637 13K SMS)
    Service Option 0x0002 supports fwd & rev  (IS-126 8K Loopback)
    Service Option 0x8002 supports fwd & rev  (8K Old Markov)
    Service Option 0x8003 supports fwd & rev  (Data Pipe)
    Service Option 0x0004 supports fwd & rev  (IS-99 8K Async Data)
    Service Option 0x0005 supports fwd & rev  (IS-99 8K Fax)
    Service Option 0x0007 supports fwd & rev  (IS-657 8K PPP)
    Service Option 0x1004 supports fwd & rev  (IS-707 8K Async Data)
    Service Option 0x1005 supports fwd & rev  (IS-707 8K Fax)
    Service Option 0x1007 supports fwd & rev  (IS-707 8K PPP)
    Service Option 0x0014 supports fwd & rev  (IS-707 8K Analog Fax)
    Service Option 0x0009 supports fwd & rev  (PN-3571 13K Loopback)
    Service Option 0x801C supports fwd & rev  (13K Old Markov)
    Service Option 0x000C supports fwd & rev  (IS-99 13K Async Data)
    Service Option 0x000D supports fwd & rev  (IS-99 13K Fax)
    Service Option 0x000F supports fwd & rev  (PN-3676 13K PPP)
    Service Option 0x8021 supports fwd & rev  (IS-99 13K Async Data Q)
    Service Option 0x8022 supports fwd & rev  (IS-99 13K Fax Q)
    Service Option 0x8020 supports fwd & rev  (PN-3676 13K PPP Q)
    Service Option 0x0015 supports fwd & rev  (IS-707 13K Analog Fax)
    Mux Option 1:
      Fwd: {Full Half Qtr 8th}
      Rev: {Full Half Qtr 8th}
    Mux Option 2:
      Fwd: {Full Half Qtr 8th}
      Rev: {Full Half Qtr 8th}

05/05/2000 01:47:23.307 [1D] Position And Speed Information Read From GPS Receiver
  Latitude 39ø 59' 12.7"N, Longitude -105ø 10' 31.7"W
  Latitude +39.98688ø,     Longitude -105.17548ø, Speed 6 mph, Heading 223, Time: 01:47:10


05/05/2000 01:47:23.528 [20] FORWARD TC CAI
  Extended Handoff Direction Message
    ack_seq 1, msg_seq 3, ack_req 1, encryption 0
    implied action time, hdm_seq 0, PSMM 841 ms ago                 Handoff message, now in soft handoff
    srch_win_a 6, t_add 28, t_drop 32, t_comp 8, t_tdrop 2
      PN 0x0158 =  344 (  344 ), combine 0, code channel 20         For PN344 use Walsh 20
      PN 0x00cc =  204 (  204 ), combine 0, code channel 41         For PN204 use Walsh 41

05/05/2000 01:47:23.587 [20] REVERSE TC CAI
  Handoff Completion Message                                        Phone ACK to EHDM
    ack_seq 3, msg_seq 2, ack_req 1, encryption 0
    last_hdm_seq 0
    pilot_pn 0x0158 =  344 (  344 )
    pilot_pn 0x00cc =  204 (  204 )

05/05/2000 01:47:23.802 [23] Temporal Analyzer Finger Info Only
  Finger #1 PN=0x0158 =  344 (  344 ): pos=0xed11, eng=37 (-14.9)   Now tracking energy in PN344 and PN204
  Finger #2 PN=0x00cc =  204 (  204 ): pos=0xedc3, eng=20 (-17.6)
  Finger #3 PN=0x0158 =  344 (  344 ): pos=0xed12, eng=0


05/05/2000 01:47:23.850 [24] FORWARD TC CAI
  Neighbor List Update Message                                      In-traffic Neighbors List Message
    ack_seq 2, msg_seq 4, ack_req 1, encryption 0
    pilot_inc 4
    nghbr_pn 0x0018 =   24 (   24 )
    nghbr_pn 0x016c =  364 (  364 )
    nghbr_pn 0x00b8 =  184 (  184 )
    nghbr_pn 0x002c =   44 (   44 )
    nghbr_pn 0x012c =  300 (  300 )
    nghbr_pn 0x0198 =  408 (  408 )
    nghbr_pn 0x018c =  396 (  396 )
    nghbr_pn 0x01a8 =  424 (  424 )
    nghbr_pn 0x0060 =   96 (   96 )
```

```
    nghbr_pn 0x0108 =  264 (  264 )
    nghbr_pn 0x00ec =  236 (  236 )
    nghbr_pn 0x0148 =  328 (  328 )
    nghbr_pn 0x0040 =   64 (   64 )
    nghbr_pn 0x0170 =  368 (  368 )
    nghbr_pn 0x0058 =   88 (   88 )
    nghbr_pn 0x0180 =  384 (  384 )
    nghbr_pn 0x01cc =  460 (  460 )
    nghbr_pn 0x01c4 =  452 (  452 )
    nghbr_pn 0x01b0 =  432 (  432 )
    nghbr_pn 0x01ec =  492 (  492 )


05/05/2000 01:47:23.890 [24] FORWARD TC CAI
  In-Traffic System Parameters Message                              In-traffic System Parameters update
    ack_seq 2, msg_seq 5, ack_req 1, encryption 0
    sid 78, nid 1
    srch_win_a 6, srch_win_n 13, srch_win_r 13
    t_add 28, t_drop 32, t_comp 8, t_tdrop 2
    nghbr_max_age 0

05/05/2000 01:47:23.930 [25] FORWARD TC CAI
  Power Control Parameters Message                                  In-traffic power control update
    ack_seq 2, msg_seq 6, ack_req 1, encryption 0
    pwr_rep_thresh 2 erasures in
    pwr_rep_frames 0x9 (113 frames)
    pwr_thresh_enable   1
    pwr_period_enable   0
    pwr_rep_delay  0x1 (4 frames)

05/05/2000 01:47:24.165 [28] Temporal Analyzer Finger Info Only
  Finger #1 PN=0x00cc =  204 (  204 ): pos=0xede4, eng=0
  Finger #2 PN=0x00cc =  204 (  204 ): pos=0xedc1, eng=0
  Finger #3 PN=0x0158 =  344 (  344 ): pos=0xed12, eng=84 (-11.4)

05/05/2000 01:47:22.207 [0F] Sparse AGC Power Control Information
  adc_therm      = 0x00cb
  batt_volt      = 0x00da
  tx_pwr_limit   = 0x00e2
  Rx AGC Average = 0xffbc, Rx Power  =  -86.031 dBm
  ADJ Average    = 0x0025, ADJ       =  -18.910 dB
  TX AGC Average = 0x008a, AGC Power =   -6.017 dBm
  TX Turnaround Power =   -5.879 dBm
   0:  Rx/Tx/Adj =  -89.581,  -48.917,  -63.500
   1:  Rx/Tx/Adj =  -89.248,  -47.917,  -63.500
   2:  Rx/Tx/Adj =  -88.248,  -47.917,  -63.500
   3:  Rx/Tx/Adj =  -88.248,  -47.917,  -63.500
   4:  Rx/Tx/Adj =  -89.248,  -47.583,  -63.500
   5:  Rx/Tx/Adj =  -87.248,  -47.917,  -63.500
   6:  Rx/Tx/Adj =  -85.915,  -48.917,  -63.500
   7:  Rx/Tx/Adj =  -86.248,  -49.583,  -63.500
   8:  Rx/Tx/Adj =  -87.248,  -49.583,  -63.500
   9:  Rx/Tx/Adj =  -85.915,  -49.917,  -63.500
  10:  Rx/Tx/Adj =  -85.915,  -50.250,  -63.500
  11:  Rx/Tx/Adj =  -87.581,  -49.917,  -63.500
  12:  Rx/Tx/Adj =  -89.581,  -48.583,  -63.500
  13:  Rx/Tx/Adj =  -88.581,  -47.917,  -63.500
  14:  Rx/Tx/Adj =  -89.581,   11.750,    0.000     Start transmitting on the Reverse link here. Start at the Open
  15:  Rx/Tx/Adj =  -89.248,   16.750,    1.000     Loop estimate, and then let closed loop start fine tuning the
  16:  Rx/Tx/Adj =  -87.248,    8.417,   -7.500     Open Loop estimate.
  17:  Rx/Tx/Adj =  -87.248,    3.750,  -12.000
  18:  Rx/Tx/Adj =  -88.248,    4.417,   -9.500
  19:  Rx/Tx/Adj =  -87.915,    5.750,   -9.500
  20:  Rx/Tx/Adj =  -88.581,    0.083,  -14.000
  21:  Rx/Tx/Adj =  -89.248,   -1.583,  -16.000
  22:  Rx/Tx/Adj =  -86.248,    2.417,  -12.000
  23:  Rx/Tx/Adj =  -85.581,    0.417,  -14.000
```

```
    24:  Rx/Tx/Adj =  -87.581,    4.417,   -9.500
    25:  Rx/Tx/Adj =  -88.248,    3.417,  -11.000
    26:  Rx/Tx/Adj =  -87.915,    1.750,  -13.000
    27:  Rx/Tx/Adj =  -88.581,    3.417,  -12.000
    28:  Rx/Tx/Adj =  -83.581,    0.750,  -13.000
    29:  Rx/Tx/Adj =  -82.581,   -1.250,  -13.000
    30:  Rx/Tx/Adj =  -83.915,    0.083,   -9.500
    31:  Rx/Tx/Adj =  -85.248,    2.417,   -8.500
    32:  Rx/Tx/Adj =  -89.248,    5.083,   -7.500
    33:  Rx/Tx/Adj =  -87.915,    5.750,   -8.500
    34:  Rx/Tx/Adj =  -86.248,    2.750,  -11.000
    35:  Rx/Tx/Adj =  -83.248,   -1.583,  -14.000
    36:  Rx/Tx/Adj =  -85.915,    0.083,  -12.000
    37:  Rx/Tx/Adj =  -86.581,    2.750,   -9.500
    38:  Rx/Tx/Adj =  -88.248,    1.417,  -12.000
    39:  Rx/Tx/Adj =  -87.248,   -0.917,  -15.000
    40:  Rx/Tx/Adj =  -86.581,   -4.583,  -18.500
    41:  Rx/Tx/Adj =  -89.248,   -1.917,  -16.000
    42:  Rx/Tx/Adj =  -85.915,    0.083,  -14.000
    43:  Rx/Tx/Adj =  -85.915,   -0.917,  -14.000
    44:  Rx/Tx/Adj =  -89.915,   -0.917,  -15.000
    45:  Rx/Tx/Adj =  -86.248,   -2.917,  -17.500
    46:  Rx/Tx/Adj =  -86.581,   -3.583,  -17.500
    47:  Rx/Tx/Adj =  -86.581,   -3.917,  -17.500
    48:  Rx/Tx/Adj =  -85.915,   -0.917,  -14.000
    49:  Rx/Tx/Adj =  -86.915,   -0.917,  -14.000
    50:  Rx/Tx/Adj =  -89.915,   -0.583,  -15.000
    51:  Rx/Tx/Adj =  -86.581,   -3.250,  -18.500
    52:  Rx/Tx/Adj =  -85.915,   -3.583,  -17.500
    53:  Rx/Tx/Adj =  -88.581,   -6.583,  -20.500


05/05/2000 01:47:24.407 [2B] REVERSE TC CAI
  Pilot Strength Measurement Message
    ack_seq 6, msg_seq 3, ack_req 1, encryption 0
    ref_pn 0x0158 =  344 (  344 )
    pilot_strength 20  ( -10.0 dB )                                  PSMM, phone still likes PN344 and PN204
    keep

    pilot_pn_phase[0] 0x3317 => 204 + 23 chips (  204 )
    pilot_strength[0] 34 ( -17.0 dB )
    keep

    pilot_pn_phase[1] 0x6323 => 396 + 35 chips (  396 )              Phone found a new PN to add in SHO, PN396
    pilot_strength[1] 20 ( -10.0 dB )
    keep

05/05/2000 01:47:24.558 [2C] Temporal Analyzer Finger Info Only
  Finger #1 PN=0x00cc =  204 (  204 ): pos=0xee1c, eng=0
  Finger #2 PN=0x00cc =  204 (  204 ): pos=0xedc4, eng=4 (-24.6)
  Finger #3 PN=0x0158 =  344 (  344 ): pos=0xed0f, eng=115 (-10.0)

05/05/2000 01:47:24.558 [2C] Position And Speed Information Read From GPS Receiver
  Latitude 39ø 59' 12.6"N, Longitude -105ø 10' 31.9"W
  Latitude +39.98686ø,      Longitude -105.17553ø, Speed 10 mph, Heading 245, Time: 01:47:11


05/05/2000 01:47:24.820 [30] Temporal Analyzer Finger Info Only
  Finger #1 PN=0x00cc =  204 (  204 ): pos=0xee1c, eng=0
  Finger #2 PN=0x00cc =  204 (  204 ): pos=0xedc5, eng=0
  Finger #3 PN=0x0158 =  344 (  344 ): pos=0xed10, eng=74 (-11.9)

05/05/2000 01:47:24.930 [31] FORWARD TC CAI
  Extended Handoff Direction Message
    ack_seq 3, msg_seq 7, ack_req 1, encryption 0                    EHDM to the PSMM
    implied action time, hdm_seq 1, PSMM 521 ms ago
    srch_win_a 6, t_add 28, t_drop 32, t_comp 8, t_tdrop 2
      PN 0x0158 =  344 (  344 ), combine 0, code channel 20          For PN344 use Walsh 20
```

```
    PN 0x00cc =  204 (  204 ), combine 0, code channel 41          For PN204 use Walsh 41
    PN 0x018c =  396 (  396 ), combine 0, code channel 36          For PN396 use Walsh 36

05/05/2000 01:47:24.987 [32] REVERSE TC CAI
  Handoff Completion Message
    ack_seq 7, msg_seq 4, ack_req 1, encryption 0
    last_hdm_seq 1
    pilot_pn 0x0158 =  344 (  344 )                                ACK to the EHDM with three way SHO
    pilot_pn 0x00cc =  204 (  204 )
    pilot_pn 0x018c =  396 (  396 )

05/05/2000 01:47:25.135 [34] Temporal Analyzer Finger Info Only
  Finger #1 PN=0x0158 =  344 (  344 ): pos=0xed12, eng=124 (-9.7)
  Finger #2 PN=0x018c =  396 (  396 ): pos=0xee28, eng=24 (-16.8)
  Finger #3 PN=0x00cc =  204 (  204 ): pos=0xedc5, eng=0

05/05/2000 01:47:25.135 [34] Position And Speed Information Read From GPS Receiver
  Latitude 39ø 59' 12.6"N, Longitude -105ø 10' 32.1"W
  Latitude +39.98686ø,     Longitude -105.17560ø, Speed 14 mph, Heading 260, Time: 01:47:12

05/05/2000 01:47:26.033 [3F] Temporal Analyzer Finger Info Only
  Finger #1 PN=0x0158 =  344 (  344 ): pos=0xed11, eng=62 (-12.7)
  Finger #2 PN=0x018c =  396 (  396 ): pos=0xee28, eng=99 (-10.6)
  Finger #3 PN=0x00cc =  204 (  204 ): pos=0xedc6, eng=37 (-14.9)


05/05/2000 01:47:26.362 [03] Temporal Analyzer Finger Info Only
  Finger #1 PN=0x0158 =  344 (  344 ): pos=0xed25, eng=0
  Finger #2 PN=0x018c =  396 (  396 ): pos=0xee28, eng=71 (-12.1)
  Finger #3 PN=0x00cc =  204 (  204 ): pos=0xedc5, eng=20 (-17.6)

05/05/2000 01:47:29.087 [25] REVERSE TC CAI
  Pilot Strength Measurement Message
    ack_seq 0, msg_seq 5, ack_req 1, encryption 0                  PSMM, phone likes 344 and 396, wants to dump 204
    ref_pn 0x0158 =  344 (  344 )
    pilot_strength 18  ( -9.0 dB )
    keep

    pilot_pn_phase[0] 0x3317 => 204 + 23 chips (  204 )
    pilot_strength[0] 38 ( -19.0 dB )
    drop

    pilot_pn_phase[1] 0x6323 => 396 + 35 chips (  396 )
    pilot_strength[1] 31 ( -15.5 dB )
    keep


05/05/2000 01:47:29.450 [2A] FORWARD TC CAI
  Extended Handoff Direction Message
    ack_seq 5, msg_seq 1, ack_req 1, encryption 0
    implied action time, hdm_seq 2, PSMM 361 ms ago
    srch_win_a 6, t_add 28, t_drop 32, t_comp 8, t_tdrop 2
     PN 0x0158 =  344 (  344 ), combine 0, code channel 20         EHDM with two way SHO, 204 is dropped
     PN 0x018c =  396 (  396 ), combine 0, code channel 36



05/05/2000 01:47:29.507 [2A] REVERSE TC CAI
  Handoff Completion Message
    ack_seq 1, msg_seq 6, ack_req 1, encryption 0
    last_hdm_seq 2
    pilot_pn 0x0158 =  344 (  344 )                                ACK to the EHDM
    pilot_pn 0x018c =  396 (  396 )

05/05/2000 01:47:29.507 [2A] Position And Speed Information Read From GPS Receiver
  Latitude 39ø 59' 12.6"N, Longitude -105ø 10' 33.9"W
  Latitude +39.98685ø,     Longitude -105.17611ø, Speed 29 mph, Heading 269, Time: 01:47:16
```

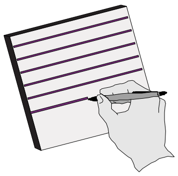
```
05/05/2000 01:47:29.777 [2E] Temporal Analyzer Finger Info Only
   Finger #1 PN=0x0158 =  344 (  344 ): pos=0xed16, eng=41 (-14.5)
   Finger #2 PN=0x018c =  396 (  396 ): pos=0xee29, eng=7 (-22.1)
   Finger #3 PN=0x0158 =  344 (  344 ): pos=0xed18, eng=0

05/05/2000 01:47:30.227 [33] REVERSE TC CAI
   Pilot Strength Measurement Message
      ack_seq 2, msg_seq 7, ack_req 1, encryption 0
      ref_pn 0x0158 =  344 (  344 )
      pilot_strength 20  ( -10.0 dB )
      keep

      pilot_pn_phase[0] 0x6323 => 396 + 35 chips (  396 )         New PSMM, wants 344 and 396, and wants to add 300
      pilot_strength[0] 34 ( -17.0 dB )
      keep

      pilot_pn_phase[1] 0x4b1f => 300 + 31 chips (  300 )
      pilot_strength[1] 25 ( -12.5 dB )
      keep

05/05/2000 01:47:30.970 [3D] FORWARD TC CAI
   Extended Handoff Direction Message
      ack_seq 7, msg_seq 3, ack_req 1, encryption 0
      implied action time, hdm_seq 3, PSMM 741 ms ago
      srch_win_a 6, t_add 28, t_drop 32, t_comp 8, t_tdrop 2
        PN 0x0158 =  344 (  344 ), combine 0, code channel 20     EHDM with three sectors in SHO
        PN 0x012c =  300 (  300 ), combine 0, code channel 20
        PN 0x018c =  396 (  396 ), combine 0, code channel 36

05/05/2000 01:47:31.027 [3D] REVERSE TC CAI
   Handoff Completion Message
      ack_seq 3, msg_seq 0, ack_req 1, encryption 0
      last_hdm_seq 3
      pilot_pn 0x0158 =  344 (  344 )
      pilot_pn 0x012c =  300 (  300 )                             ACK to EHDM
      pilot_pn 0x018c =  396 (  396 )

05/05/2000 01:48:26.867 [37] REVERSE TC CAI
   Release Order                                                  Call is over, release from mobile
      ack_seq 1, msg_seq 6, ack_req 1, encryption 0
      Normal release

05/05/2000 01:48:26.875 [37] Temporal Analyzer Finger Info Only
   Finger #1 PN=0x0158 =  344 (  344 ): pos=0xed4c, eng=32 (-15.5)
   Finger #2 PN=0x012c =  300 (  300 ): pos=0xedf1, eng=111 (-10.1)
   Finger #3 PN=0x00cc =  204 (  204 ): pos=0xedb1, eng=35 (-15.2)

05/05/2000 01:48:26.875 [37] Position And Speed Information Read From GPS Receiver
   Latitude 39ø 59' 12.4"N, Longitude -105ø 11' 27.6"W
   Latitude +39.98678ø,      Longitude -105.19100ø, Speed 46 mph, Heading 267, Time: 01:48:13

05/05/2000 01:48:27.108 [3A] FORWARD TC CAI
   Release Order
      ack_seq 6, msg_seq 7, ack_req 0, encryption 0
      implied action time                                         Release from Base Station
      Ordq 0x00


05/05/2000 01:48:27.148 [3B] FORWARD TC CAI
   Release Order
      ack_seq 6, msg_seq 7, ack_req 0, encryption 0               A 2nd release from Base Station
      implied action time
      Ordq 0x00


05/05/2000 01:48:27.476 [3F] Temporal Analyzer Finger Info Only
   Finger #1 PN=0x0000 =    0 (    0 ): pos=0x45f1, eng=76 (-11.8)
   Finger #2 PN=0x0000 =    0 (    0 ): pos=0x46c4, eng=0
```

Finger #3 PN=0x00cc = 204 (204): pos=0x45f8, eng=0

05/05/2000 01:48:27.730 [02] SYNC CAI	
Sync Channel Message	When released from Traffic, we go back to Init
p_rev 3, bit_len: 170 (+ Len_byte + CRC = 3 superframes)	
min_p_rev 1	Minimum p_rev this Base Station will talk to is one
sid 78	Network SID = 78
nid 1	Network ID=1
pilot_pn 0x012c = 300 (300)	Listening in Idle mode to PN300
lc_state 35FF5D2FDE5	42 bits of long code state
sys_time 1DDF97888 (05/05/2000 01:48:28.160 diff=0.430 sec)	GPS time
lp_sec 13	13 leap seconds since Jan13 1980
ltm_off 0x34 (-6.0 hours)	Local time offset from GPS in Denver is 6 hours
daylt 1	We are using daylight savings time
prat 0	9600 bps Paging Channel
cdma_freq 384	384 has the primary Paging Channel

05/05/2000 01:48:28.243 [09] Bad Paging Channel CRC (slot=137)

05/05/2000 01:48:28.263 [09] PAGING CAI
Access Parameters Message
pilot_pn 0x012c = 300 (300)
acc_msg_seq 1
acc_chan 0
nom_pwr 3, (nom_pwr_ext=0)
init_pwr -3
pwr_step 5
num_step 3
max_cap_sz 3
pam_sz 1
psist_0_9:0, 10:0, 11:0, 12:0, 13:0, 14:0, 15:0
msg_psist 0
reg_psist 0
probe_pn_ran 0
acc_tmo 1
probe_bkoff 0
bkoff 0
max_req_seq 3, max_rsp_seq 3
auth 0



Comments/Notes

QUALCOMM cdma university

Section 7: Handoffs

SECTION
7

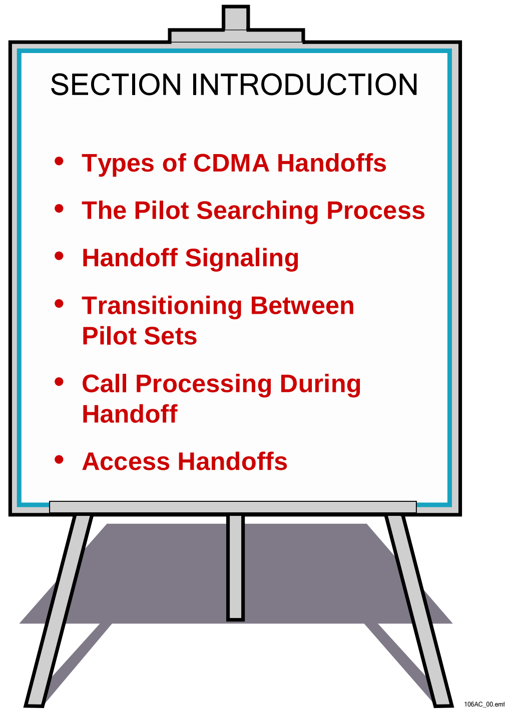
Handoffs

Notes

QUALCOMM cdma university

Section Introduction

CDMA2000 1x RC1 & RC2 Section 7-2



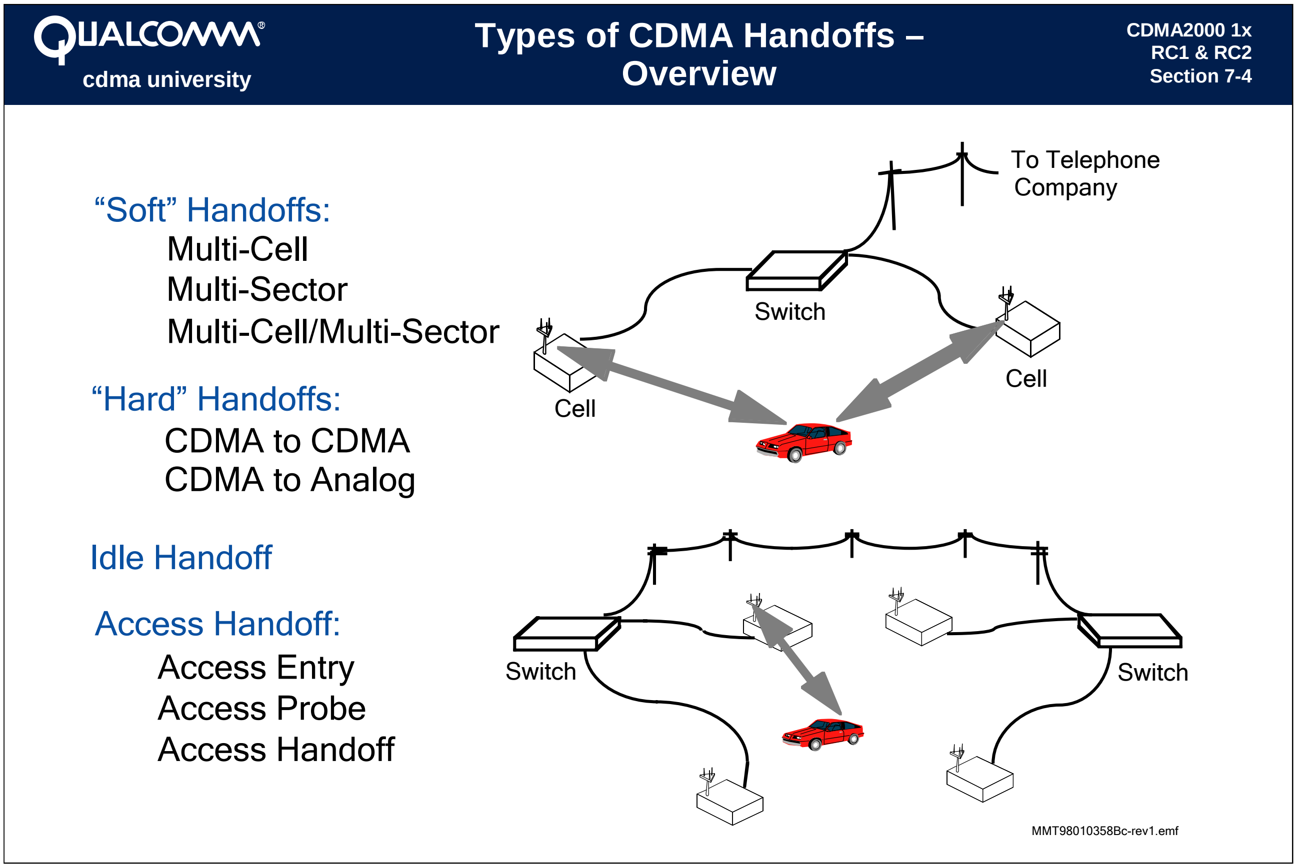
Notes

Section Learning Objectives

Describe Handoffs in a CDMA System:

- List the types of CDMA handoffs.
- Describe the Pilot Searching process.
- Recognize the messages important in the handoff process and explain how each message is used.
- List and explain key handoff parameters.

Notes



Types of CDMA Handoffs – Overview

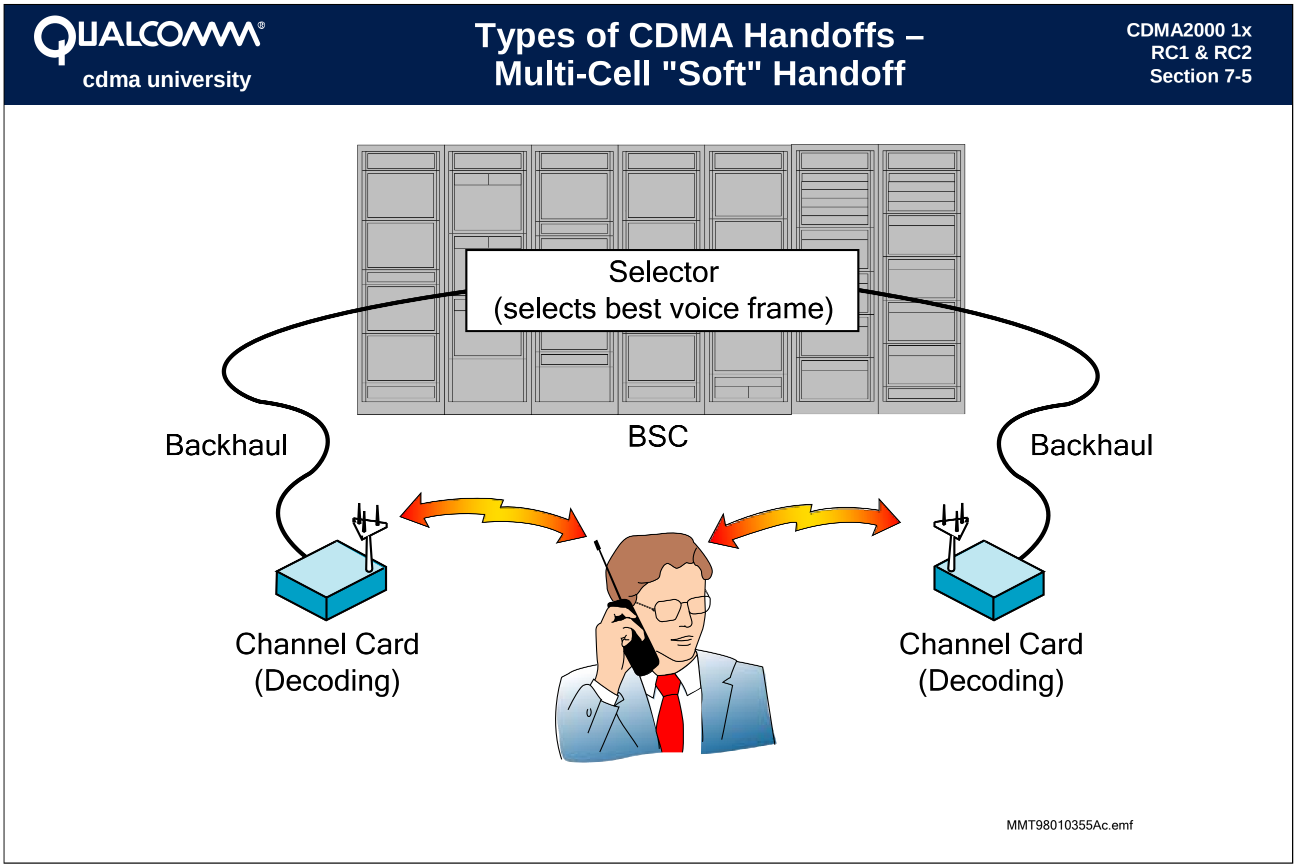
CDMA supports handoffs of the mobile from one cell to another while the mobile is on a Traffic Channel or in the Idle state.

The in-traffic transition from one cell to another can be either a *soft handoff* or a *hard handoff*. These terms will be discussed later in this section.

Transition from one cell to another while in the Idle state must be a hard handoff.

Access handoff has multiple forms:

- Access Entry handoff is an Idle handoff before the handoff process begins.
- Access Probe Handoff sends the Access probes to different sectors or different Base Stations.
- Access Handoff transfers the reception of the Paging Channel from one Base Station to another while the mobile is in the System Access State, but after an Access Attempt.



Soft Handoff is Mobile Assisted

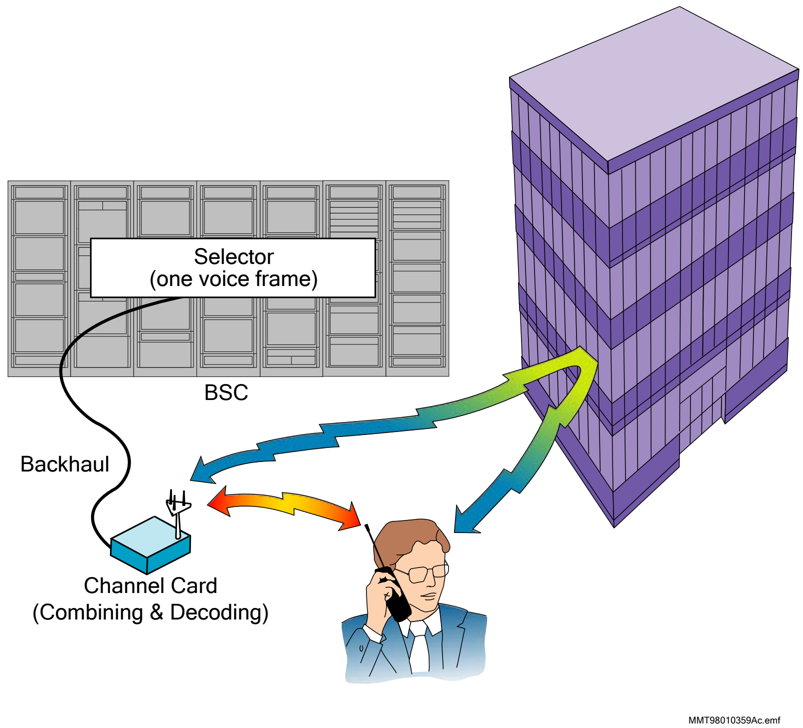
Soft handoff is a the process of establishing a link with a target cell before breaking the link with a serving cell.

In the CDMA system the mobiles continuously search for Pilot Channels on the current frequency. The purpose of this search is to detect potential candidates for handoff. When the mobile detects a Pilot Channel that is not associated with any of the Forward Traffic Channels currently demodulated, it sends a message to the serving cell. This report contains the PN phase (PN offset plus differential path delay) at which the Pilot Channel is received and an estimate of the SNR of the Pilot Channel. The PN offset is then obtained by the cell (or BSC) from the PN phase, and used to determine the identity of the Pilot Channel (i.e., which cell is transmitting it). The PN phase can also be used to obtain an estimate of the path delay between the mobile and the target cell, which in turn facilitates acquisition of the mobile by that cell. The Pilot Channel SNR provides an indication to the system as to the importance of setting up the handoff.

Requires Both Cells to Be on the Same Frequency

The mobile typically contains only one RF receiver section. Therefore soft handoff requires that both the serving cell and the target cell be transmitting on the same frequency.

Types of CDMA Handoffs – Multi-Cell "Softer" Handoff



All Cells Deliver Vocoded Frames to the BSC

All cells participating in a soft handoff transmit identical frames. The mobile combines the frames and presents a single frame to the vocoder. The Channel element performs this same function in each of the cells involved in the handoff. All cells deliver vocoded frames to the BSC.

Softer Handoff

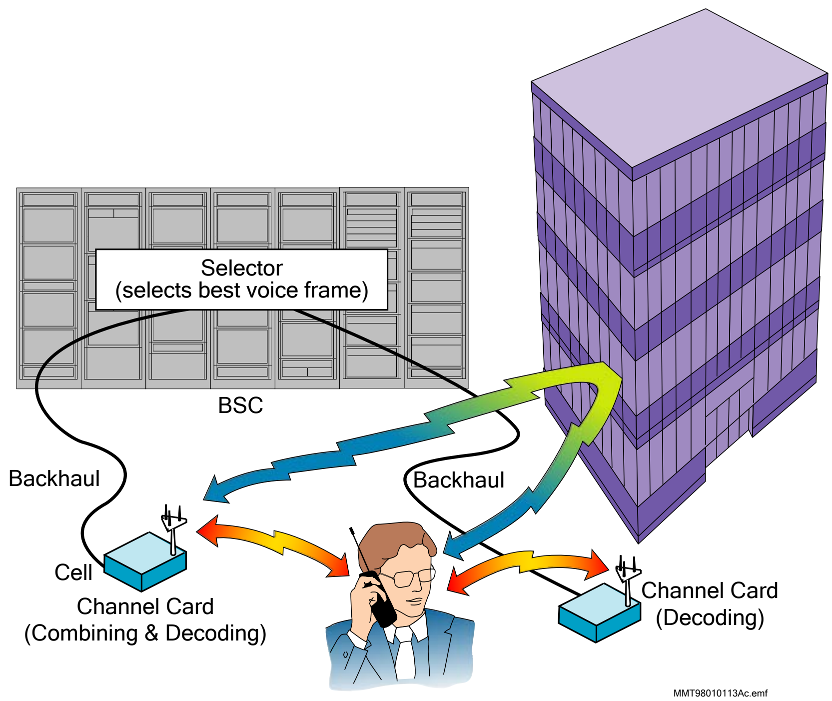
Softer handoff is a handoff between two sectors of the same cell.

Signals received by different sectors can all be directed to the same rake receiver in the BTS and combined non-coherently. Only one voice frame is then advanced to the BSC. Softer handoff enables greater efficiency in the use of hardware. Only one Channel element is required to support a softer handoff.

QUALCOMM cdma university

Types of CDMA Handoffs – Multi-Cell/Multi-Sector Handoff

CDMA2000 1x RC1 & RC2 Section 7-7



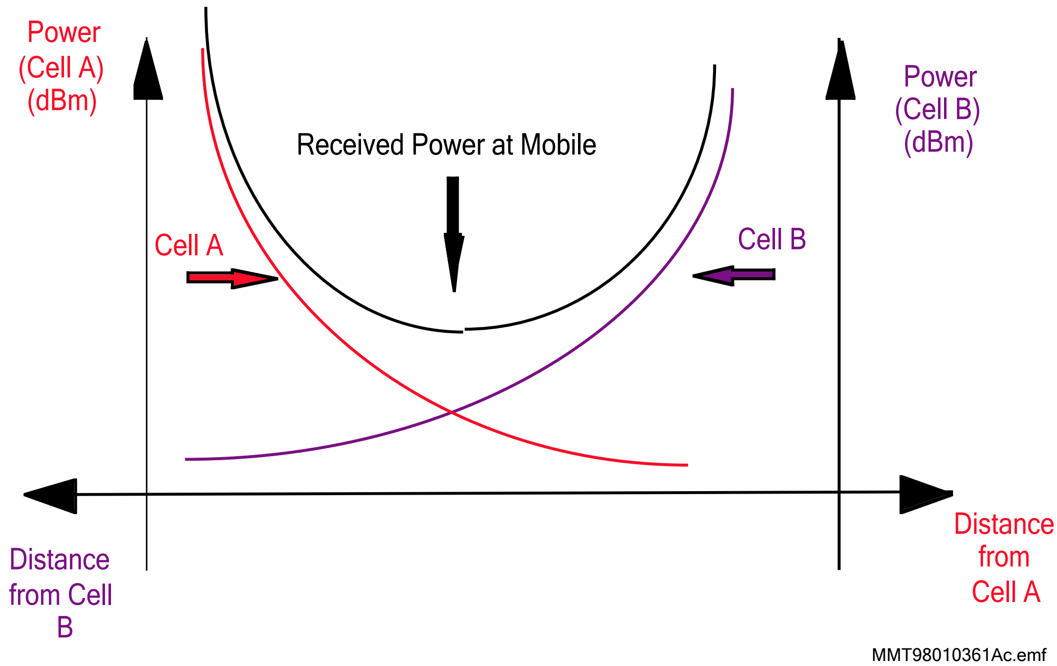
Multi-Cell/Multi-Sector Handoff

Multiple cells and multiple sectors can be involved in a handoff in a variety of ways. The figure depicts a scenario where a mobile is in softer handoff with two sectors of the same cell and is also in soft handoff with another cell. The BSC will receive a vocoded frame from each cell and choose the frame that is error-free.

QUALCOMM cdma university

Types of CDMA Handoffs – Soft Handoff Gain

CDMA2000 1x RC1 & RC2 Section 7-8



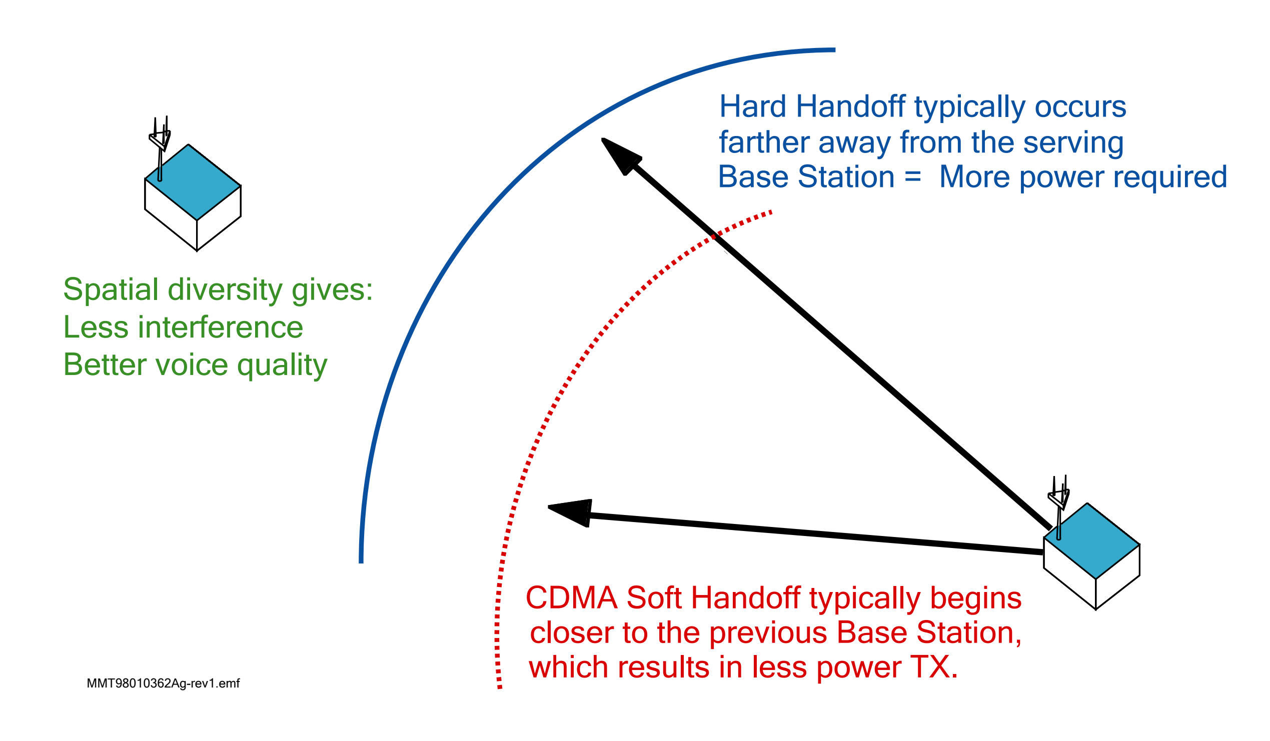
Soft Handoff Gain

CDMA receivers use a rake receiver design. This receiver has at least four fingers in the mobile. One of the fingers is used for searching and correlating with different Pilots and strong multipaths. During handoff two or even three fingers will be correlating with different Pilots and combining the received energy. This capability greatly improves the voice quality while reducing the transmit power requirement on both Forward and Reverse links.

QUALCOMM cdma university

Types of CDMA Handoffs – Soft Handoff Increases Capacity

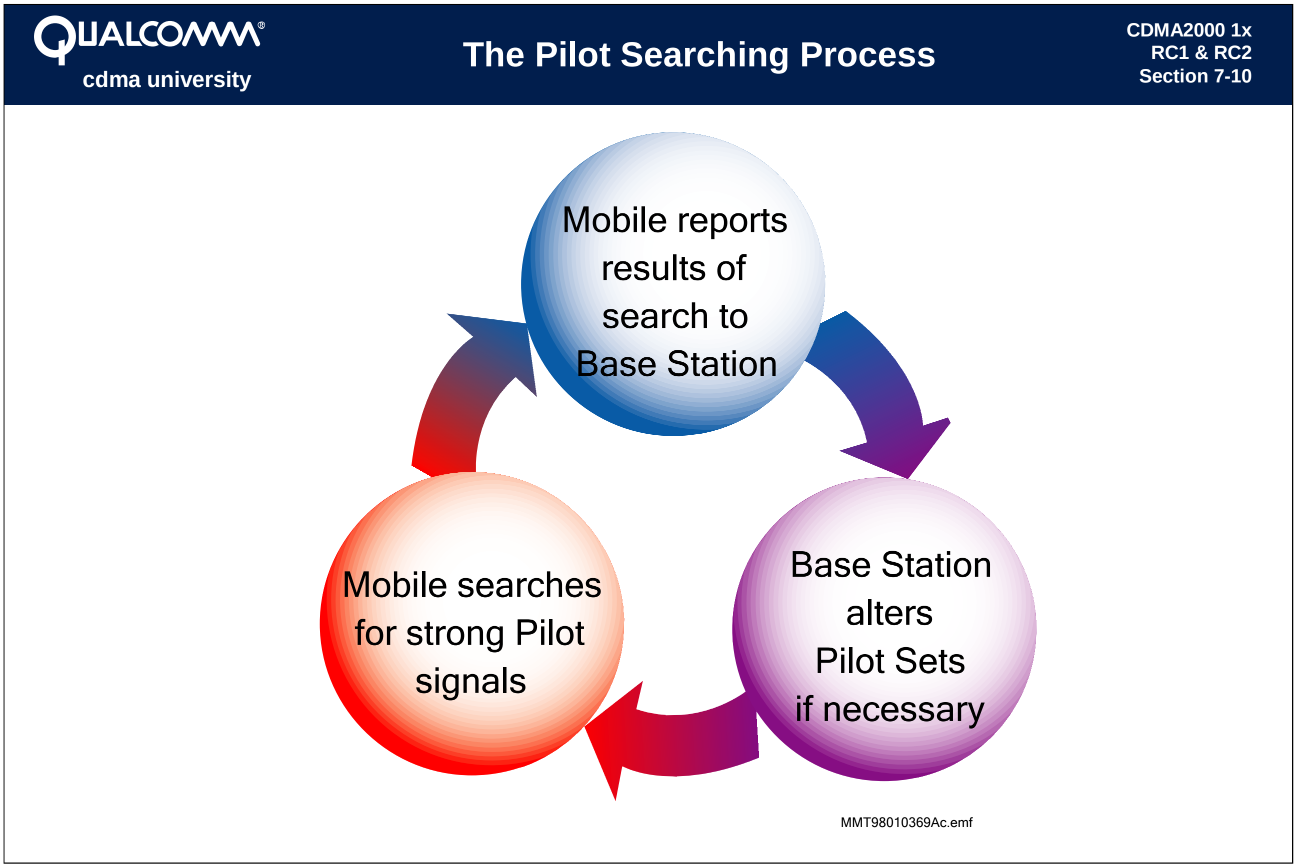
CDMA2000 1x RC1 & RC2 Section 7-9



Soft Handoff Increases Capacity

There are several important reasons to place in soft handoff any additional Base Stations that can be detected by the mobile as soon as possible:

1. **Improved voice quality:** Cell boundaries usually offer poor coverage coupled with increased interference from other cells and therefore, Forward Traffic Channel diversity from additional cells will improve voice quality.
2. **Controlled mobile interference:** While on a boundary of a cell, the mobile's interference to mobiles in other cells is maximal and therefore, it is important to be able to power control it from these cells.
3. **Reduce call dropping probabilities:** Handoff areas are areas in which the Forward link is most vulnerable. A slow handoff process coupled with a vehicle moving at a high speed may cause the call to be dropped since the mobile might no longer be able to demodulate the Forward link transmitted from the original cell, losing the Handoff Direction Message.
4. **Increase capacity and coverage:** Soft handoff considerably increases both the capacity of a heavily loaded cellular system and the coverage of each individual cell in a lightly loaded system.



The Mobile Searches for Strong Pilots

The searching process is continuous. Searching is conducted not only to find handoff candidates, but also to identify usable multipath arrivals from the serving cell.

The Mobile Reports

The handoff process is *mobile-assisted*. When the mobile detects a Pilot of sufficient strength, it reports the event to the Base Station. The BSC controls this signaling by adjusting thresholds.

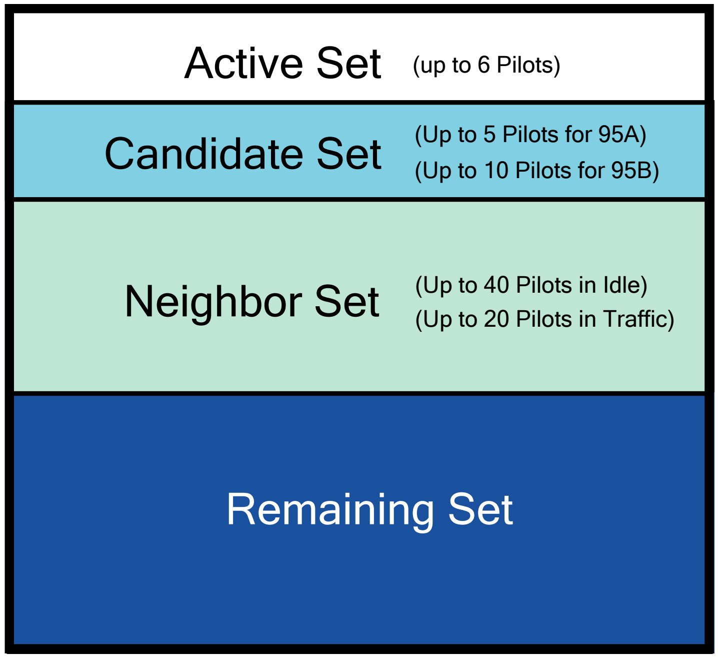
The Base Station Directs

When the Base Station receives a report from the mobile, a handoff decision is made. The Base Station determines the most appropriate course of action and directs the mobile to perform the handoff. The mobile does not conduct handoff autonomously on the Traffic Channel.

QUALCOMM cdma university

The Pilot Searching Process – Pilot Sets

CDMA2000 1x RC1 & RC2 Section 7-11



MMT98010414Ac-rev3.emf

Pilots are Grouped Into Sets

Pilots are grouped into four sets, which prioritize them and increase the efficiency of searching. Searching is prioritized according to the following:

Active Set – Pilot Channels associated with Forward Traffic Channels currently assigned to the mobile. This is a search for additional multipaths of the same Pilot Channels.

Candidate Set – Pilot Channels whose strength, as measured by the mobile, exceeds an over-the-air given threshold.

Neighbor Set – Pilot Channels transmitted by cells in the vicinity of the cells currently transmitting to the mobile. These Pilot Channels are identified for the mobile by the serving BSC.

Remaining Set – All other Pilot Channels that are possible within the current system. This search is conducted to allow the system to configure itself (i.e., cells can be made aware of their “neighbors” through reports received from mobiles rather than by providing careful mapping of the cell), as well as to account for special coverage spots within the cell.

QUALCOMM cdma university

The Pilot Searching Process – Searcher Window Sizes

CDMA2000 1x RC1 & RC2 Section 7-12

Searcher Window Sizes

SRCH_WIN_A SRCH_WIN_N SRCH_WIN_R	Window Size (PN chips)	SRCH_WIN_A SRCH_WIN_N SRCH_WIN_R	Window Size (PN chips)
0	4	8	60
1	6	9	80
2	8	10	100
3	10	11	130
4	14	12	160
5	20	13	226
6	28	14	320
7	40	15	452

MMT98010371Ag.emf

Search Windows

The propagation delay between the BTS and the mobile is not known. This unknown delay produces an unknown shift in the PN codes. The searching process attempts to determine this unknown shift. To do this, the mobile shifts in time the output of its own PN code generators. The shift is centered on the first arriving multipath signal. The amount of shift is called the *search window*. The size of the search window is controlled by the BSC. Specifically, the search window defines the number of PN chips that the mobile will shift as it searches for multipath arrivals.

Search Window Sizes

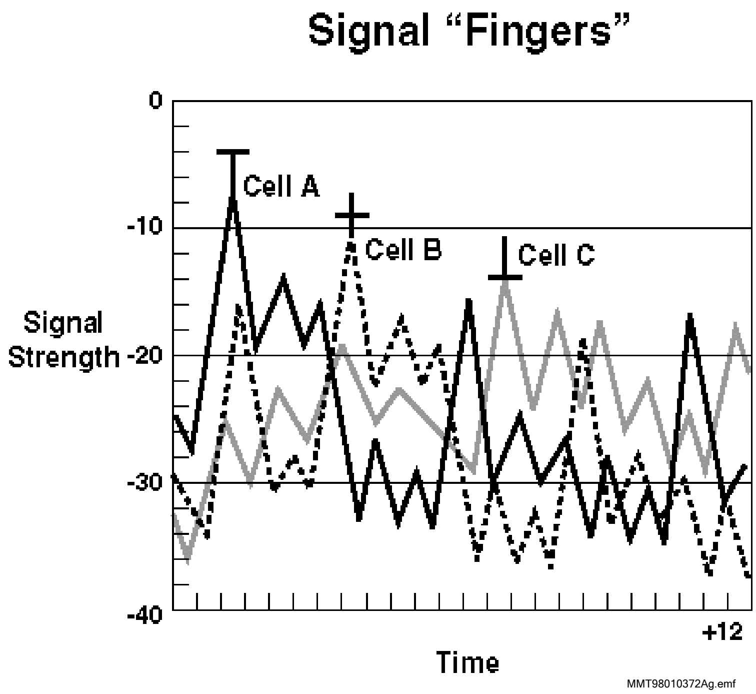
The appropriate size of the search window depends on several factors including the priority of the Pilot, the speed of the searching processors, and the anticipated delay spread of the multipath arrivals. The CDMA standards define three search window parameters. The searching of Pilots in both the Active and Candidate Sets is governed by Search Window "A." Neighbor Set Pilots are searched over Search Window "N" and Remaining Set Pilots over Search Window "R."

Window sizing is a trade-off between search speed and the probability of missing a strong multipath lying outside the search window. As a rule of thumb, the mobile should never miss a direct path in the Active Set (this can happen if a small window is centered on a path that isn't the direct path and the mobile comes out of a shadow). The mobile should also be capable of finding a direct path carrying a Pilot from the Neighbor Set.

cdma university

The Pilot Searching Process – Multipath Arrivals

CDMA2000 1x RC1 & RC2 Section 7-13



Multipath Arrivals

The figure depicts the multipath signals arriving from three different cells. This is a typical display found on QUALCOMM's Mobile Diagnostic Monitor (MDM).

The horizontal axis is time, in PN chips. The vertical axis is the Pilot signal-to-noise ratio E_c/I_o in dB. Each peak on the display indicates a multipath arrival.

The demodulator in this phone can demodulate the three strongest peaks. A cross at the top of a peak indicates that a demodulator is assigned to that multipath.

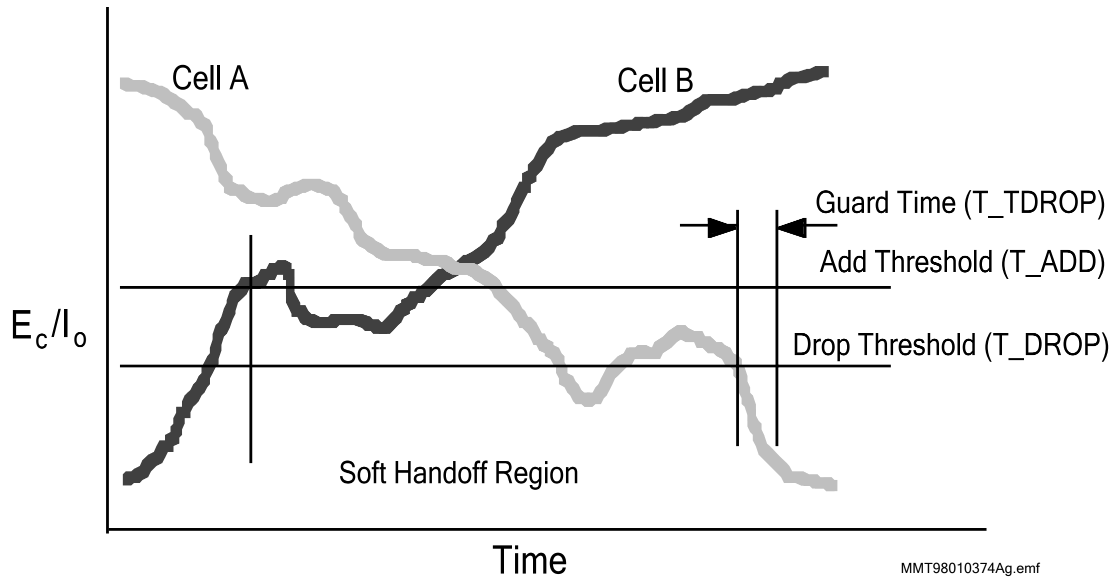
Handoff Signaling

- Pilot Strength Measurement Message
- Handoff Direction Message
- Extended Handoff Direction Message
- Handoff Completion Message
- Analog Handoff Direction Message

Handoff Signaling Messages

The typical exchange between the Base Station and mobile uses the PSMM (Pilot Strength Measurement Message) to report changing Pilot strengths, an EHDM (Extended Handoff Direction Message) to change the Active Pilot Set, and an acknowledgment by the mobile using the HCM (Handoff Completion Message).

Handoff Signaling – Regulating Parameters



Parameters that Regulate Handoff Signaling

Since the time required to detect a new Pilot should be minimized, the amount of filtering done on searcher results for Pilots in the Neighbor Set should be minimal. Therefore, the lower bound on T_ADD is a value high enough to prevent false alarms without relying on extensive filtering. The upper bound on T_ADD is dictated by considerations such as deterioration in voice quality prior to the establishment of the handoff, vulnerability of the Forward Traffic Channel, and the percent of time the network engineer wants to have mobile in handoff.

The upper bound considerations for T_DROP follow from the need to avoid inadvertent loss of a good Pilot (and the consequent loss of a useful Traffic Channel). The lower bound considerations follow from cell size considerations and the requirement to actually let go of a Pilot that is not being used. Lastly, the network engineer should take care of preventing signaling-related thrashing that can result from values of T_ADD and T_DROP that are close to each other, coupled with a small value of T_TDROP.

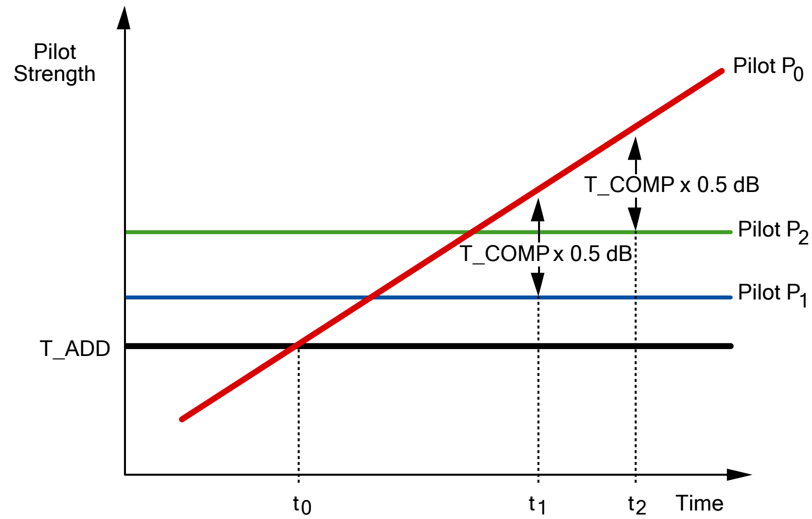
T_COMP should be set to a value that would prevent the mobile from continuously sending Pilot Strength Measurement Messages as a consequence of small changes in the strengths of Pilots in the Active Set and the Candidate Set. However, too large a value would introduce substantial delay before a Pilot Strength Measurement Message is issued, delaying the handoff setup.

A good lower bound on the value of T_TDROP is the time required to establish a handoff, to prevent signaling related thrashing. T_TDROP should also be set in accordance with the specific terrain.

cdma university

Handoff Signaling – The Comparison Threshold

CDMA2000 1x RC1 & RC2
Section 7-16



Candidate Set: Pilot P_0
Active Set: Pilots P_1, P_2
t_0 – Pilot Strength Measurement Message sent, P_0 > T_ADD
t_1 – Pilot Strength Measurement Message sent, P_0 > P_1 + T_COMP x 0.5dB
t_2 – Pilot Strength Measurement Message sent, P_0 > P_2 + T_COMP x 0.5dB

MMT98010375Ag-rev1.emf

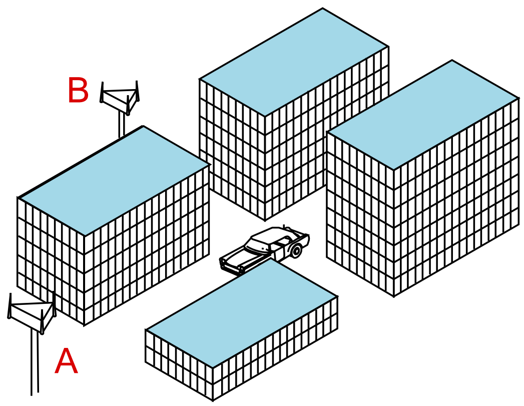
The Comparison Threshold: T_COMP

An additional parameter, T_COMP, is used to control handoff signaling. When the strength of a new Pilot exceeds the strength of the current serving Pilot by the amount of the comparison threshold, the mobile will signal the BTS.

QUALCOMM cdma university

Handoff Signaling – Handoff Drop Timer Expiration Values

CDMA2000 1x RC1 & RC2 Section 7-17



Handoff Drop Timer Expiration Values

T_TDROP	Timer Expiration (seconds)	T_TDROP	Timer Expiration (seconds)
0	0	8	27
1	1	9	39
2	2	10	55
3	4	11	79
4	6	12	112
5	9	13	159
6	13	14	225
7	19	15	319

Handoff Drop Timer

To avoid sending a Pilot Strength Measurement Message requesting to drop a Pilot that is undergoing a fade, the mobile maintains a handoff drop timer for every Pilot in the Active Set and Candidate Set. The timer is started whenever the strength of the corresponding Pilot becomes less than T_DROP and is reset and disabled if the strength of the corresponding Pilot exceeds T_DROP. The timer value is specified using the parameter T_TDROP and the values in the table.

The figure shows how T_TDROP can be used to deliberately maintain a cell in handoff. In the figure, the mobile is in constant communication with cell A. The signal from cell B however, is only received (with substantial strength) when the mobile crosses the intersections in the grid. Since typical handoff setup times can be in seconds, this signal can only be demodulated if the cell is kept in handoff.

QUALCOMM cdma university

Handoff Signaling – Pilot Strength Measurement Message

CDMA2000 1x RC1 & RC2 Section 7-18

Field	Length (bits)
MSG_TYPE	8
ACK_SEQ	3
MSG_SEQ	3
ACK_REQ	3
ENCRYPTION	2
REF_PN	9
PILOT_STRENGTH	6
KEEP	1
Zero or more occurrences of the following record:	
PILOT_PN_PHASE	15
PILOT_STRENGTH	6
KEEP	1
RESERVED	0 - 7 (as needed)

MMT98010377Ag.emf

The Pilot Strength Measurement Message (PSMM)

The mobile sends a PSMM when it finds a Pilot of sufficient strength that is not associated with any of the Forward Traffic Channels currently being demodulated, or when the strength of a Pilot that is associated with one of the Forward Traffic Channels being demodulated drops below a threshold.

The mobile sends a PSMM following the detection of an increase in the strength of a Pilot when:

- The strength of a Neighbor Set or Remaining Set Pilot is found to be above the threshold T_ADD.
- The strength of a Candidate Set Pilot is found to be above T_ADD and a PSMM carrying this information has not been sent since the last Handoff Direction Message was received.
- The strength of a Candidate Set Pilot exceeds the strength of an Active Set Pilot by T_COMP dB and a PSMM carrying this information has not been sent since the last Handoff Direction Message was received.

QUALCOMM cdma university

Handoff Signaling – PSMM Example

CDMA2000 1x RC1 & RC2 Section 7-19

05/05/2000 01:47:22.687 [15] REVERSE TC CAI
Pilot Strength Measurement Message

ack_seq 0, msg_seq 0, ack_req 1, encryption 0	phone is now on Traffic Channel, and sends PSMM on Reverse traffic channel
ref_pn 0x0158 = 344 (344)	
pilot_strength 21 (-10.5 dB)	phone likes PN344 and wants to keep it
keep	
pilot_pn_phase[0] 0x3317 => 204 + 23 chips (204)	phone wants to add PN204 in soft handoff
pilot_strength[0] 19 (-9.5 dB)	
keep	

PSMM Example

This example shows a phone on the Traffic Channel, which is reporting two strong Pilots (at PN offsets 344 and 204) that it would like to have in the Active Set.

The phone reports the strength of the Pilots, and the time offset of the Pilots. The first Pilot reported is the Reference PN, and the subsequent Pilots reported are measured relative to the Reference PN.

Note that the PN phase of pilot 204 is reported not as 204, but as the true PN timing measurement of 3317_{16}.

QUALCOMM cdma university

Handoff Signaling – Extended Handoff Direction Message

CDMA2000 1x RC1 & RC2 Section 7-20

Field	Length (bits)
MSG_TYPE ('00010001')	8
ACK_SEQ	3
MSG_SEQ	3
ACK_REQ	1
ENCRYPTION	2
USE_TIME	1
ACTION_TIME	6
HDM_SEQ	2
SEARCH_INCLUDED	1
SRCH_WIN_A	0 or 4
T_ADD	0 or 6
T_DROP	0 or 6
T_COMP	0 or 4
T_TDROP	0 or 4
HARD_INCLUDED	1
FRAME_OFFSET	0 or 4
PRIVATE_LCM	0 or 1
RESET_L2	0 or 1
RESET_FPC	0 or 1
RESERVED	0 or 1
ENCRYPT_MODE	0 or 2
NOM_PWR_EXT	0 or 1
NOM_PWR	0 or 4
NUM_PREAMBLE	0 or 3
BAND_CLASS	0 or 5
CDMA_FREQ	0 or 11
ADD_LENGTH	3
Additional fields	8 x ADD_LENGTH

Field	Length (bits)
One or more occurrences of the following record:	
PILOT_PN	9
PWR_COMB_IND	1
CODE_CHAN	8
RESERVED	0 - 7 (as needed)

MMT98010378Ag.emf

Handoff Direction Message

The Handoff Direction Message contains three groups of parameters: specifications for Forward Traffic Channels assigned to the mobile, parameters governing the transmission of future PSMM, and parameters that pertain specifically to CDMA-to-CDMA hard handoff.

For each Forward Traffic Channel that is assigned to the mobile, the message identifies the PN offset index used to spread it (the Pilot using the same offset index is then added to the Active Set), its code channel (the Walsh function number used to cover it), and a bit specifying if this Forward Traffic Channel carries identical power control symbols as the previous Forward Traffic Channel listed in the message. Also logically related to this group is the FRAME_OFFSET parameter that is specified only once.

QUALCOMM cdma university

Handoff Signaling – Handoff Direction Message Example

CDMA2000 1x RC1 & RC2 Section 7-21

05/05/2000 01:47:24.930 [31] FORWARD TC CAI
Extended Handoff Direction Message
ack_seq 3, msg_seq 7, ack_req 1, encryption 0 — EHDM to the PSMM

implied action time, hdm_seq 1, PSMM 521 ms ago
srch_win_a 6, t_add 28, t_drop 32, t_comp 8, t_tdrop 2
PN 0x0158 = 344 (344), combine 0, code channel 20 — for PN344 use Walsh 20
PN 0x00cc = 204 (204), combine 0, code channel 41 — for PN204 use Walsh 41
PN 0x018c = 396 (396), combine 0, code channel 36 — for PN396 use Walsh36

Notes

QUALCOMM cdma university

Handoff Signaling – Handoff Completion Message

CDMA2000 1x RC1 & RC2 Section 7-22

Field	Length (bits)
MSG_TYPE;	8
ACK_SEQ	3
MSG_SEQ	3
ACK_REQ	1
ENCRYPTION	2
LAST_HDM_SEQ	2
One or more occurrencesof the following field:	
PILOT_PN	9
RESERVED	0 - 7 (as needed)

MMT98010379Ag.emf

Handoff Completion Message

The Handoff Completion Message is transmitted by the mobile on the Reverse Traffic Channel to inform the system that the handoff is completed (i.e., after tuning to the new Forward Traffic Channels specified in the Handoff Direction Message). The Handoff Completion Message carries the Pilot offset indices of the Pilots in the Active Set.

QUALCOMM cdma university

Handoff Signaling – Handoff Completion Example

CDMA2000 1x RC1 & RC2 Section 7-23

05/05/2000 01:47:24.987 [32] REVERSE TC CAI

Handoff Completion Message

ack_seq 7, msg_seq 4, ack_req 1, encryption 0

last_hdm_seq 1

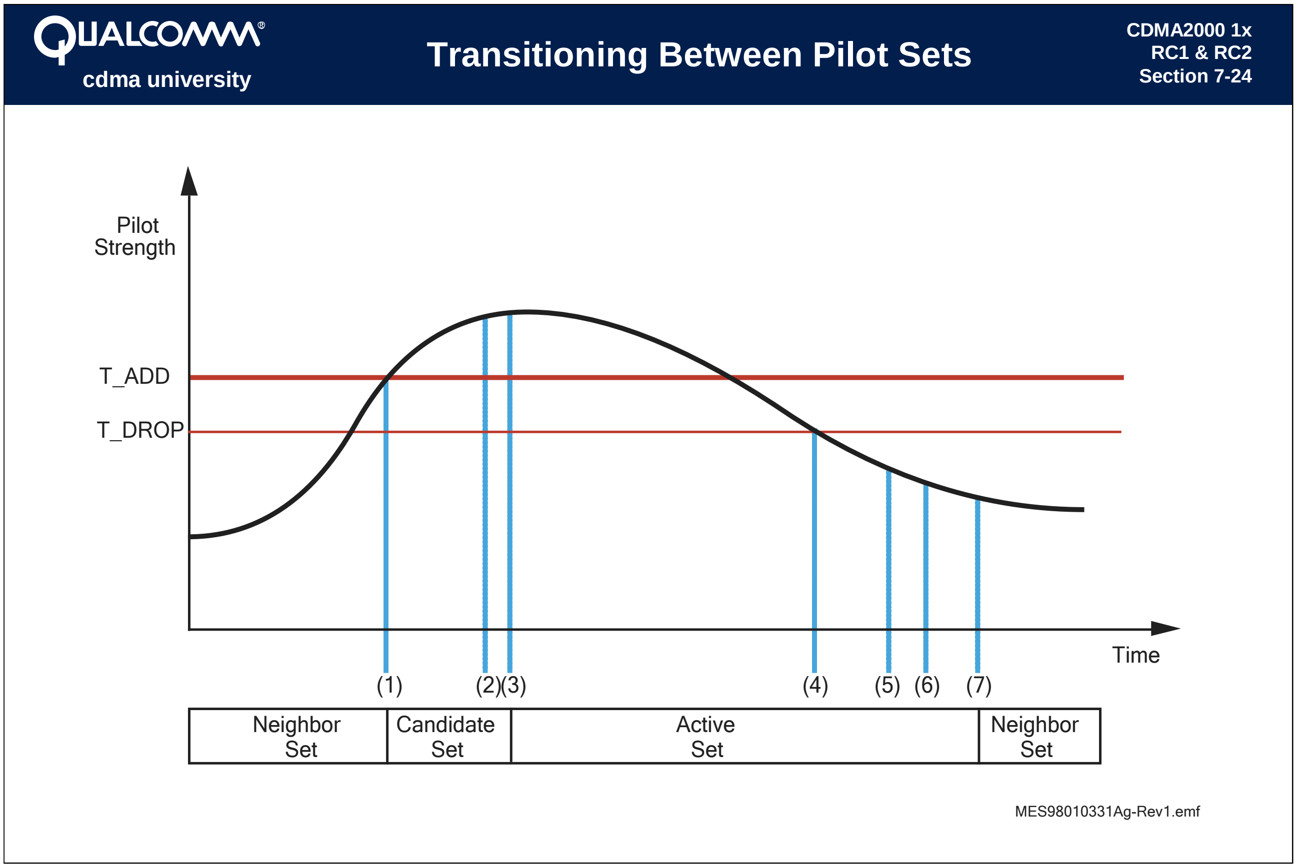
pilot_pn 0x0158 = 344 (344) ACK to the EHDM with three way SHO

pilot_pn 0x00cc = 204 (204)

pilot_pn 0x018c = 396 (396)

Handoff Completion Example

This example of a Handoff Completion Message acknowledges three PN's (344, 204, 396) in the Active Set.



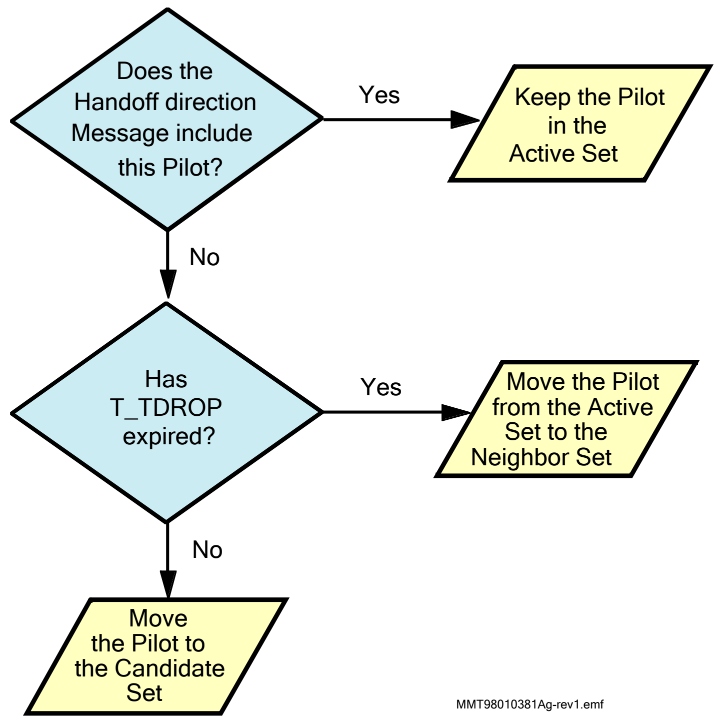
The Mobile Adjusts the Priority of Pilots As Necessary

When the strength of a Pilot rises above T_ADD, the mobile autonomously adds that Pilot to its Candidate Set and signals the Base Station by sending a PSMM. If the Base Station directs the mobile to handoff, the new Pilot is added to the mobile's Active Set. If the strength of the Pilot falls below T_DROP for a sufficient period of time, T_TDROP, the mobile again signals the Base Station with a PSMM.

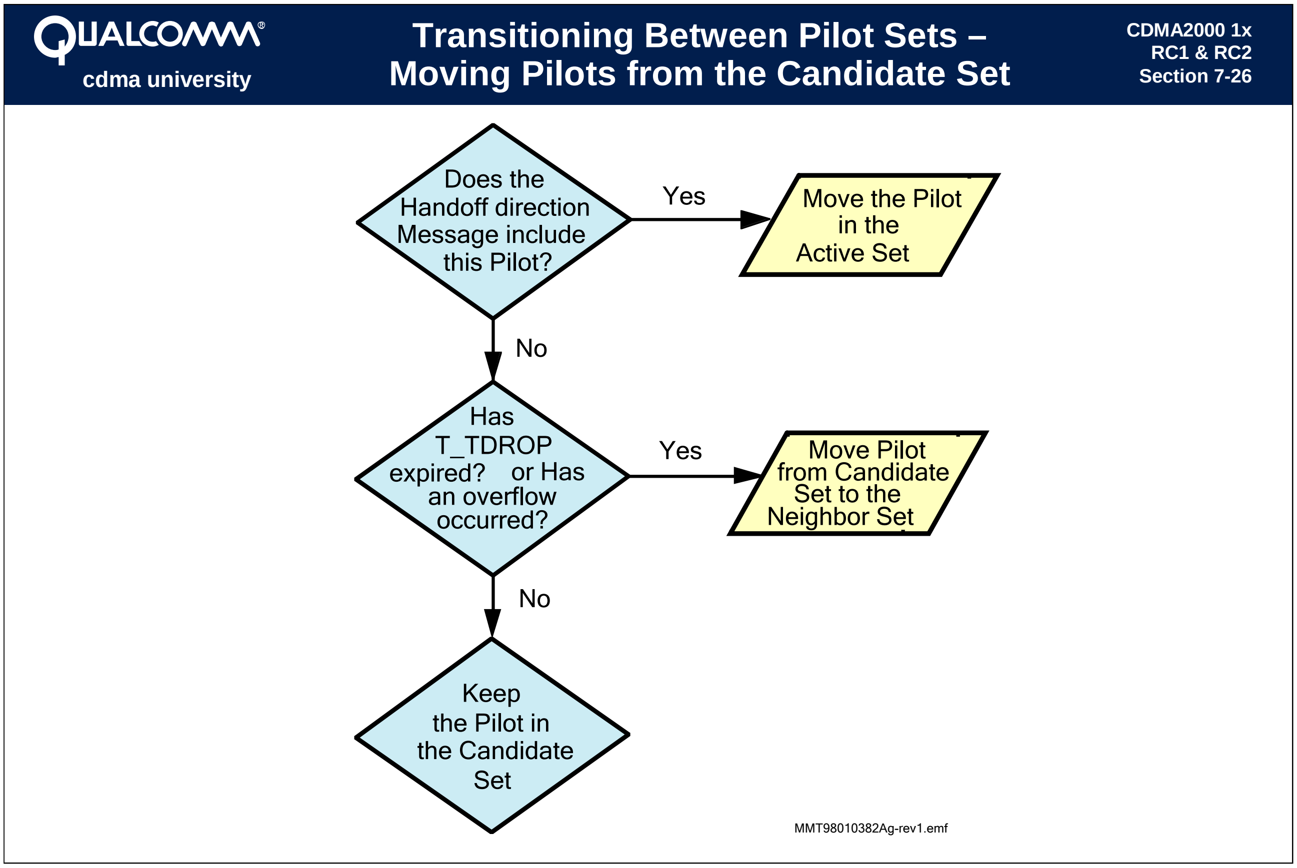
QUALCOMM cdma university

Transitioning Between Pilot Sets – Moving Pilots from the Active Set

CDMA2000 1x RC1 & RC2 Section 7-25



Notes

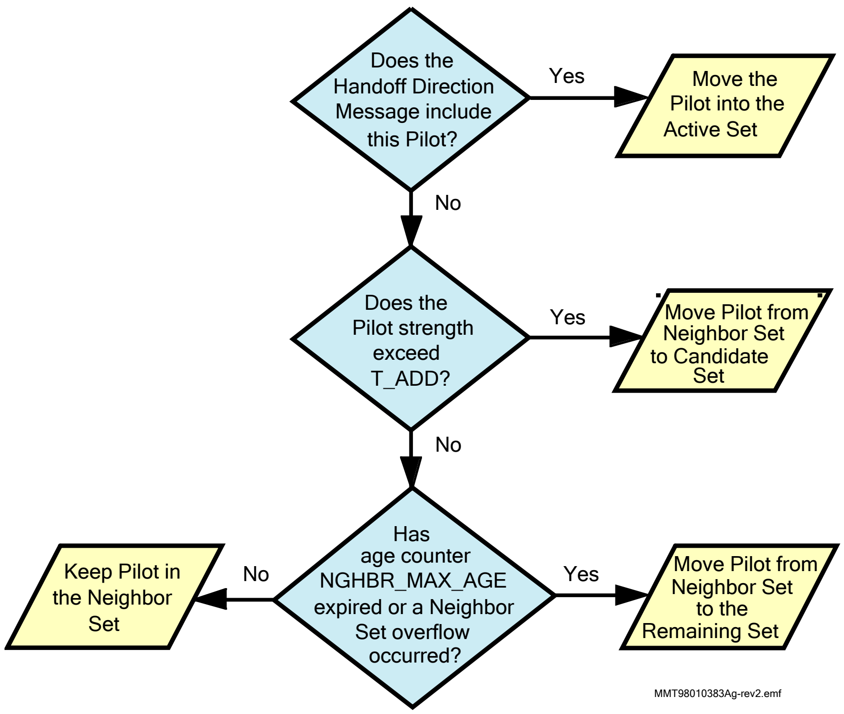

QUALCOMM
cdma university
Transitioning Between Pilot Sets –
Moving Pilots from the Candidate Set
CDMA2000 1x
RC1 & RC2
Section 7-26
Does the Handoff direction Message include this Pilot?
Yes
Move the Pilot in the Active Set
No
Has T_TDROP expired? or Has an overflow occurred?
Yes
Move Pilot from Candidate Set to the Neighbor Set
No
Keep the Pilot in the Candidate Set
MMT98010382Ag-rev1.emf

Notes

QUALCOMM cdma university

Transitioning Between Pilot Sets – Moving Pilots from the Neighbor Set

CDMA2000 1x RC1 & RC2 Section 7-27

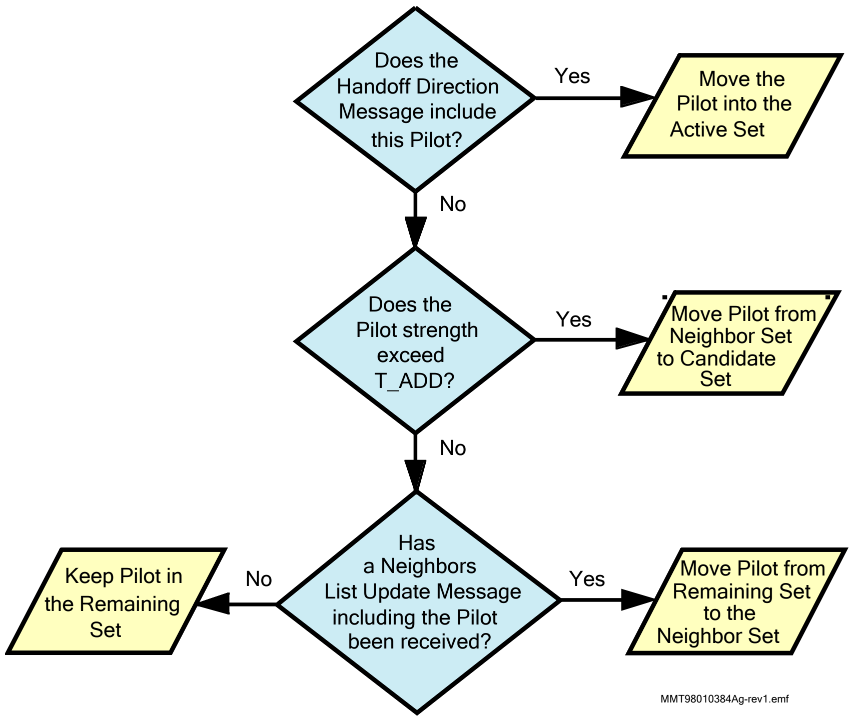


Notes

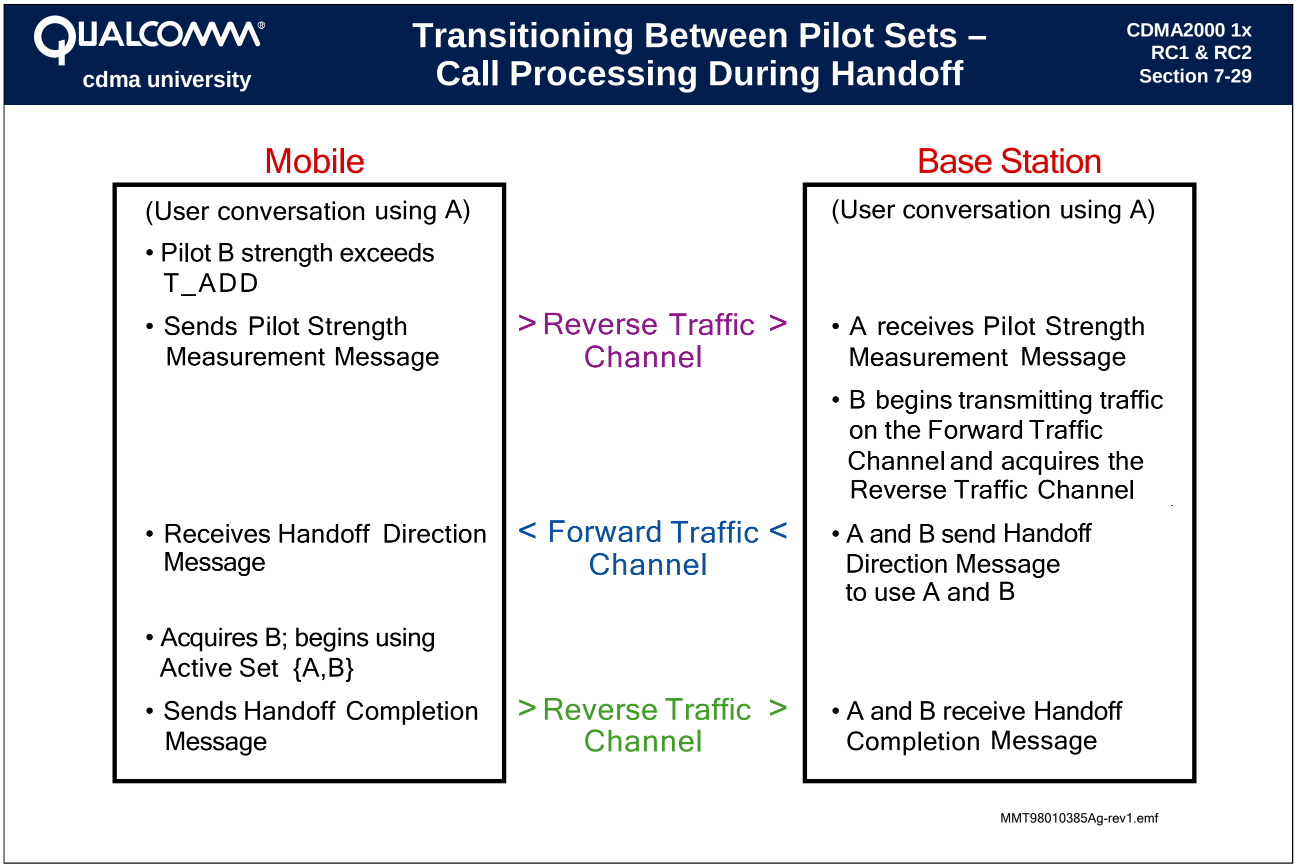
cdma university

Transitioning Between Pilot Sets – Moving Pilots from the Remaining Set

CDMA2000 1x RC1 & RC2 Section 7-28



Notes



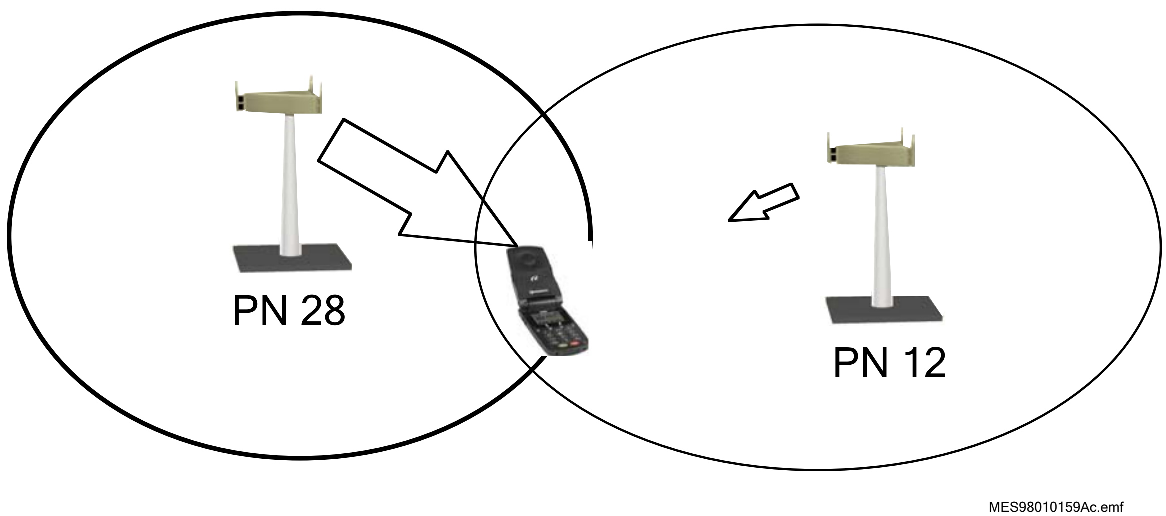
Call Processing During Traffic Handoff

The figure shows an example of call flow between the mobile and the Base Station during soft handoff in the Traffic state.

QUALCOMM cdma university

Transitioning Between Pilot Sets – TIA/EIA-95B Unnecessary Handoff

CDMA2000 1x RC1 & RC2 Section 7-30



The TIA/EIA-95B Handoff Technique

The current procedure is not necessarily optimal but does have the advantage of simplicity since adding or dropping Pilots from the Active Set is based on a set of fixed thresholds (T_ADD and T_DROP). TIA/EIA-95 defines a more optimal approach that is based on the understanding that the combined Pilot E_c/I_o of all the Pilots in the Active Set ultimately drives the performance of the Forward link.

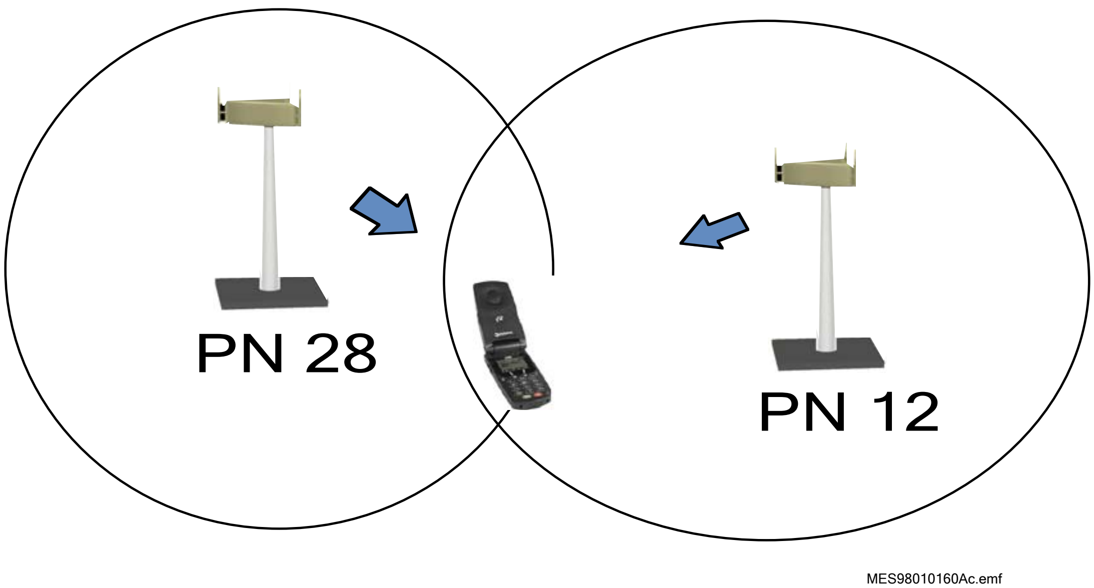
Take the following for example:

- A mobile that is currently demodulating a Base Station with a Pilot E_c/I_o of -6 dB, suddenly detects a Pilot crossing the T_ADD threshold (-13 dB). Very little would be gained by adding this Pilot to the Active Set. On the other hand, a mobile demodulating a Pilot with E_c/I_o = -12 dB will gain considerably by adding a Base Station with a Pilot E_c/I_o of -13 dB.
- The above simple observation leads to the need for an algorithm whereby a Pilot Strength Measurement Message is triggered based on comparisons of Pilots to the overall combined energy of the current Active Set.

cdma university

Transitioning Between Pilot Sets – TIA/EIA-95B Necessary Handoff

CDMA2000 1x
RC1 & RC2
Section 7-31



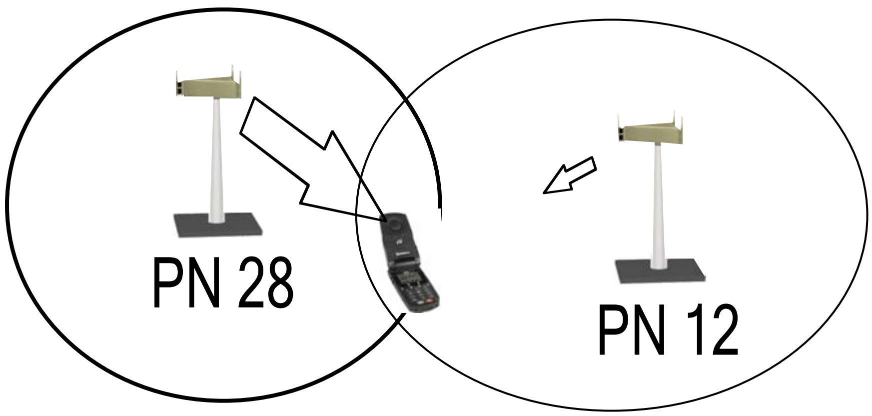
TIA/EIA-95B Necessary Handoff

When the E_c/I_o of the two Pilot signals are small, and nearly equal in power, the system should put the mobile into soft handoff with the two Base Stations.

cdma university

Transitioning Between Pilot Sets – Dynamic T_ADD

CDMA2000 1x RC1 & RC2 Section 7-32



- T_Add = S*(Total E_c/I_0 of Active Set) +I_A

  Where I_A: Add_Intercept;

  S: Soft_Slope (can be 0)

MES98010161Ac.emf

Dynamic T_ADD

For the mobile to derive these new *dynamic thresholds,* TIA/EIA-95 defines three new parameters included in the Extended System Parameters Message. They are:

- SOFT_SLOPE – The slope in the inequality criterion for adding a Pilot to the Active Set, or dropping a Pilot from the Active Set.
- ADD_INTERCEPT – The intercept in the inequality criterion for adding a Pilot to the Active Set.
- DROP_INTERCEPT – The intercept in the inequality criterion for dropping a Pilot from the Active Set.

Backward compatibility issues can easily be resolved by setting SOFT_SLOPE to zero.

Total Pilot E_c/I_o

Since Pilot strengths are measured in dB, they can be viewed as a percentage value. When more than one Pilot is in the Active Set, the total percentage of Pilot energy in the Active Set equals the sum of percentages of each individual Pilot. Total Active Set Pilot energy can then be converted back to dB and be used in defining “dynamic” handoff thresholds.

QUALCOMM cdma university

Transitioning Between Pilot Sets – Dynamic T_DROP

$$T\_Drop_i = S * (\text{Total } E_c/I_0 \text{ of Pilots stronger than Pilot i in Active Set}) + I_D$$

Dynamic T_DROP

The process for moving Pilots from Active Set to Candidate Set requires that the mobile first sort Pilots in the Active Set in an ascending order:

PS1<PS2<PS3<…<PSNA

Next the mobile compares each Pilot to the *dynamic* threshold:

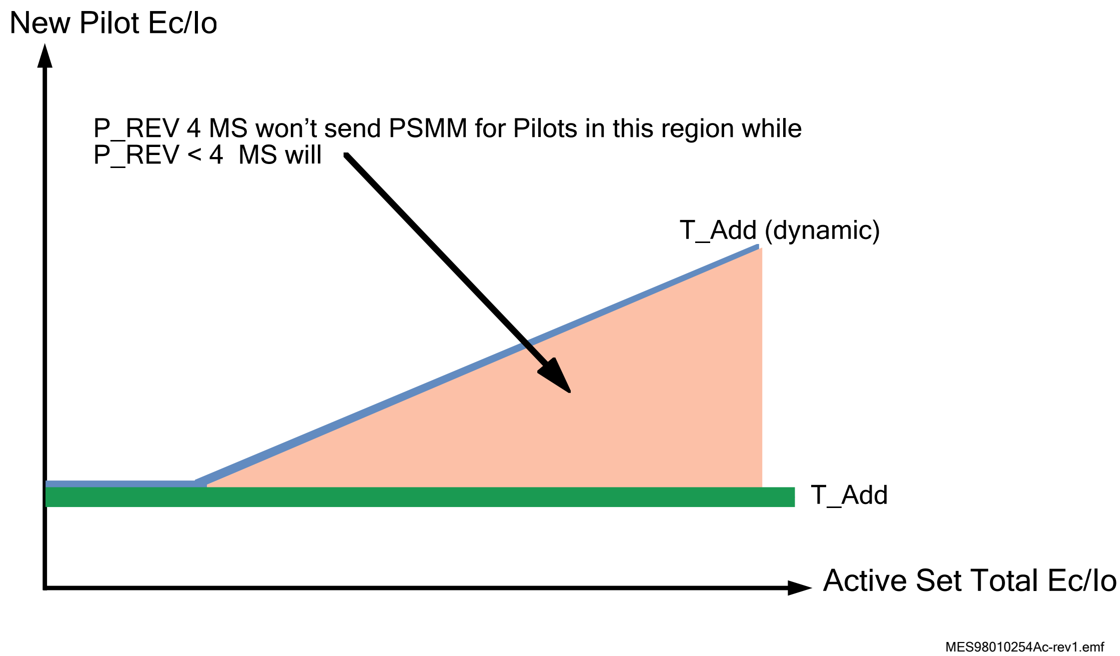
$$10\log(P_{aj}) \leq MAX(soft\_Slope \; 10\log\left(\sum_{i>j}^{N_A} P_{ai}\right) + Drop\_intercept, T\_DROP)$$

If Active Pilot j satisfies the above inequality, the mobile starts the T_Tdrop timer. If the timer expires, the mobile sends a PSMM to the Base Station requesting that Pilot j be removed from the Active Set.

QUALCOMM cdma university

Transitioning Between Pilot Sets – Adding a Pilot to the Active Set

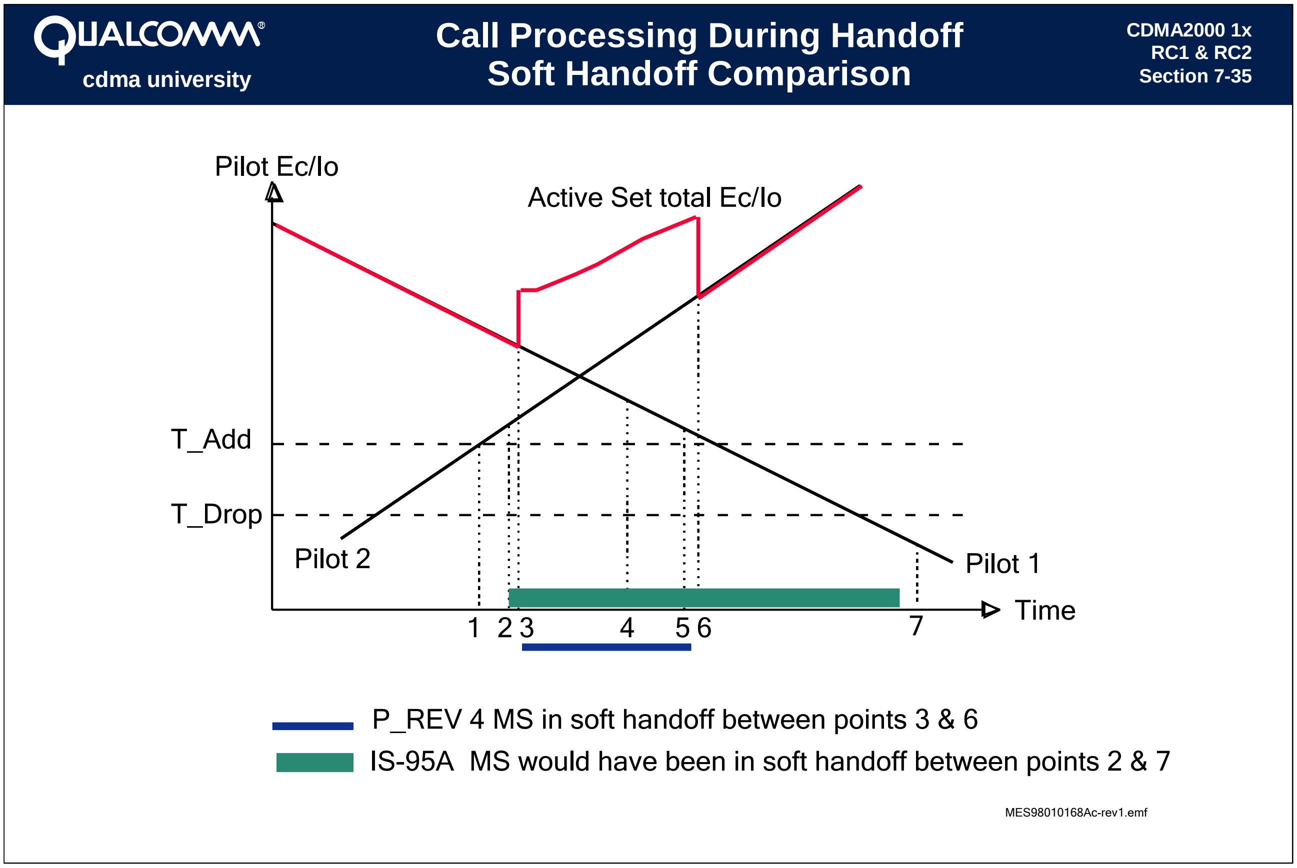
CDMA2000 1x RC1 & RC2 Section 7-34



Adding a Pilot to the Active Set

By incorporating the slope intercept formula, you can see that the mobile will only request a Pilot that it really needs (maximum of T_ADD or the "dynamic" add). The candidate must satisfy the following inequality to be considered worthy of reporting:

$$10\log(P_{cj}) \geq \text{SOFT\_SLOPE}\ 10\log\left(\sum_{i=1}^{N_A} P_{ai}\right) + \text{ADD\_INTERCEPT}$$



Soft Handoff Comparison

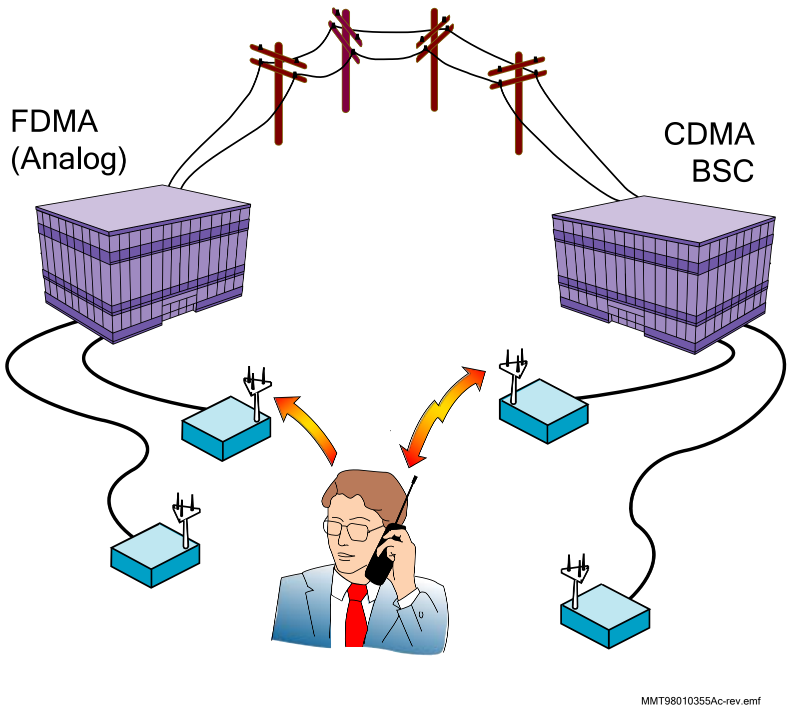
Notice in the illustration how the new soft handoff algorithm achieves its objective of reducing the percentage of time the phone is in handoff without affecting the system performance. The IS-95A mobile is in handoff from points 2 through 7. A P_REV 4 mobile would be in handoff from points 3 through 6.

- Pilot 2 exceeds T_ADD. MS moves it to Candidate Set.
- Pilot 2 Exceeds “dynamic” T_ADD. MS sends PSMM.
- MS receives EHDM to add Pilot 2 to Active Set.
- Pilot 1 drops below “dynamic” T _DROP (relative Pilot 2).
- Handoff timer expires on Pilot 1. MS sends PSMM.
- MS receives EHDM to move Pilot 1 to Neighbor Set.
- T_TDROP sec after Pilot 1 drops below T_DROP.

Call Processing During Handoff – CDMA to Analog Hard Handoff

QUALCOMM cdma university

CDMA2000 1x RC1 & RC2 Section 7-36



CDMA to Analog Hard Handoff

A *hard handoff* entails a brief disconnection from a current serving cell prior to establishing a connection with the target cell during the handoff.

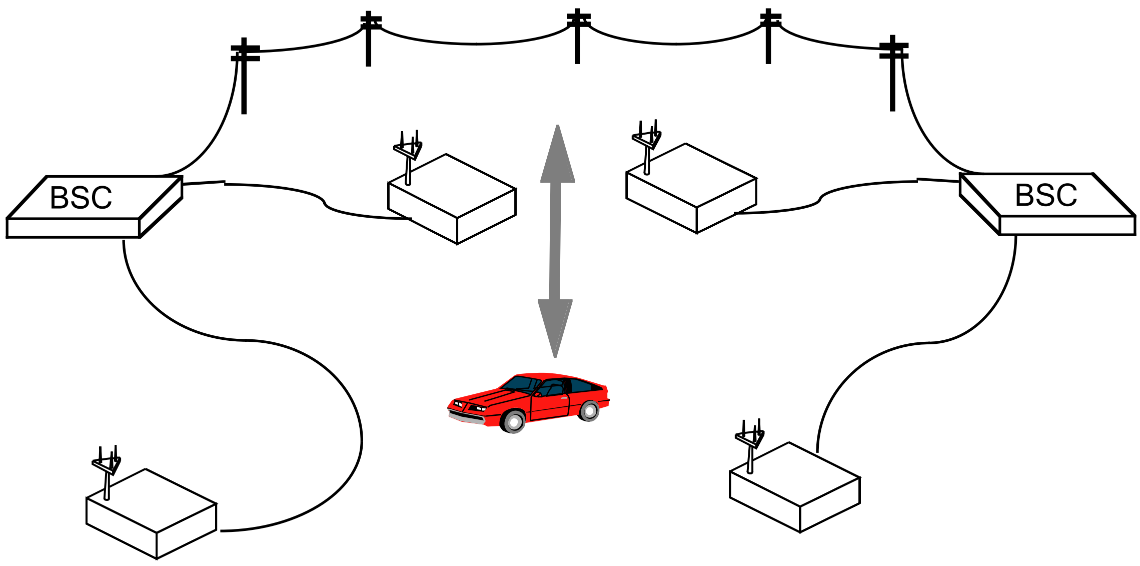
Hard handoffs can occur for several reasons. Hard handoff occurs when a soft handoff cannot take place (either due to lack of resources or due to the inability to transmit identical frames from both cells).

The figure illustrates a hard handoff from a CDMA system to an analog system. Hard handoffs can also occur between CDMA cells. CDMA-to-CDMA hard handoffs are due to frequency mismatches, frame offset misalignment, or disjoint cells.

QUALCOMM cdma university

Call Processing During Handoff – Intersystem Hard Handoff

CDMA2000 1x RC1 & RC2 Section 7-37



Intersystem Hard Handoffs

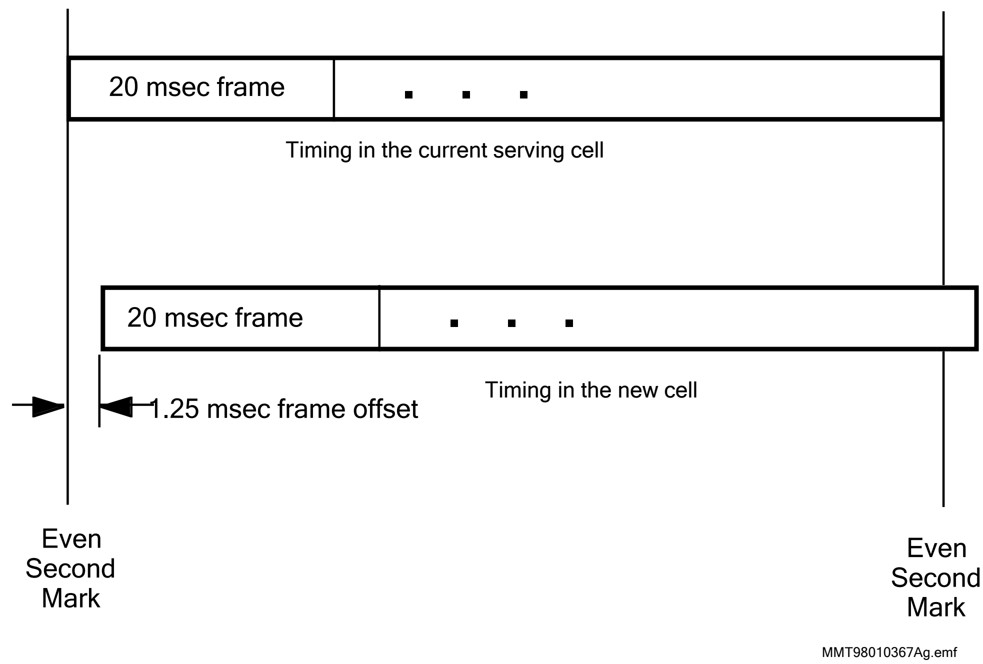
Cells that are controlled by separate BSCs are referred to as *disjoint cells*. In the case of a handoff between disjoint cells, a soft handoff is often not practical because it would require rapid coordination between the BSCs. Coordination between any two BSCs would require a very high-speed link in order to perform the processing in a timely manner. If this connection between BSCs is not practical or not supported, the system resorts to a hard handoff.

Since the frequency is not changed, this type of hard handoff does not affect the CDMA Reverse Channel. The target cell can begin acquisition of the mobile before the handoff takes effect. Given a good estimate of the signal arrival time, the acquisition of the target cell by the mobile is very fast. Thus, this type of handoff has little impact on voice quality.

QUALCOMM cdma university

Call Processing During Handoff – Frame-Offset Hard Handoffs

CDMA2000 1x RC1 & RC2 Section 7-38



Frame-Offset Hard Handoffs

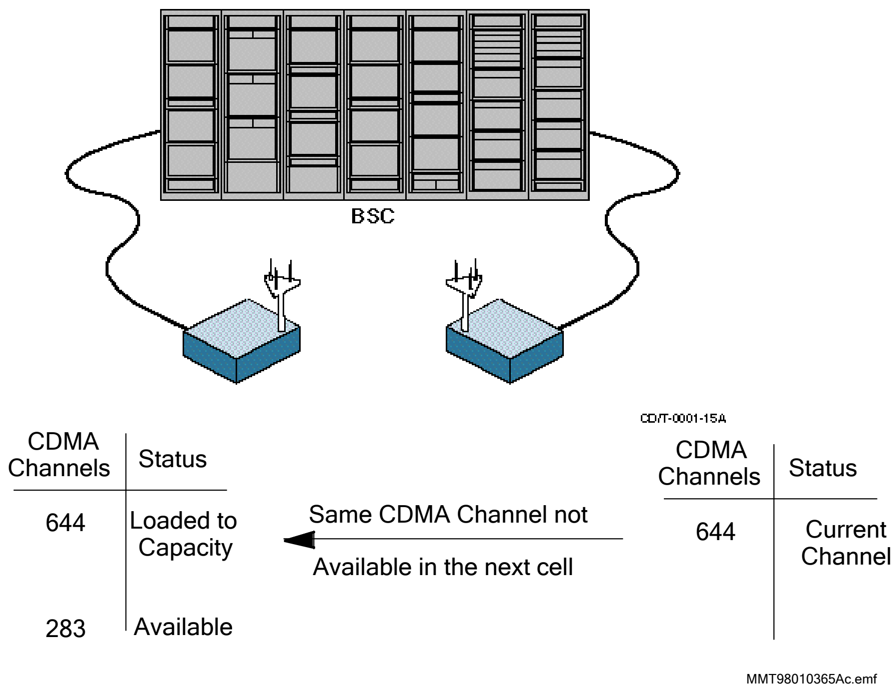
In order to evenly distribute the load over the backhaul, Traffic Channel frames are offset from system time. This offset is in increments of 1.25 ms and is called the *frame offset*.

In order to support a soft handoff, the target cell must use the same frame offset as the current serving cell. If the same time offset is not available, a hard handoff is performed. This type of hard handoff must be completed within 20 ms after receiving the Handoff Direction Message.

QUALCOMM cdma university

Call Processing During Handoff – Frequency Change Hard Handoffs

CDMA2000 1x RC1 & RC2 Section 7-39



Frequency Change Hard Handoffs

Soft handoff is not possible when a frequency change is required. As the mobile moves from the coverage area of one cell to another, the same frequency must be available for soft handoff. Any time the frequency is changed, a hard handoff is mandated.

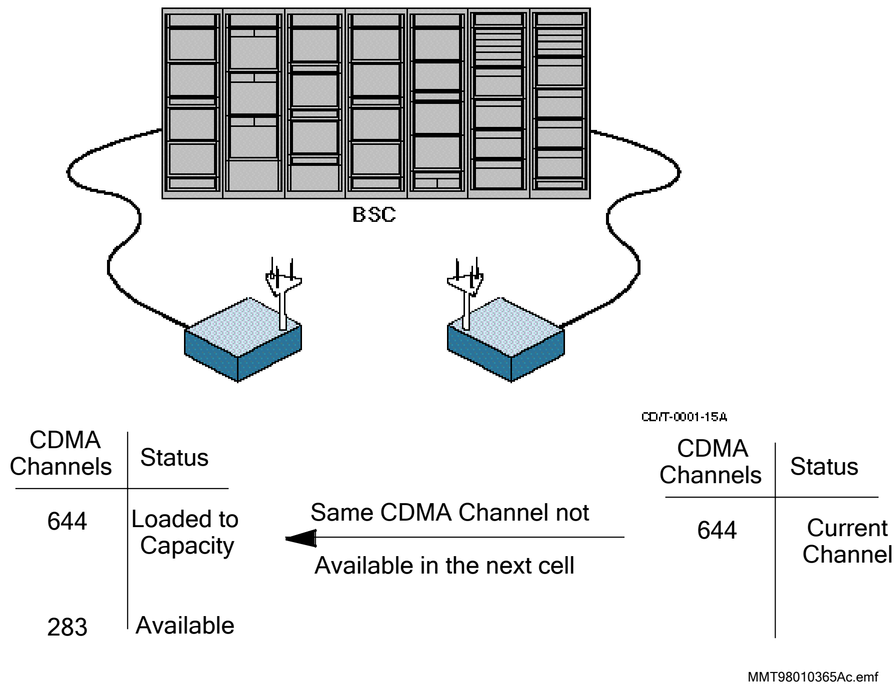
TIA/EIA-95 specifies that hard handoffs that occur due to a change in frequency must be completed within 60 ms after receiving the Handoff Direction Message.

A hard handoff consists of a short disconnection of the call while transitioning from one serving link to the other. When a frequency change is required, a soft handoff cannot occur since a hard handoff requires the mobile to let go of the current frequency to tune to a new frequency. Hard handoffs are required for a variety of reasons such as system operator requirements, capacity constraints, and coverage imbalances.

QUALCOMM cdma university

Call Processing During Handoff – Frequency Change Hard Handoffs (cont.)

CDMA2000 1x RC1 & RC2 Section 7-40



Frequency Change Handoff Scenarios

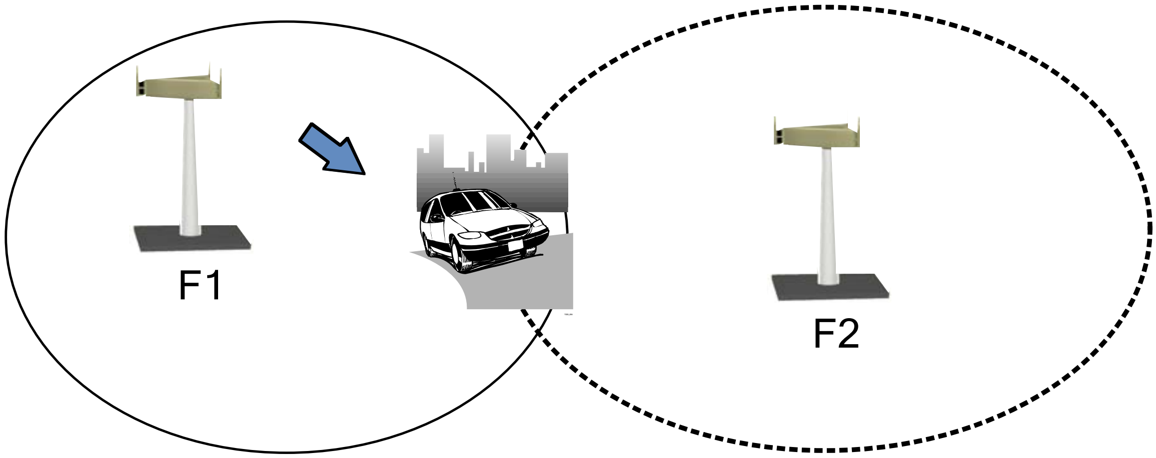
Inter-Frequency hard handoffs may also be required to support the following handoff scenarios:

1. 800 MHz CDMA to AMPS (dual mode)
2. 1.9 GHz to AMPS (dual band/dual mode)
3. 800 MHz CDMA to some other 800 MHz CDMA
4. 1.9 GHz CDMA to some other 1.9 GHz CDMA
5. 1.9 GHz CDMA to 800 MHz CDMA
6. 800 MHz CDMA to 1.9 GHz CDMA

QUALCOMM cdma university

Call Processing During Handoff – Hard Handoff Techniques

CDMA2000 1x RC1 & RC2 Section 7-41



- Round Trip Delay (RTD)
- Pilot Beacon Unit (PBU)

MES98010169Ac.emf

Hard Handoff Techniques

Currently there exist a few possible solutions to the hard handoff issue that can be accomplished by proper use of the information currently available to the Base Stations.

Round Trip Delay (RTD)

The Base Station can make an estimate of the mobile's distance from the cell and use a defined threshold to trigger a hard handoff. This method does have the advantage of being very inexpensive to implement; however, some fundamental limitations exist. In particular, the multipath nature of the channel makes distance difficult to measure accurately, often resulting in premature handoff.

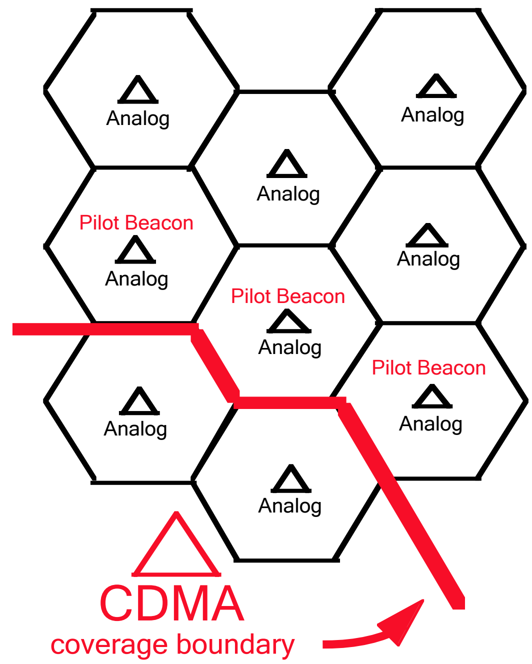
Pilot Beacon Unit (PBU)

When the mobile detects the PN of the PBU, the Base Station can trigger a hard handoff. This method ensures the mobile can "see" the adjacent cell (assuming coverage areas match). This method, however, does require additional network expense.

cdma university

Call Processing During Handoff – Pilot Beacons

CDMA2000 1x RC1 & RC2 Section 7-42



MMT98010366Ac.emf

Pilot Beacons

Since it is not expected that the mobile will contain the hardware necessary to search for Pilot Channels on frequencies other than the one currently used, other means of determining the target cell and when to perform the handoff are required.

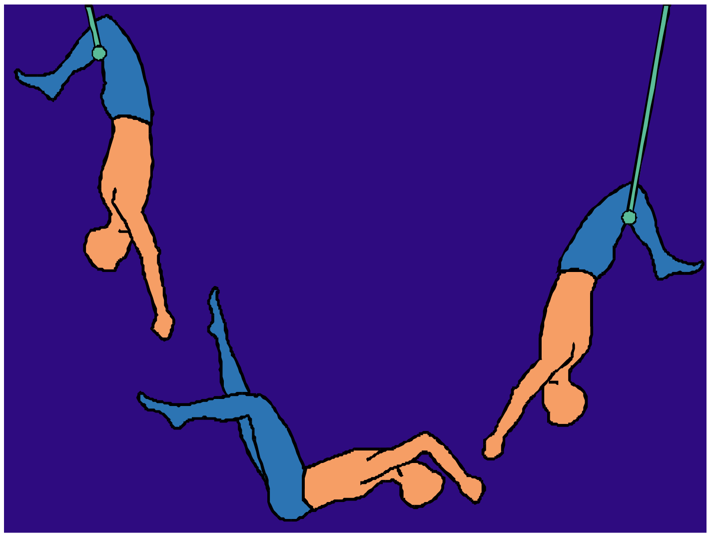
A Pilot Channel can be placed at potential target cells at the frequency of the CDMA Forward Channel in the serving cell with negligible interference. Detection of this Pilot Channel by the mobile would then trigger the handoff. The acquisition process in the mobile following a hard handoff to a different frequency in a different cell consists of tuning to the new frequency and searching for the new Pilot Channel.

QUALCOMM cdma university

Call Processing During Handoff – Hard Handoff Performance

CDMA2000 1x RC1 & RC2 Section 7-43

What if Hard Handoff fails? What should Target Active Set be?



MES98010170Ac.emf

Hard Handoff Performance

Hard handoffs can fail for many reasons. A hard handoff can fail because it is prematurely directed to handoff and one or both of the links are unable to support traffic. A hard handoff failure could result from the mobile being given a less than optimal Active Set from the Handoff Direction message. If any of these events occur, IS-95A provides no mechanism for the mobile to return to the old frequency.

The Hard Handoff Problem

There are some critical questions one should ask when performing a CDMA-to-CDMA hard handoff. The first question is whether a hard handoff is required. Secondly, if it is required, when should it be implemented? Finally, what should the Active Set consist of? Once the need to handoff is determined there can still be a residual uncertainty about the composition of the new Active Set for the other frequency. Occasionally, the number of possible candidate Forward link sectors on the neighboring frequency can be too large to all be in the new Active Set. Also, since a fast-moving mobile’s environment changes rapidly, the best new Active Set for the mobile will also tend to vary over time.

Inter-Frequency Hard Handoff Improvement Requirement

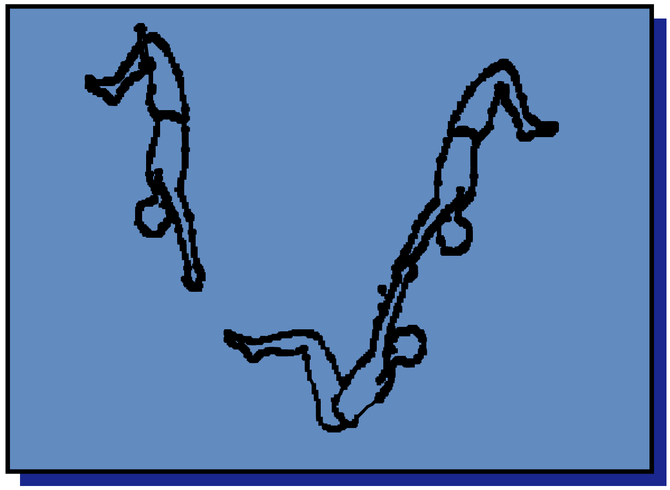
With IS-95A there is no simple answer to the Active Set membership. In addition, for mobiles that could not successfully complete the hard handoff, IS-95A provided no procedure for returning to the originating system. The inter-frequency hard handoff procedure outlined in TIA/EIA-95 is designed as a simple method to overcome these issues that plagued IS-95A systems.

QUALCOMM cdma university

Call Processing During Handoff – Improved Inter-Frequency Hard Handoff

CDMA2000 1x RC1 & RC2 Section 7-44

- Return if Handoff Fails
- Search-only Visits
- Configurable Search



MES98010171Ac.emf

Improved Inter-Frequency Hard Handoff

To aid in the support of adjacent/overlaying systems on different frequencies and to better determine hard handoff timing and target Active Set members, TIA/EIA-95 specifies the following improvements:

- Provides a procedure for the mobiles to return to the old frequency if a handoff fails.
- "Search-only" visit to candidate frequency (this would aid the Base Station in determining when to direct the handoff and which Pilots to include in the Active Set).
- Optional search for AMPS.
- Configurable per-candidate frequency neighbor search window sizes. Thresholds to prevent unnecessary searching and or reporting. Remember the mobile is searching a different frequency while assigned to a Traffic Channel. As a result, frames are erased whenever the mobile searches. The degradation of the call then is a function of searcher and synthesizer speed.

QUALCOMM cdma university

Call Processing During Handoff – New Inter-Frequency HHO Messages

CDMA2000 1x RC1 & RC2 Section 7-45

- Candidate Frequency Search Request Message
- Candidate Frequency Search Response
- Candidate Frequency Search Control Message
- Candidate Frequency Search Report Message
- General Handoff Direction Message

New Inter-Frequency Hard Handoff Messages

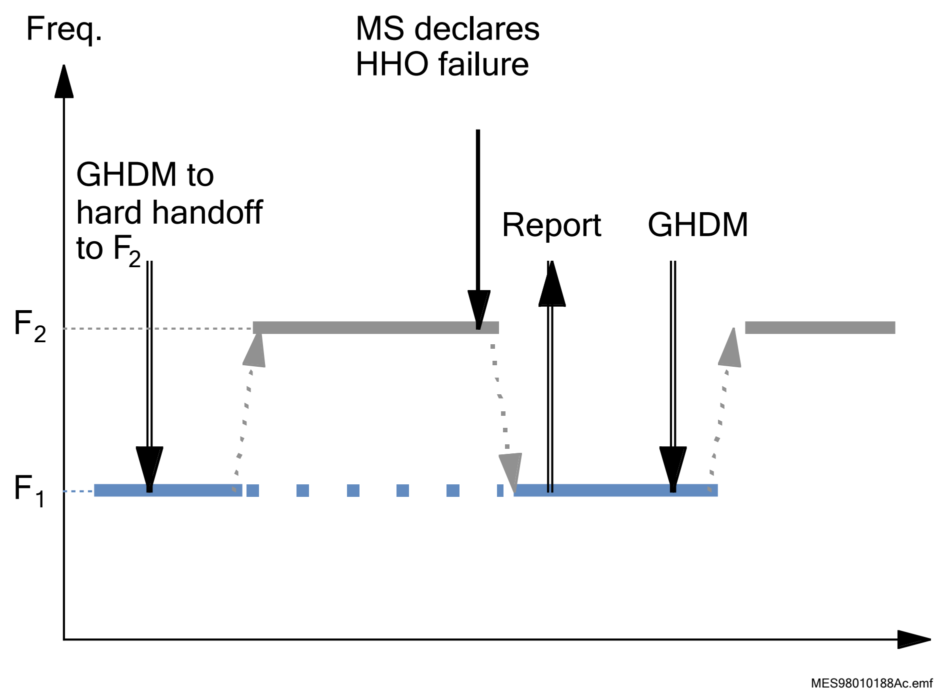
Several new messages are defined to support this new procedure.

- On the Forward link – Candidate Frequency Search Control Message (CFSCM), Candidate Frequency Search Request Message, and General Handoff Direction Message (GHDM).
- On the Reverse link – Candidate Frequency Search Response Message and Candidate Frequency Search Report Message.

QUALCOMM cdma university

Call Processing During Handoff – Inter-Frequency Handoff Failure Recovery

CDMA2000 1x RC1 & RC2 Section 7-46



Inter-frequency Hard Handoff Failure Recovery

One of the shortcomings of IS-95A was the inability to recover from an unsuccessful inter-frequency hard handoff. TIA/EIA-95 provides controllable mechanisms for failure determination and recovery. If the mobile declares the handoff attempt to be unsuccessful, it restores the configuration to what it was before the handoff attempt and sends a Candidate Frequency Search Report Message. Some of the failure criteria are:

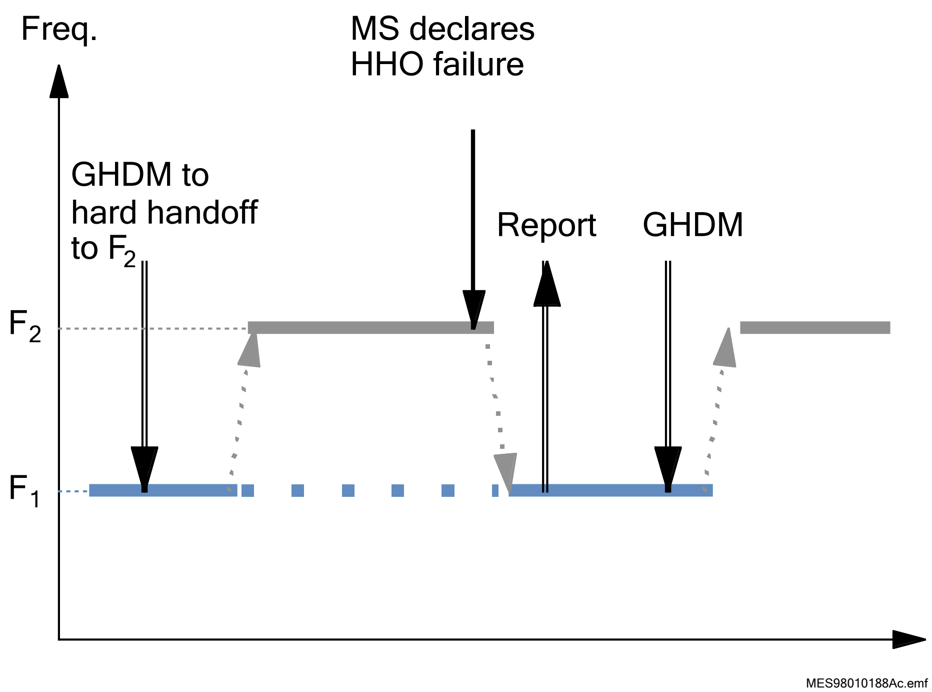
RX PWR THRESH

A threshold for the mobile received power, used to quickly abandon the Pilot search if there is not sufficient in-band energy on the other frequency. The DIFF RX PWR THESH field in the Candidate Frequency Search Request Message is used in defining the actual minimum power threshold.

TOTAL PILOT EC/IO

A threshold for the new Active Set, used to abandon the handoff attempt if the total Pilot E_c/I_o from all Active Set members does not exceed the MIN TOTAL PILOT EC/IO defined in the threshold Candidate Frequency Search Request Message. This threshold can also be used in the periodic search mode to determine whether a report is worth issuing.

Call Processing During Handoff – Inter-Frequency HO Failure Recovery (cont.)



CF WAIT TIME

A timer value that specifies the maximum amount of time the mobile is to wait for the first correctly received frame on the new frequency, even if the new Active Set meets the initial total E_c/I_o requirement. When the timer expires, the mobile makes sure the Pilot search is completed before returning to the old frequency. It is important to note that the original serving frequency must continue to provide a Forward link until the expiration of this timer.

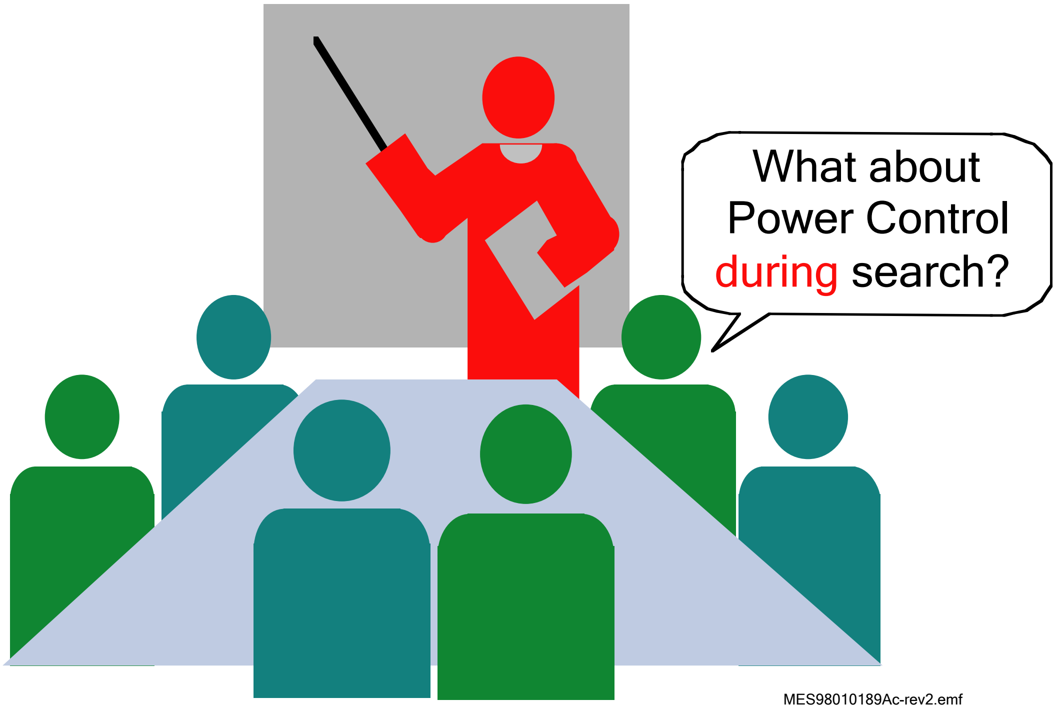
Periodic Search

A periodic search mode that requires the mobile to search the candidate frequency at given intervals after a handoff failure or a search-only handoff.

QUALCOMM cdma university

Call Processing During Handoff – Power Control

CDMA2000 1x RC1 & RC2 Section 7-48



MES98010189Ac-rev2.emf

Power Control During Search and Hard Handoff

At the action time specified for a search or for a General Handoff Direction Message, the mobile disables its transmitter, disables the fade timer, and suspends incrementing TOT_FRAMES and BAD_FRAMES. If Rate Set 2 is in use on the Reverse Traffic Channel, the mobile stores the erasure indicator bits for the last two frames received on the Forward Traffic Channel. The mobile records and stores the current transmit power level, and locks the accumulation of valid level changes in the closed loop mean output power. The mobile ignores received power control bits related to the period that the transmitter is disabled. Once on the new frequency, counters relating to power measurement reporting are to be suspended.

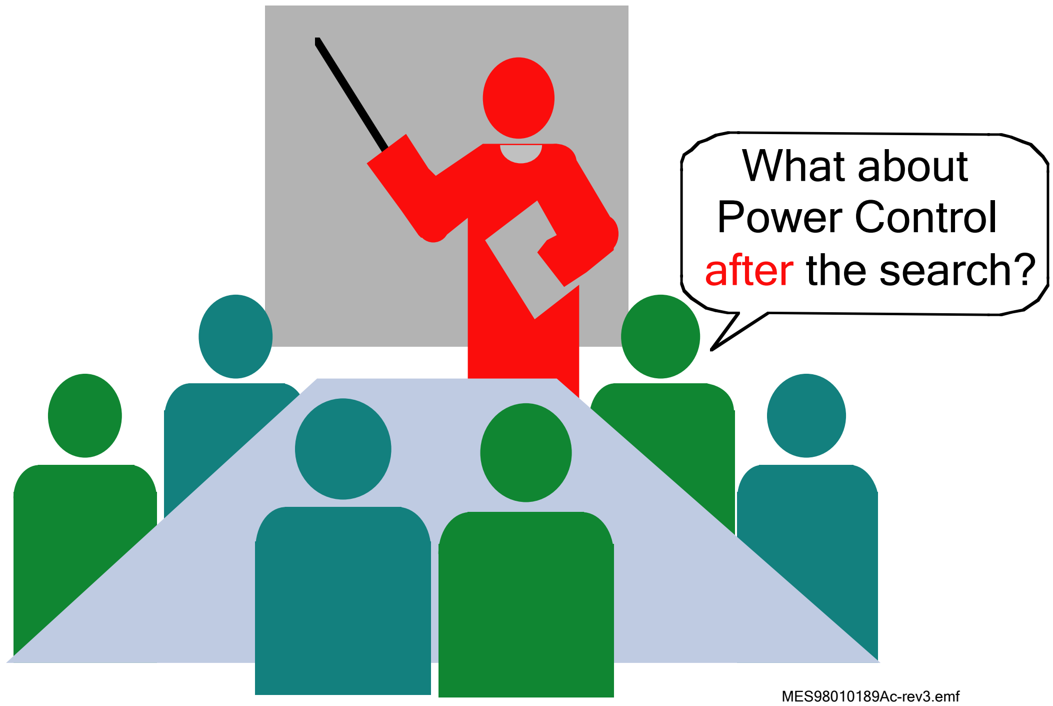
Power Control After the Search

Following the search on the candidate frequency, the mobile has to return to the serving frequency and most likely report the conditions it encountered. The report requires a transmission, and, as you know, in CDMA controlling mobile transmit power is critical to system performance. Therefore TIA/EIA-95 provides the following rules regarding re-enabling of the mobile transmitter upon return to the serving frequency.

QUALCOMM cdma university

Call Processing During Handoff – Power Control (continued)

CDMA2000 1x
RC1 & RC2
Section 7-49



MES98010189Ac-rev3.emf

Power Control After the Search (continued)

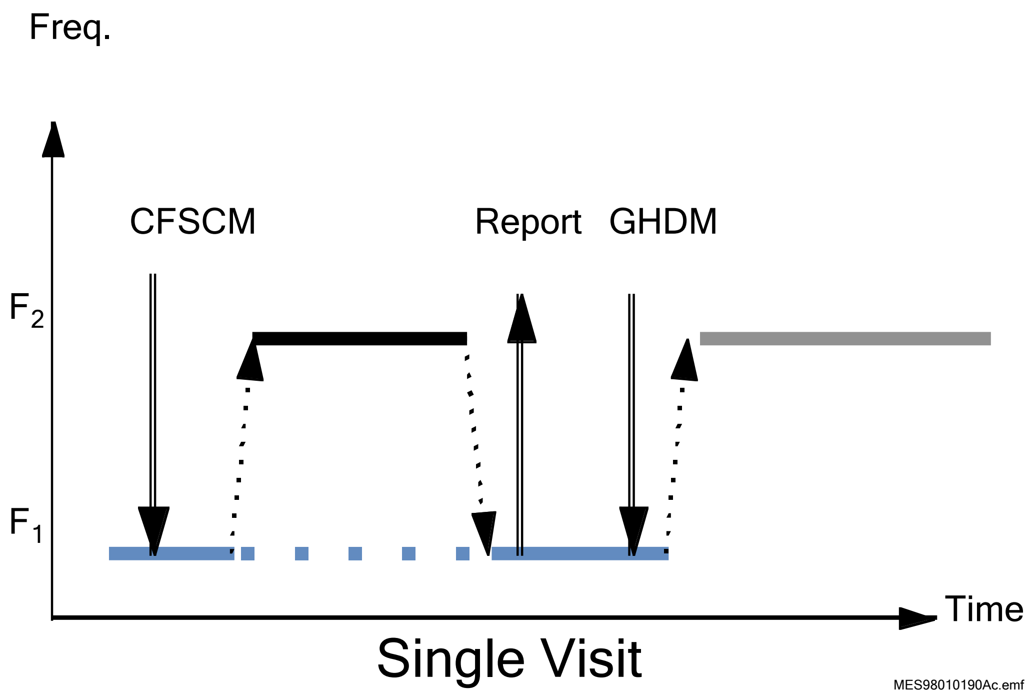
- If the interval between the time that the mobile disables its transmitter and the time that it resumes using the Serving Frequency Active Set is equal to or greater than 12 frames (N2m X.02 seconds) in time, the mobile waits to receive 2 consecutive good frames before it re-enables its transmitter.
- Otherwise, the mobile re-enables its transmitter as soon as any of the following are true:
  - The mobile's mean output power is within 6 dB of desired output.
  - The mobile's mean output power is equal to its mean output power before it tuned to the Candidate Frequency.
  - N3m X 0.02 seconds have elapsed since the mobile re-tuned to the serving frequency.

The mobile begins responding to valid power control commands. If Rate Set 2 is in use on the Reverse Traffic Channel, the mobile sends the stored erasure indicator bits in the first two frames when it resumes transmission.

QUALCOMM cdma university

Call Processing During Handoff – Single/Periodic Search

CDMA2000 1x RC1 & RC2 Section 7-50



Single Search

The mobile conducts a *single search* of a the Candidate Frequency Search Set in response to a Candidate Frequency Search Control Message by measuring the total received power and the strength of all Pilots in the Candidate Frequency Search Set in one or more visits to the Candidate Frequency.

Once the mobile completes the measurements, it sends a Candidate Frequency Search Report Message reporting the received power on the Candidate Frequency and on the Serving Frequency, and the phase and strength for each Pilot in the Candidate Frequency Search Set that measures above CF_T_ADD.

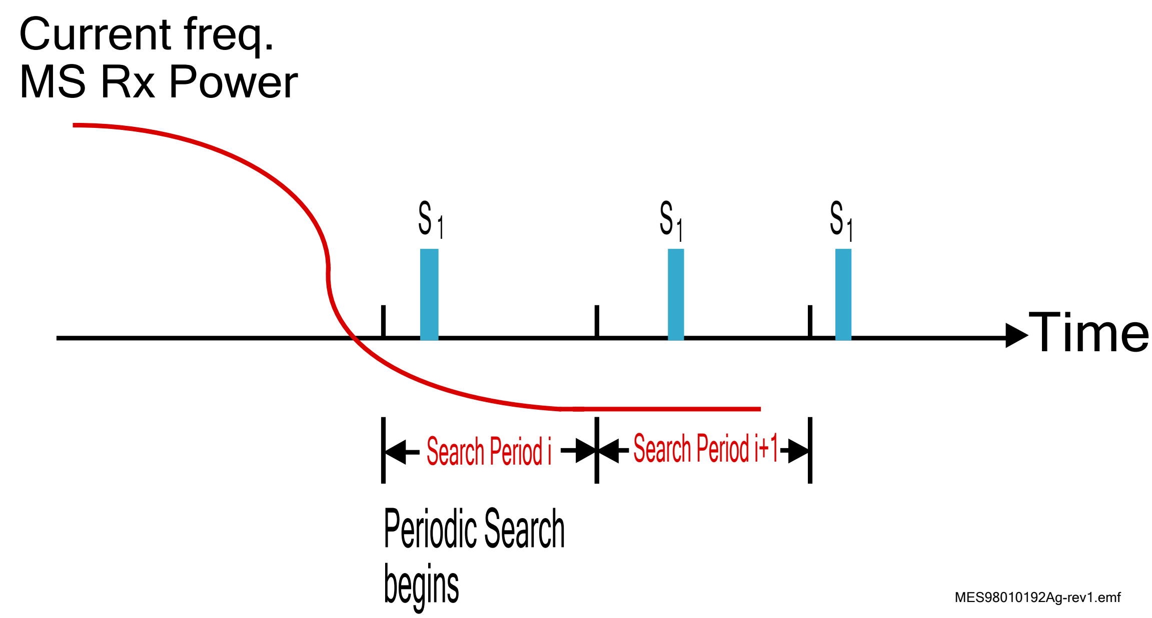
Periodic Search

When the mobile performs a *periodic search*, it periodically searches the Candidate Frequency Search Set and reports the results to the Base Station in the Candidate Frequency Search Report Message. The mobile may measure all Pilots in the Candidate Frequency Search Set in one visit to the Candidate Frequency, or it may visit the Candidate Frequency several times in a search period, each time measuring all or some of the Pilots in the Candidate Frequency Search Set. The mobile is required to maintain a periodic search timer by setting the expiration time to the value corresponding to SEARCH_PERIOD table.

QUALCOMM cdma university

Call Processing During Handoff – Periodic Search with Receive Thresholds

CDMA2000 1x RC1 & RC2 Section 7-51



Periodic Search with Receive Thresholds

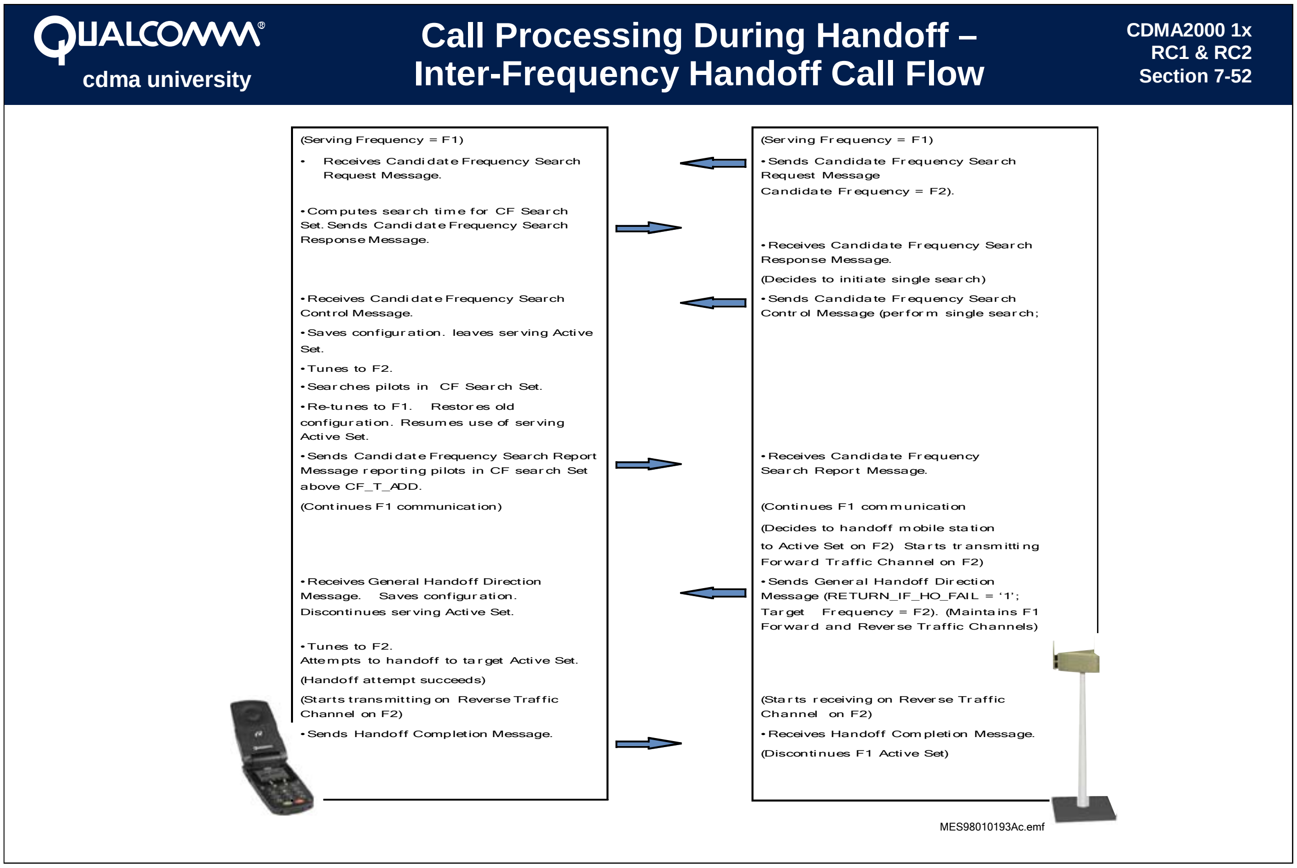
If SF_RX_PWR_THRESHs is not equal to '11111' while tuned to the Serving Frequency, the mobile measures the received power on the Serving Frequency once every frame (0.02 second) and maintains the average of the received power over the last 10 frames and does the following:

Periodic Search With Thresholds

- If avg_serving_freq_pwr for a frame is not less than SF_RX_PWR_THRESH and the periodic search timer is enabled, the mobile disables the timer.
- If PERIODIC_SEARCHs is equal to '1' and if the average serving frequency power for a frame is less than SF_RX_PWR_THRESH and if the periodic search timer is disabled, then the mobile resets the expiration time of the periodic search timer.

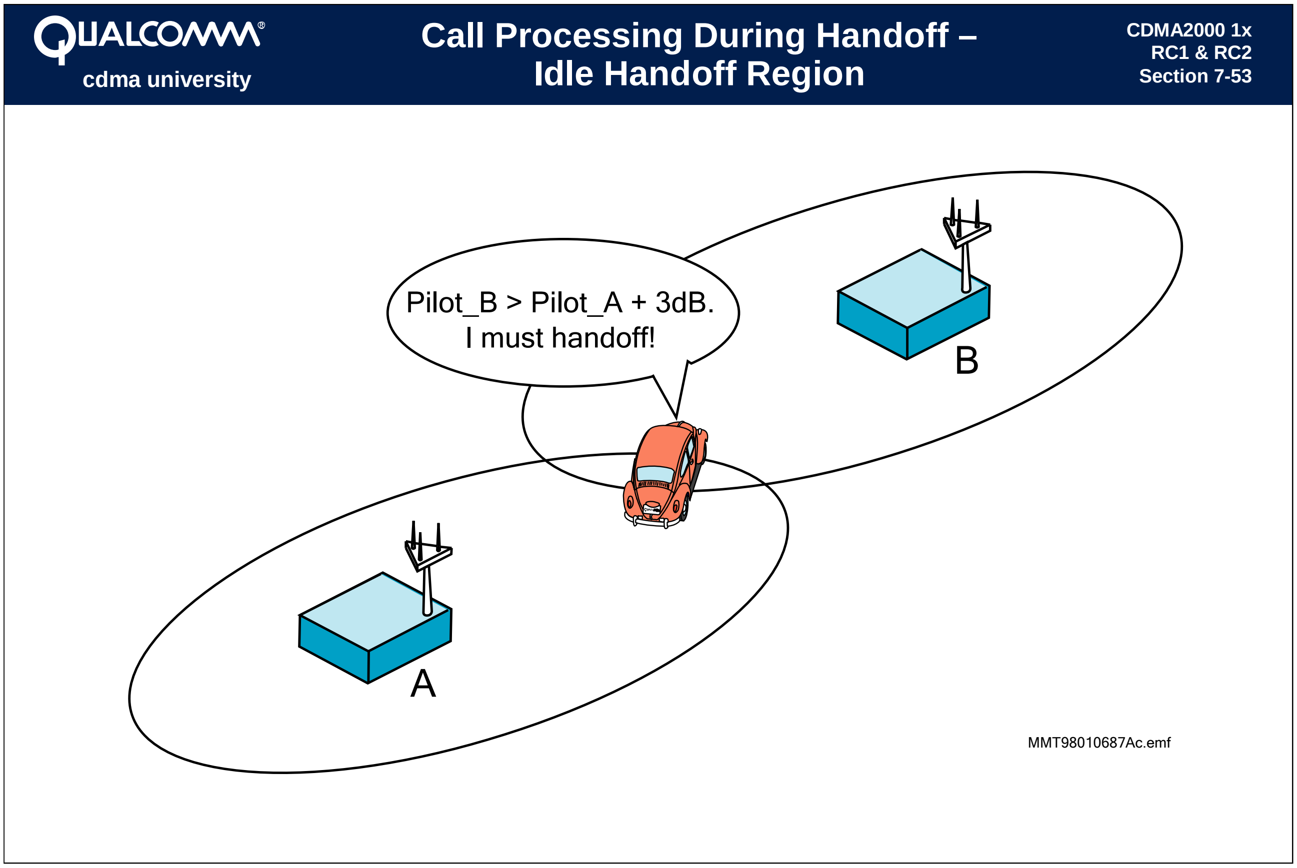
Periodic Search Without Thresholds

If SF_RX_PWR_THRESHs is equal to '11111', the mobile maintains the periodic search timer independent of the received power on the Serving Frequency. Before the timer expires, the mobile measures the strength of all Pilots in the Candidate Frequency Search Set at least once, and sends a Candidate Frequency Search Report Message if MIN_TOTAL_PILOT_EC_IOs is equal to '00000' or if the sum of the measured E_c/I_o for the Pilots in the Candidate Frequency Search Set is not less than MIN_TOTAL_PILOT_EC_IOs.



Inter-Frequency Handoff Call Flow

This slide shows an example of a successful hard handoff between two frequencies, F1 and F2.



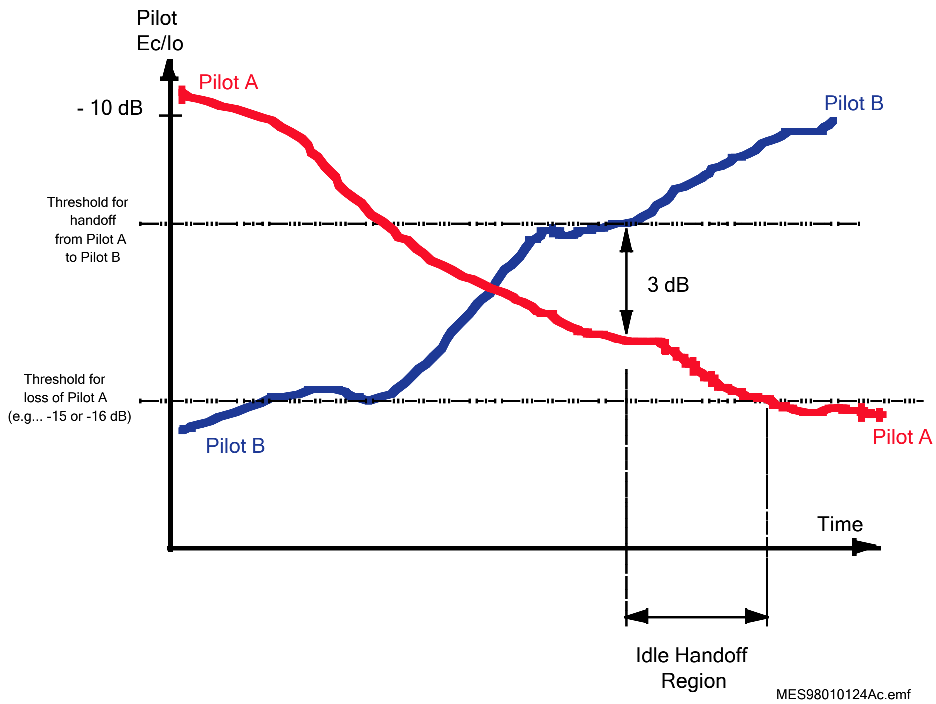
Idle Handoff Region

While in the Idle state, the mobile may move from one cell to another. Idle handoff arises from the transition between any two cells. Idle handoff is initiated by the mobile when it measures a Pilot signal significantly stronger (3 dB) than the current serving Pilot.

QUALCOMM cdma university

Call Processing During Handoff – Idle Handoff Region (continued)

CDMA2000 1x RC1 & RC2 Section 7-54



Consequences of "No Handoff During Access"

The Idle Handoff Process

As the mobile moves from cell to cell, it must handoff to a new Paging Channel. The mobile performs this idle handoff autonomously when the strength of a new Pilot exceeds the strength of the serving Pilot by 3 dB.

The Idle Handoff Region

The *idle handoff region* is the area where the mobile should perform the handoff to a new Paging Channel. It is not formally defined. The idle handoff region is the area in which the strength of a non-serving Pilot is at least 3 dB greater than the strength of the serving Pilot and the serving Pilot is still usable (e.g., serving Pilot E_c/I_o > - 15 dB).

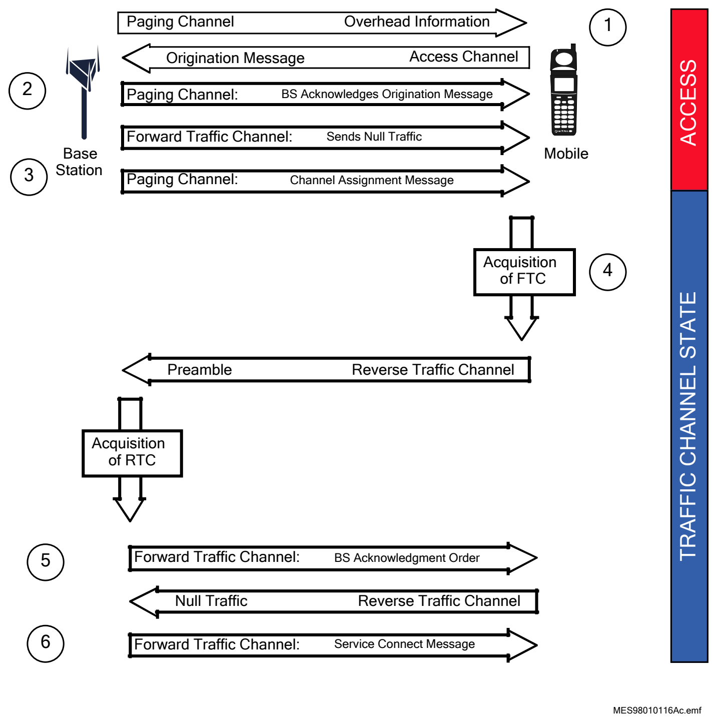
Access/Handoff Contention

If the mobile enters the idle handoff region while in the System Access State, idle handoff is not permitted in IS-95A systems. As a result, the Paging Channel of the serving Base Station may degrade as the mobile proceeds farther into the idle handoff region. If the mobile continues to proceed through the idle handoff region, the Paging Channel may fail before the access can be completed.

QUALCOMM cdma university

Call Processing During Handoff – Call Set Up

CDMA2000 1x RC1 & RC2 Section 7-55



Call Set Up: Origination Sequence

The figure shows the sequence of events in originating a mobile-to-land call.

1. The mobile must read the overhead messages on the Paging Channel.
2. The Base Station must acknowledge receipt of the Origination Message. The Base Station can use a Base Station Acknowledgment Order to do this. The mobile may need to transmit the Origination Message several times before acknowledgment.
3. The Base Station must assign resources to the mobile. The Base Station sets up a Forward Traffic Channel, begins transmitting null traffic on the channel, and sends a Channel Assignment Message.
4. After receipt of the Channel Assignment Message, the mobile attempts to acquire the Forward Traffic Channel.
5. When the Forward Traffic Channel is successfully demodulated, the mobile can begin transmitting on the Reverse Traffic Channel. When the Reverse Traffic Channel is acquired, the Base Station sends a Base Station Acknowledgment Order on the Forward Traffic Channel.
6. The Base Station sends a Service Connect Message to the mobile.

Access Handoffs – IS-95A Text on Handoffs During Access

IS-95A states:

"While in the system access state, the mobile station should continue its pilot search … but shall not perform idle handoffs."

(paragraph 6.6.3.1.3)

The IS-95A Strategy: Prohibit Handoffs During Access

Idle handoffs during Access are prohibited in IS-95A to avoid adding additional complexity to the Access process (IS-95A paragraph 6.6.3.1.3).

QUALCOMM cdma university

Access Handoffs – Challenges

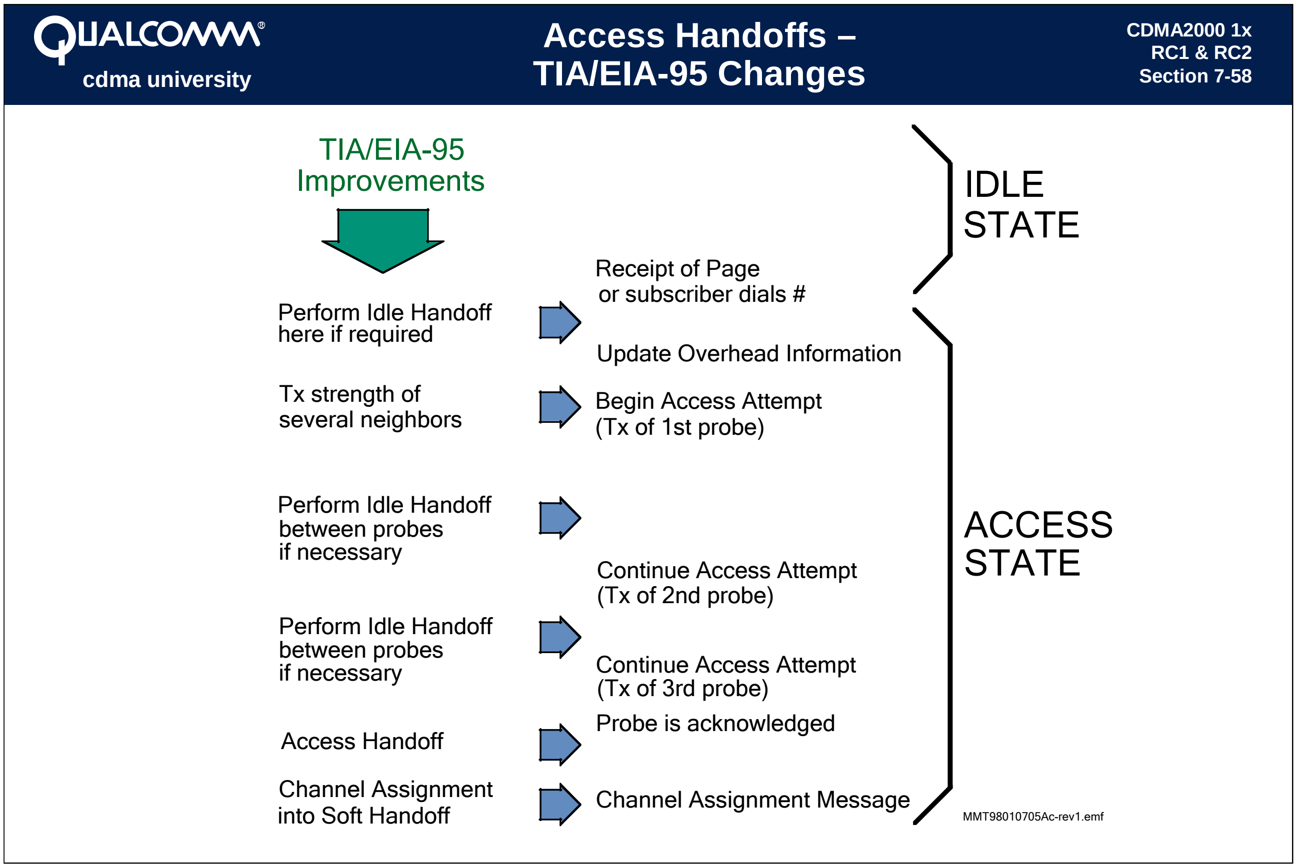
CDMA2000 1x RC1 & RC2 Section 7-57

- Traffic Channel Set-Up
- Multiple Authentication Calculations
- Unnecessary Registrations
- Message Sequence # Confusion
- Communication Between BSCs

The Challenges of Handoffs During Access

Permitting idle handoffs during Access can add significant complexity and inefficiency to the process. This results from several factors:

- The Base Station is no longer certain of the location of the mobile. During Originations and Page Responses, the Base Station must set up a Traffic Channel. Additional complexity must be added to help the Base Station set up the Traffic Channel in the proper cell/sector.
- Authentication parameters may vary from sector to sector. If the mobile performs handoff during Access, the mobile may be required to perform multiple authentication calculations. These multiple calculations provide no additional benefit and should be avoided to reduce the processing required in the mobile.
- Unnecessary registrations may result as the mobile moves from sector to sector during Access.
- Layer 2 acknowledgments may be performed by the BTS. Mobiles moving from BTS to BTS during Access complicate the task of acknowledging using the proper message sequence number.
- The mobile may respond to a BTS that is controlled by a different BSC. The new BSC may not be aware of the previous message exchanges.



Access Handoffs – TIA/EIA-95 Changes

Handoff in the Access state is specifically prohibited in IS-95A. This prohibition made Access processes easier to implement during the initial development of the early CDMA systems. Performance was sacrificed for simplicity.

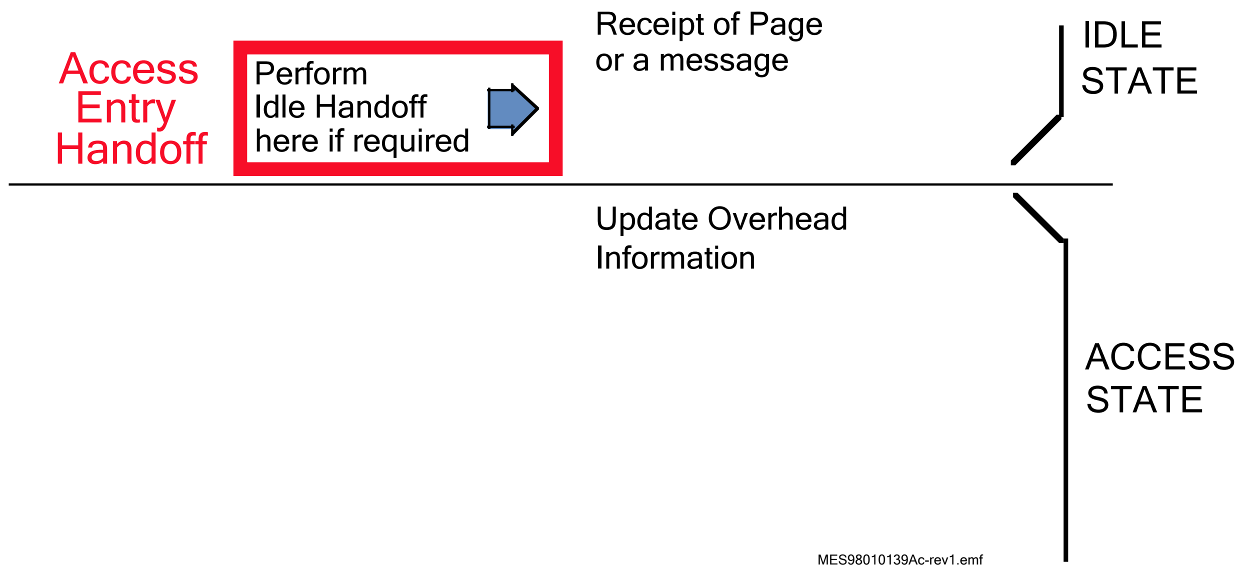
Access failures in the handoff region were a significant performance deficiency, however, and TIA/EIA-95 includes the following handoff techniques to improve performance:

- Access Entry Handoff
- Access Probe handoff
- Access Handoff
- Channel Assignment into Soft Handoff

cdma university

Access Handoffs – Access Entry Handoff

CDMA2000 1x RC1 & RC2 Section 7-59



Access Entry Handoff

Access entry handoff is a special form of idle handoff that the mobile may perform after it has determined that an Access is required but immediately prior to entering the Update Overhead Information Substate. The system operator controls Access entry handoff by configuring parameters in the Extended System Parameters Message.

Note: Optional for both the Base Station and the mobile.

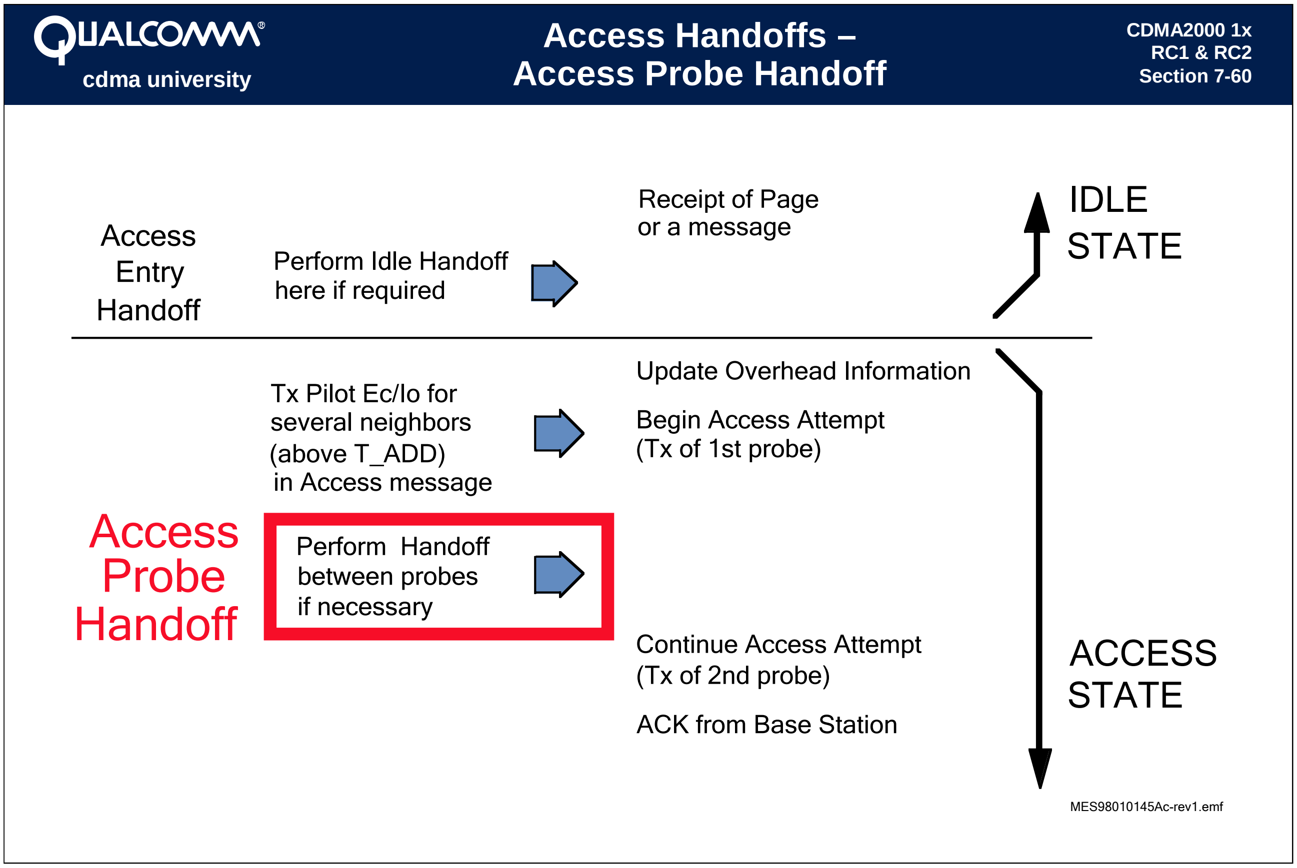
Response Access Attempts

The system operator may enable or disable Access entry handoff for response access attempts.

Reference: See paragraph 6.6.2.3 of TIA/EIA-95.

Request Access Attempts

Access entry handoff for Request Access Attempts (Origination, Registration, Message Transmission, PACA Cancel) is not addressed in TIA/EIA-95. Mobile manufacturers may implement access entry handoff for Request Accesses at their discretion.



Access Probe Handoff

An Access attempt begins with the transmission of a probe on the Access Channel. The Access attempt remains in progress until the mobile receives an acknowledgment to any probe sent during the Access attempt (or until the maximum # of probes is sent). While an Access attempt is in progress, a new Pilot may become sufficiently strong and the mobile determines that a handoff to the new Pilot is necessary. A handoff conducted during an Access attempt is called an *Access probe handoff*.

Access probe handoff is permitted only in the Origination and Page Response Substates.

The system operator controls Access probe handoff using parameters found in the Extended System Parameters Message.

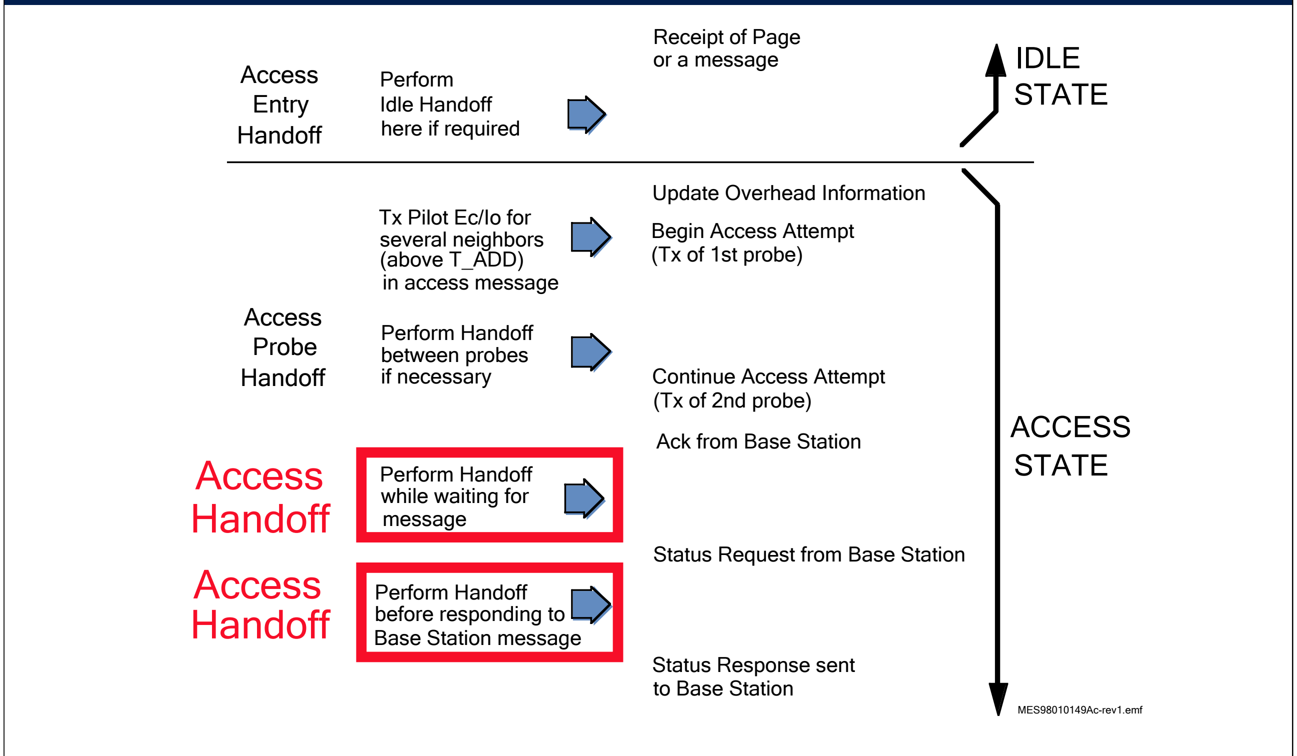
Note: Optional for both the mobile and the Base Station.

Reference: TIA/EIA-95 6.6.3.1.3.3

QUALCOMM cdma university

Access Handoffs – Access Handoff

CDMA2000 1x RC1 & RC2 Section 7-61



Access Handoff

Access handoff is defined as the act of transferring reception of the Paging Channel from one Base Station to another while the mobile is in the System Access State, but after an Access attempt.

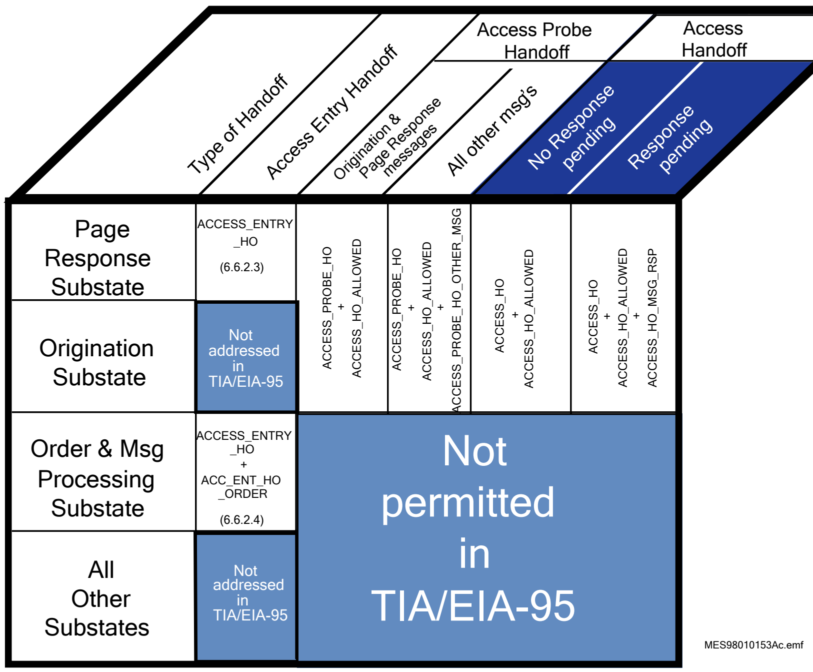
Access handoff is permitted only in the Origination and Page Response Substates. As is the case with Access probe handoff, Access handoff is controlled by the system operator using parameters in the Extended System Parameters Message.

Note: Mandatory for the mobile. Optional for the Base Station.

Reference: TIA/EIA-95 6.6.3.1.2

Access Handoffs – Summary of Handoffs During Access

QUALCOMM cdma university — CDMA2000 1x RC1 & RC2 Section 7-62



Summary of Handoffs During Access

The figure lists the parameters that affect each type of handoff during the System Access State. In each case, all parameters listed must be set to 1 in order to enable the specific type of handoff to the neighbor.

There is an ACCESS_ENTRY_HO value and an ACCESS_HO_ALLOWED value for every neighbor. All other parameters are 1 bit parameters to enable or disable the various techniques.

cdma university

Access Handoffs – Extended System Parameters Message

Extended System Parameters Message

Field	Length (bits)
more fields	
• •	
NGHBR_SET_ENTRY_INFO	1
ACC_ENT_HO_ORDER	0 or 1
NGHBR_SET_ACCESS_INFO	1
ACCESS_HO	0 or 1
ACCESS_HO_MSG_RSP	0 or 1
ACCESS_PROBE_HO	0 or 1
ACCESS_PROBE_HO_OTHER_MSG	0 or 1
MAX_NUM_PROBE_HO	0 or 3
NGHBR_SET_SIZE	0 or 5

If NGHBR_SET_ENTRY_INFO = 1, NGHBR_SET_SIZE occurrences of the following field:

Field	Length (bits)
ACCESS_ENTRY_HO	1

If NGHBR_SET_ACCESS_INFO = 1, NGHBR_SET_SIZE occurrences of the following field:

Field	Length (bits)
ACCESS_HO_ALLOWED	1

MES98010134Ag.emf

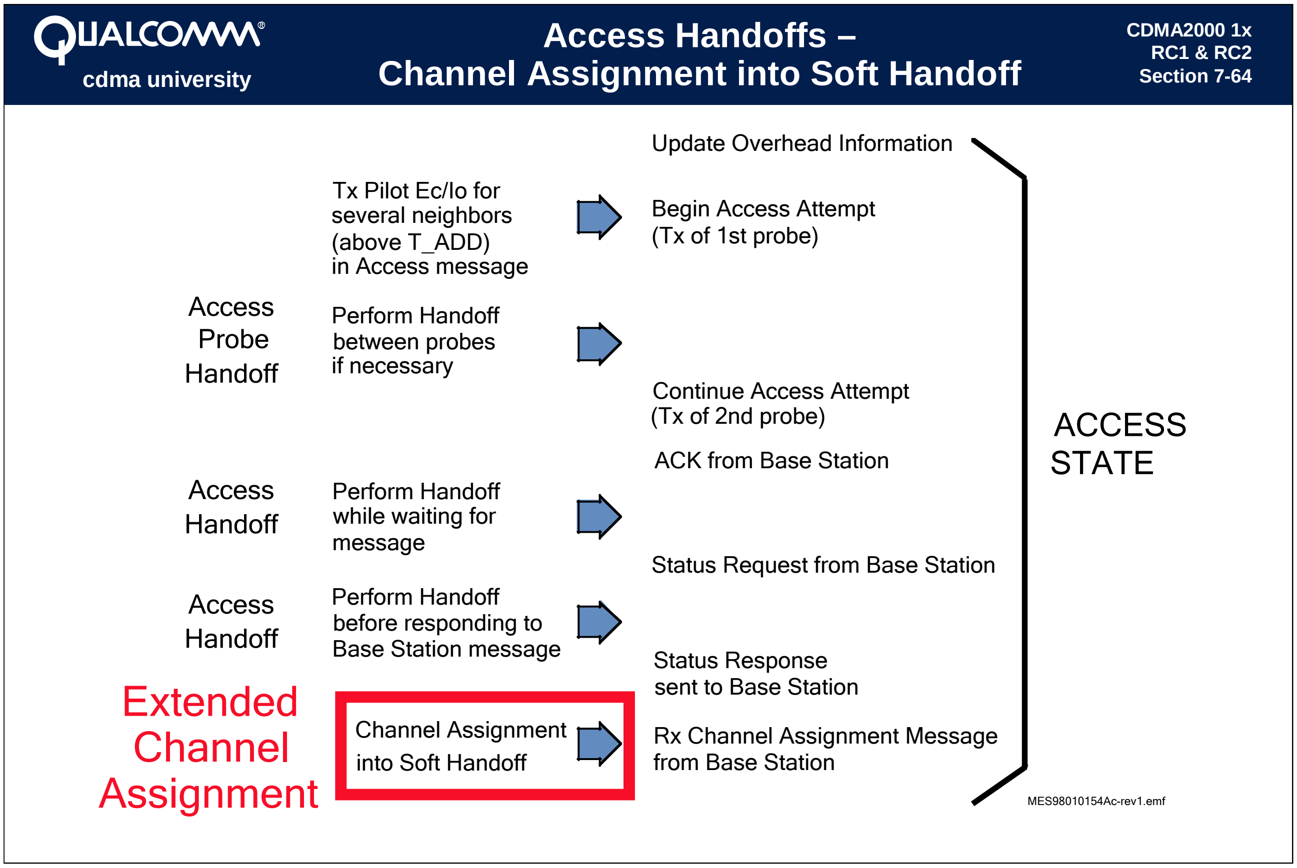
Extended System Parameters Message

The Extended System Parameters Message has been modified to add several new parameters that can be used to enable or disable the new handoff techniques.

Pilot Strength Reporting

In order to assist the Base Station decision-making process, TIA/EIA-95 specifies that the mobile must transmit a defined minimum of Pilot strength measurements in Access Channel messages. More extensive optional reporting is also supported. This information enables the Base Station to make informed decisions concerning Channel Assignment into soft handoff, for example.

Pilot reporting is also controlled using a parameter in the Extended System Parameters Message (PILOT_REPORT).



Channel Assignment into Soft Handoff

If the mobile reports the strength of more than one Pilot in the Access Channel Message, this gives the Base Station an opportunity to place the mobile into soft handoff using the Extended Channel Assignment Message.

QUALCOMM cdma university

What We Learned in This Section

CDMA2000 1x RC1 & RC2 Section 7-65

- ✓ The types of CDMA handoffs.
- ✓ The Pilot Searching process.
- ✓ The messages important in the handoff process and how each message is used.
- ✓ Key handoff parameters.

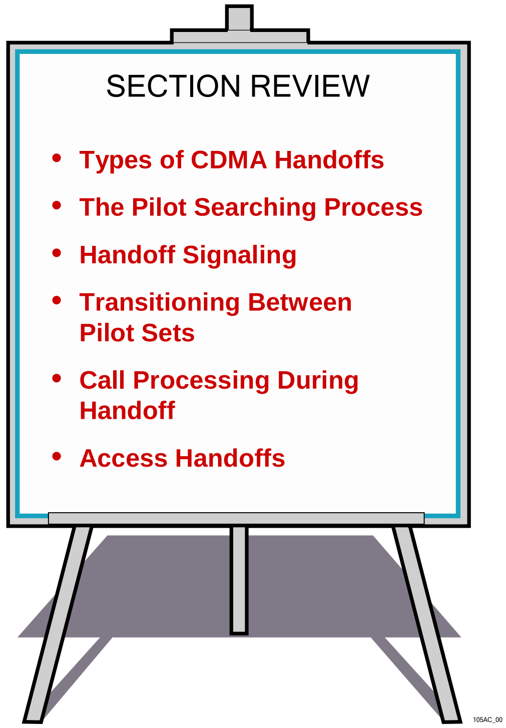
Review Questions

1. What are the types of handoff supported by the CDMA specifications?
2. What are the four Pilot sets?
3. Which message is used to provide the Base Station with information on the strength of Pilots measured by the mobile?
4. Define T_ADD, T_DROP, T_TDROP and T_COMP.

QUALCOMM cdma university

Handoffs – Review

CDMA2000 1x RC1 & RC2 Section 7-66



Notes

QUALCOMM cdma university

Section 8: Registration

CDMA2000 1x
RC1 & RC2
Section 8-1

SECTION 8

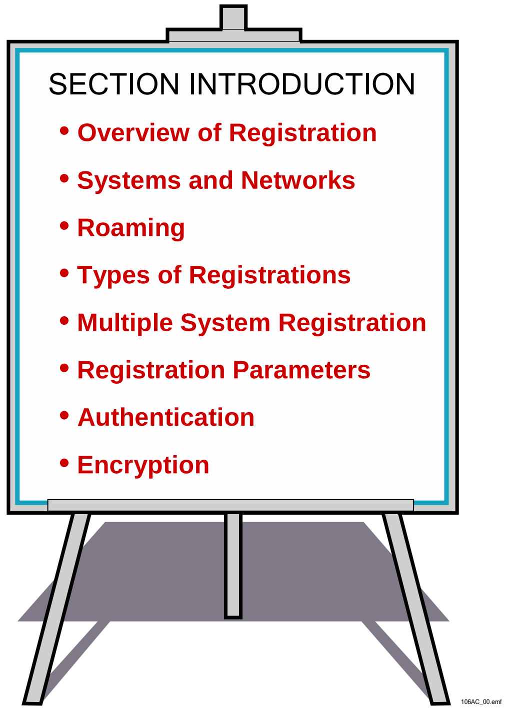
Registration

Notes

cdma university

Section Introduction

CDMA2000 1x
RC1 & RC2
Section 8-2



Notes

QUALCOMM cdma university

Section Learning Objectives

CDMA2000 1x RC1 & RC2 Section 8-3

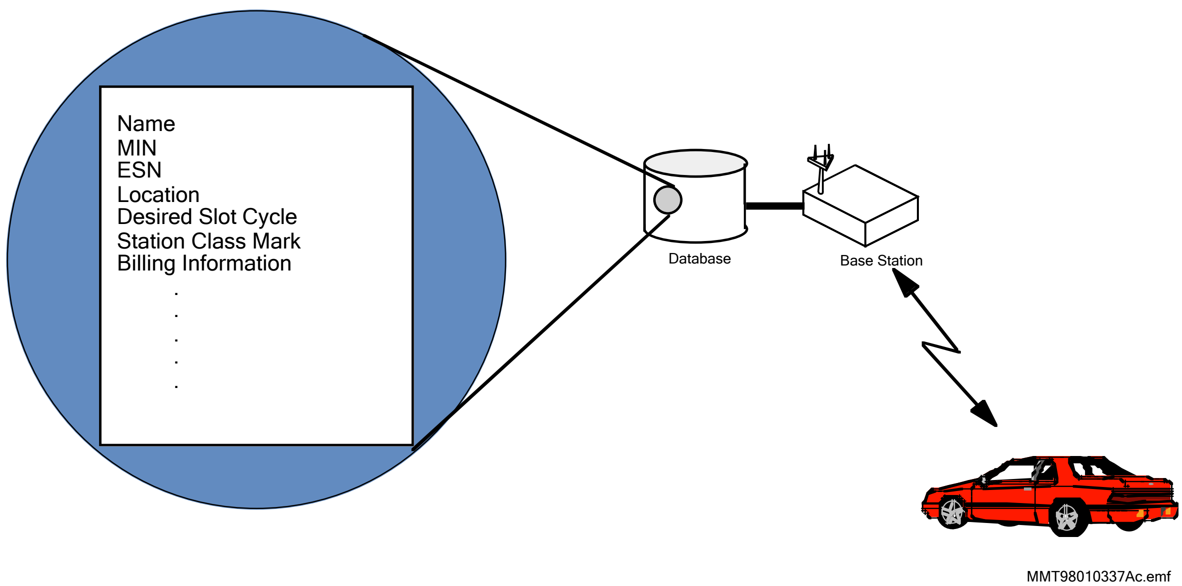
- List the messages that contain registration information.
- List and explain the types of registrations supported by the CDMA specifications.
- Identify the parameters that control the registration process.
- Describe the authentication and encryption processes supported by the CDMA specifications.

Notes

QUALCOMM cdma university

Registration Overview
Registration Updates a Database

CDMA2000 1x RC1 & RC2 Section 8-4



Registration Updates a Database

Registration refers to the process by which mobiles make their whereabouts known to the cellular system.

Cellular systems use registration as a means to balance the load between the Access Channel and the Paging Channel. Without any type of registration, mobiles must be paged over the entire cellular system, resulting in the need for transmitting on the order of C pages per call delivery for a system with C Base Stations.

Requiring a mobile to register every time it moves to the coverage area of a new Base Station would reduce the number of pages per call delivery to unity. However, such an approach would create overwhelming load on both the Paging and Access Channels due to the transmission of the registration messages and their acknowledgments.

cdma university

Registration Overview – The Registration Message

CDMA2000 1x
RC1 & RC2
Section 8-5

Field	Length (bits)
MSG_TYPE; ('00000001')	8
ACK_SEQ	3
MSG_SEQ	3
ACK_REQ	1
VALID_ACK	1
ACK_TYPE	3
MSID_TYPE	3
MSID_LEN	4
MSID	8´ MSID_LEN
AUTH_MODE	2
AUTHR	0 or 18
RANDC	0 or 8
COUNT	0 or 6
REG_TYPE	4
SLOT_CYCLE_INDEX	3
MOB_P_REV	8
SCM	8
MOB_TERM	1
RESERVED	6

MMT98010338Ag-rev1.emf

Types of Registration

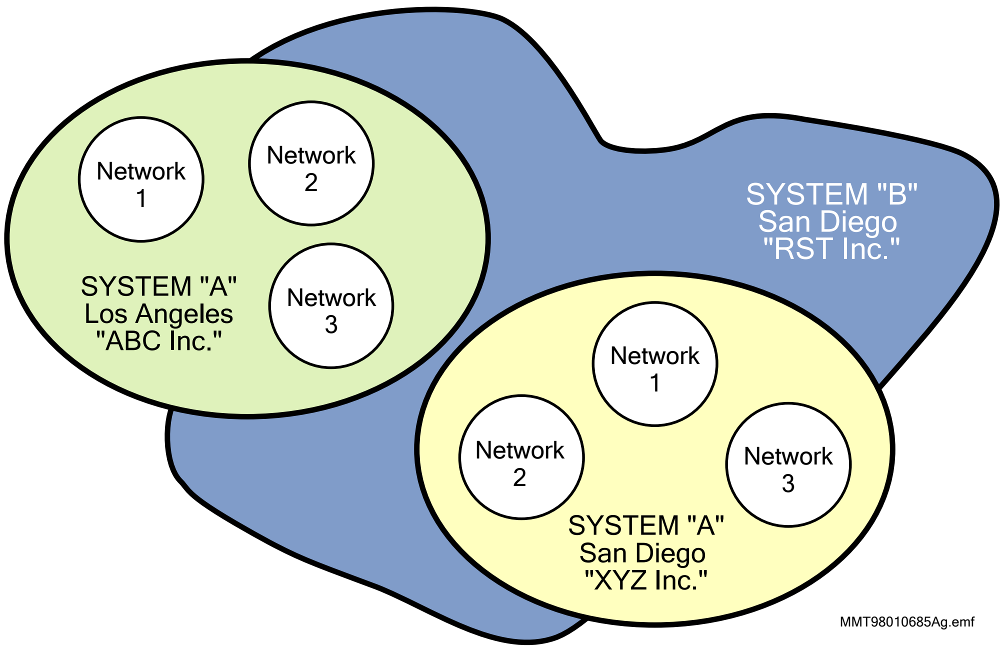
The registration method a cellular carrier should choose is a function of parameters such as the cellular system size, the expected mobility within the system, and call delivery statistics. Since systems are expected to vary substantially with respect to these measures, CDMA specifications offer multiple ways of initiating registration. The different registration procedures can be enabled or disabled independently allowing the cellular carriers to tailor any subset of registration methods to optimize the use of their systems.

The REG_TYPE field is used to indicate Timer-Based, Power Up, Zone-Based, Power Down, Parameter-Change, and Ordered or Distance-Based registration.

cdma university

Systems and Networks

CDMA2000 1x RC1 & RC2 Section 8-6



Systems and Networks

TIA/EIA-95 recognizes the established construct of systems, as defined by SIDs or System Identification numbers. With respect to treatment of SIDs, TIA/EIA-95 is in general compatible with AMPS and TDMA.

The proposed CDMA system provides a network identifier (NID) for the cells within a system. A network is a subset of the cells in a system. A network might be set up in several ways, including the following:

- The network consists of cells belonging to a group of BSCs that share a common Visitor Location Register (VLR); *or*
- The network consists of a group of cells belonging to a single BSC; *or*
- The network consists of a group of cells belonging to a private network operating within the public system. It is possible for the private network to share a BSC with the public system or with other private networks.

It is assumed here that a separate VLR is associated with each network, i.e., with each distinct (SID, NID) pair. The NID broadcast by the cells allows an extension of the roaming concept, permitting a CDMA mobile to be configured to enable or disable roaming from NID to NID within a system. The NID can also provide additional flexibility in autonomous registration.

QUALCOMM cdma university

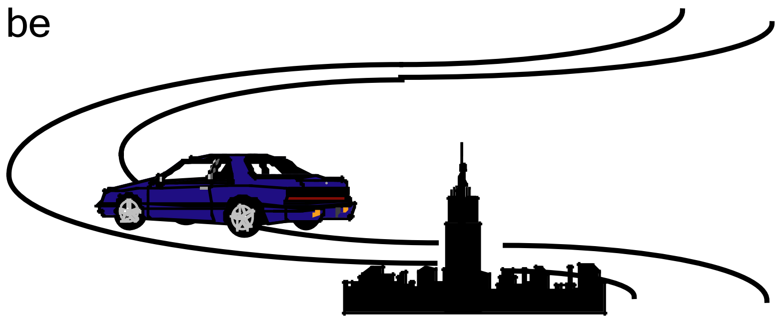
Roaming – Determining Roaming States

CDMA2000 1x RC1 & RC2 Section 8-7

Cellular Service is normally subscribed to from a particular system.

Obtaining Service from another system is possible, but additional charges are generally incurred.

Users traveling outside their normal Service area are said to be Roaming.



MMT98010340Ac-rev1.emf

Determining Roaming States

The mobile’s roaming state has implications both for the types of registration it will perform and for its call termination indicator.

A CDMA mobile can be programmed independently not to receive mobile-terminated calls in any one of its three possible roaming states. The mobile’s call termination indicator is thus equal to the mobile’s roaming state ANDed with the call termination preference programmed for that state.

The first five forms of registration, as a group, are enabled by roaming status for any Mobile Identification Number (MIN). The serving system can, for example, enable registration of roaming mobiles while not requiring registration for mobiles that are not roaming. The mobile user can also disable these forms of autonomous registration while roaming by specifying that a MIN is not configured to receive mobile-terminated calls when roaming.

QUALCOMM cdma university

Roaming – The Mobile's "Home"

CDMA2000 1x RC1 & RC2 Section 8-8

<27, 1> ; <27, 2>

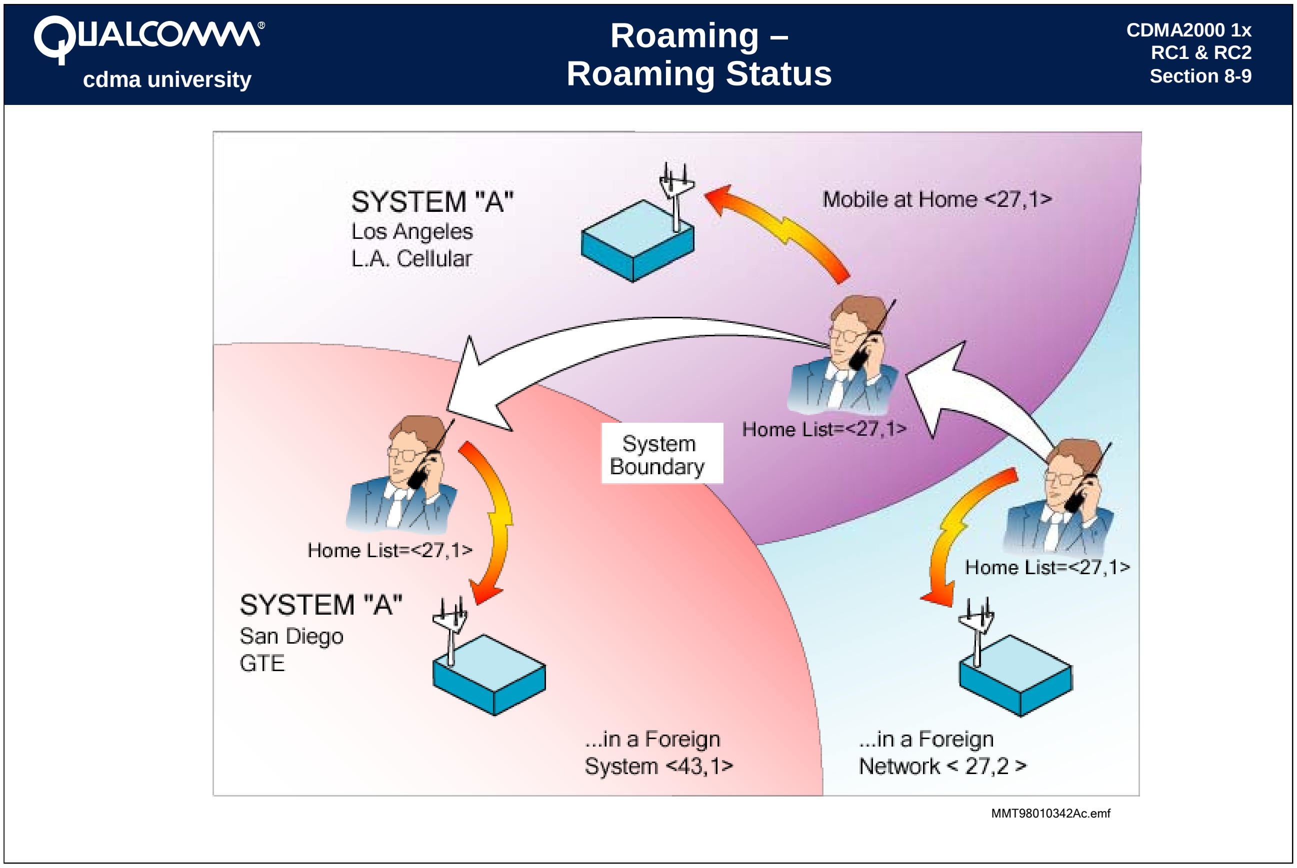
System 27, Network 1 System 27, Network 2

MMT98010686Ag.emf

The Mobile's "Home"

The mobile maintains a list of systems and networks that it has subscribed service from.

This is the *Home List*.



Roaming Status

The mobile can be in one of three roaming states: home (not roaming), NID roaming, or SID roaming.

The mobile has a list of (SID,NID) pairs which it considers as *home* (i.e., systems and networks that are associated with the organization from which the mobile user commonly obtains service).

- When the mobile is in the coverage area of a Base Station associated with a system and network that appears in that list, the mobile is considered to be home.
- When the mobile is in the coverage area of a Base Station associated with a system that appears in that list and a network that does not appear with that system on the list, the mobile is considered to be a NID roamer.
- Otherwise, the mobile is considered to be a SID roamer. This last case corresponds to the usual roaming status of analog and TDMA mobiles.

The special value 65535 may not be used as a valid NID value by the cellular system. If the mobile contains this value as a NID value in the list of its (SID,NID) home pairs, it will consider any network in that particular system to be a home network.

QUALCOMM cdma university

Types of Registrations – TIA/EIA-95

CDMA2000 1x RC1 & RC2 Section 8-10

- Power-Up
- Power-Down
- Timer-Based
- Distance-Based
- Zone-Based
- Ordered
- Traffic Channel
- Parameter Change
- Implicit

TIA/EIA-95 Registrations

The CDMA specifications support features that can enhance registration performance and provide extended mobile capabilities. Support of these features is required in the mobile, but the use of the features in the system is optional. These features include:

- Advanced methods for autonomous registration.
- Registration cancellation (and renewal) by timeout.
- Support for simultaneous registration in multiple systems.
- Support for sub-systems (e.g., private cellular networks) within a cellular system.
- Registration of multiple MINs for a mobile.
- Ability for the mobile to specify whether a MIN is configured to receive mobile-terminated calls in its current roaming status.
- Support of a discontinuous reception mode in the mobile for power reduction.
- Support of registration processes while a mobile has a call active.

CDMA recognizes a total of nine registration methods, each of which we will discuss. The first five modes of registration are called autonomous registration and can be enabled or disabled as a group, based on the roaming status of the mobile. All autonomous registration methods as well as the parameter-change-based registration can be enabled or disabled individually.

QUALCOMM cdma university

Types of Registrations – CDMA2000

CDMA2000 1x RC1 & RC2 Section 8-11

- Same as IS-95
- Plus:

Zone-Based Registration

CDMA2000 Registrations

- User zone-based registration – the Tiered Services supported by CDMA2000 may require that the mobile register when it enters a User Zone.

- Power-Up
- Power-Down
- Timer-Based
- Distance-Based
- Zone-Based

Autonomous Registration Methods

TIA/EIA-95 supports several different forms of registration. The first six forms are *autonomous registrations*, where the mobile initiates the registration in response to an event, without being explicitly directed to register by the BSC:

- **Power-up registration –** The mobile registers when it powers on, switches from using the alternate serving system, or switches from using the analog system.
- **Power-down registration –** The mobile registers when it powers off if previously registered in the current serving system.
- **Timer-based registration –** The mobile registers when a timer expires.
- **Distance-based registration –** The mobile registers when the distance between the current serving cell and the serving cell in which it last registered exceeds a threshold.
- **Zone-based registration –** The mobile registers when it enters a new zone.

The various forms of autonomous registration can be globally enabled or disabled by the BSC. The forms of registration that are enabled and the corresponding registration parameters are communicated in an overhead message transmitted on the CDMA Paging Channels.

QUALCOMM cdma university

Types of Registrations – Non-Autonomous Methods

CDMA2000 1x RC1 & RC2 Section 8-13

- Ordered
- Traffic Channel
- Parameter Change
- Implicit

Non-Autonomous Registration Methods

Non-autonomous registration methods provide the ability to update the HLR/VLR when responding to orders on the Paging Channel, or using the Access Channel or Traffic Channel.

cdma university

Types of Registrations – Non-Autonomous: Request Order

CDMA2000 1x RC1 & RC2 Section 8-14

Field	Length (bits)
MSG_TYPE	00000111

One or more occurrences of the following record:

ACK_SEQ	3
MSG_SEQ	3
ACK_REQ	1
VALID_ACK	1
ADDR_TYPE	3
ADDR_LEN	4
ADDRESS	8 ´ ADDR_LEN
ORDER	011011
ADD_RECORD_LEN	001
order-specific fields (if used)	00000001

MMT98010346Ag-rev1.emf

Non-Autonomous: Request Order

The cellular system may become aware of a mobile within its coverage area for which it does not possess all the information required to deliver a call (e.g., following receipt of an Origination Message from the mobile). In this case, the cellular system can order the mobile to register using the Registration Order. The mobile responds with a Registration Message on the Access Channel and updates its data structures as for any other registration.

Traffic Channel Registration

Traffic Channel registration refers to a method in which the mobile receives registration-related information while on the Traffic Channel. Since information exchange on the Traffic Channel provides less interference to other users than exchanges occurring on the Paging and Access Channels, TIA/EIA-95 provides for transmission of registration information on the Traffic Channel, preventing in many cases an automatic registration following a call. An example where such registrations occur is calls involving intersystem handoffs.

Provision of registration information to a mobile can be done following the reception of a Release Order from the mobile and prior to transmission of a Release Order to the mobile. At this stage, information exchanges between the Base Station and the mobile have no effect on voice quality.

QUALCOMM cdma university

Types of Registrations – Non-Autonomous: Parameter Change

CDMA2000 1x
RC1 & RC2
Section 8-15

Field	Length (bits)
MSG_TYPE; ('00000001')	8
ACK_SEQ	3
MSG_SEQ	3
ACK_REQ	1
VALID_ACK	1
ACK_TYPE	3
MSID_TYPE	3
MSID_LEN	4
MSID	8´ MSID_LEN
AUTH_MODE	2
AUTHR	0 or 18
RANDC	0 or 8
COUNT	0 or 6
REG_TYPE	4
SLOT_CYCLE_INDEX	3
MOB_P_REV	8
SCM	8
MOB_TERM	1
RESERVED	6

MMT98010338Ag-rev1.emf

Non-Autonomous: Parameter Change Registration

Certain parameters in the mobile directly affect the process of delivering calls to the mobile and therefore should be updated in the system whenever a change in them occurs. These parameters are the mobile's Station Class Mark (SCM), preferred slot cycle, and mobile-terminated call indicator.

The SCM can change in transportables or phones that can be attached to a vehicle and then detached and used as a portable phone. Since under these different incarnations the mobile would transmit different powers and have different reception capabilities, the Base Station should be made aware of the change, so it can use the information in its call delivery algorithm.

The preferred slot cycle index refers to a capability certain CDMA phones have of monitoring the Paging Channel only in selected time slots, thus reducing processing and increasing battery life. A Base Station that attempts to page a mobile must be aware of the slot cycle being used by the mobile so that it transmits the pages in those slots in which the mobile monitors the Paging Channel.

QUALCOMM cdma university

Types of Registrations – Non-Autonomous: Parameter Change (cont.)

CDMA2000 1x RC1 & RC2 Section 8-16

Field	Length (bits)
MSG_TYPE; ('00000001')	8
ACK_SEQ	3
MSG_SEQ	3
ACK_REQ	1
VALID_ACK	1
ACK_TYPE	3
MSID_TYPE	3
MSID_LEN	4
MSID	8´ MSID_LEN
AUTH_MODE	2
AUTHR	0 or 18
RANDC	0 or 8
COUNT	0 or 6
REG_TYPE	4
SLOT_CYCLE_INDEX	3
MOB_P_REV	8
SCM	8
MOB_TERM	1
RESERVED	6

MMT98010338Ag-rev1.emf

Non-Autonomous: Parameter Change Registration

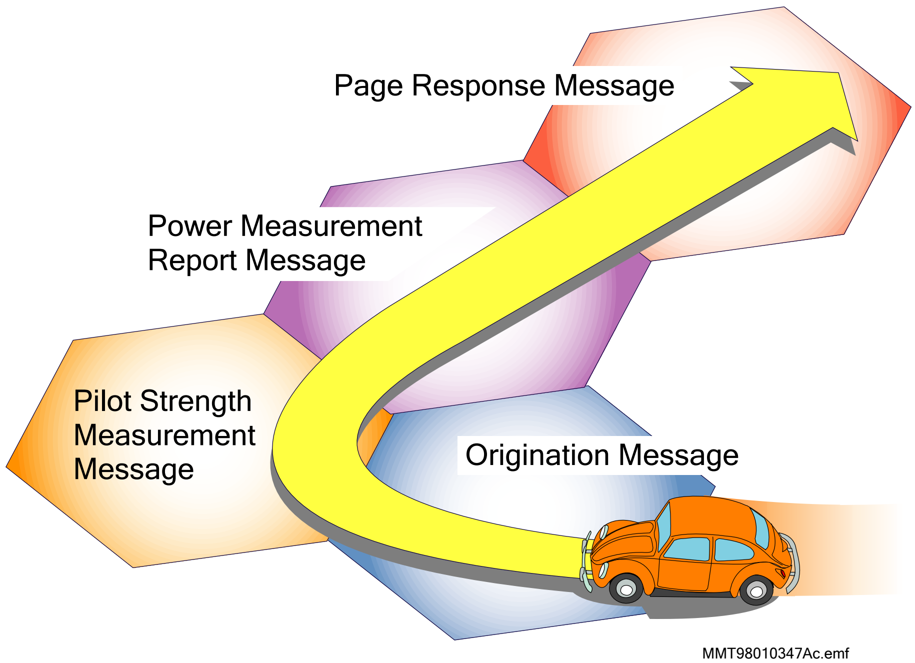
Finally, the mobile maintains a call termination indicator. A CDMA phone can be programmed independently to accept calls when in the coverage area of a Base Station belonging to the system from which service is provided (the "home" system), when roaming in the serving system but a different network (a "NID roamer"), or when roaming in a different system (a "SID roamer").

The call termination indicator is therefore a function of the mobile roaming status and the call termination preference programmed for that roaming status. If the call termination indicator changes (either due to a change in roaming status or to a change in preference), the Base Station should be notified so it can determine if pages should be transmitted to the mobile.

QUALCOMM cdma university

Types of Registrations – Non-Autonomous: Implicit

CDMA2000 1x
RC1 & RC2
Section 8-17



Non-Autonomous: Implicit Registration

Implicit registration occurs when the mobile and Base Station exchange messages that are not directly related to registration but convey sufficient information to identify the mobile and its location (to within a Base Station coverage area) to the cellular system.

For compatibility reasons with registration schemes used in AMPS and IS-54, the mobile considers that it has implicitly registered only after a successful transmission of an Origination Message or a Page Response Message.

QUALCOMM cdma university

Types of Registrations – The Origination Message

CDMA2000 1x RC1 & RC2 Section 8-18

Field	Length (bits)
MSG_TYPE ;('00000100 ')	8
ACK_SEQ	3
MSG_SEQ	3
ACK_REQ	1
VALID_ACK	1
ACK_TYPE	3
MSID_TYPE	3
MSID_LEN	4
MSID	8 ´ MSID_LEN
AUTH_MODE	2
AUTHR	0 or 18
RANDC	0 or 8
COUNT	0 or 6
MOB_TERM	1
SLOT_CYCLE_INDEX	3
MOB_P_REV	8
SCM	8
REQUEST_MODE	3
SPECIAL_SERVICE	1
SERVICE_OPTION	0 or 16
PM	1
DIGIT_MODE	1
NUMBER_TYPE	0 or 3
NUMBER_PLAN	0 or 4

During routine operation, the mobile can provide status updates to the system in Origination Messages and Page Response Messages.

This capability reduces the number of Registration Messages that are necessary.

MMT98010348Ag_rev1.emf

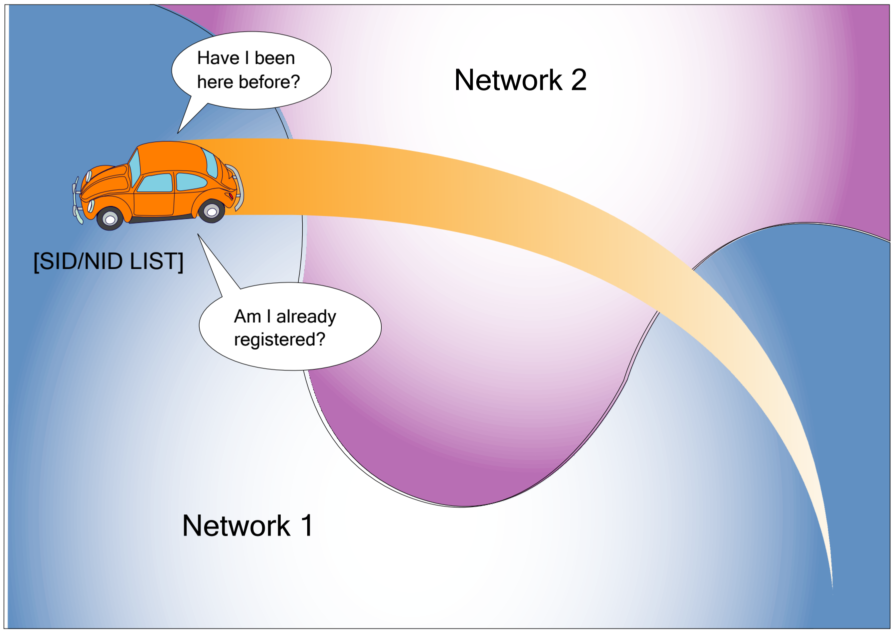
The Origination Message

The Origination Message, sent by the Mobile, contains enough information to implicitly register the mobile.

QUALCOMM cdma university

Multiple System Registration – Mobile on a System Boundary

CDMA2000 1x RC1 & RC2 Section 8-19



MMT98010349Ac.emf

Mobile on a System Boundary

A number of known issues exist regarding paging of mobiles that operate near system boundaries. Among these issues is the determination of the proper BSC for paging a mobile that moves from one system to another. Autonomous registration after each change of system helps, but cannot completely resolve this problem. Since registration cannot be instantaneous, there is always some period during which the Home Location Register (HLR) is unaware that the mobile has changed serving systems.

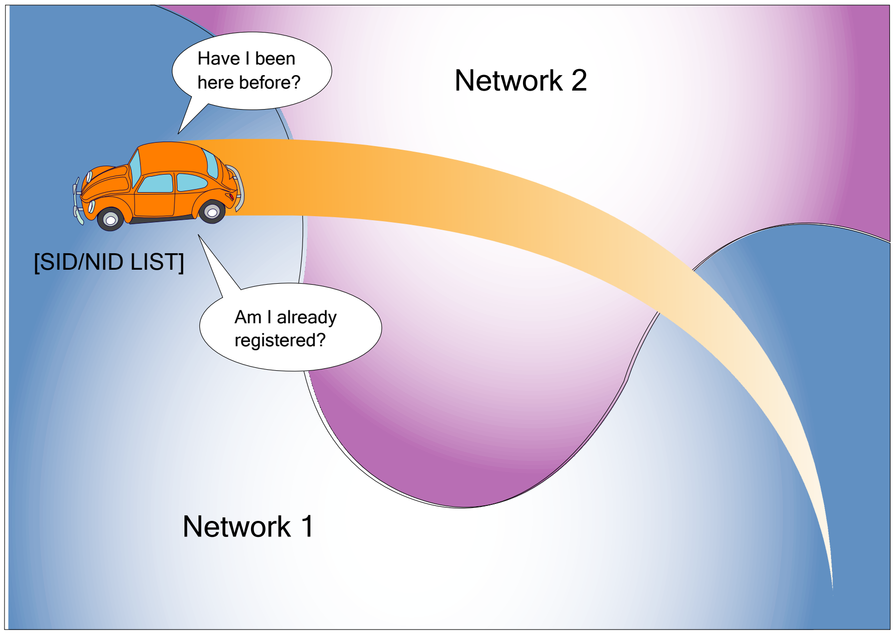
If autonomous registration occurs each time a mobile enters a cell in a new serving system, another issue arises: mobiles that register upon each change of serving system could issue an excessive number of registration requests when moving along a system boundary. This is because propagation effects can cause the optimum serving system from the mobile's viewpoint to change rapidly while the mobile is in motion.

The mobile maintains a list of SIDs and NIDs (Network Identification Numbers) in which it registered, the SID_NID_LIST. When the mobile registers in a given (SID,NID) pair, it adds the pair to the list and starts a timer for the pair corresponding to the SID and NID in which it previously registered. If the mobile returns to the coverage area of a Base Station that belongs to a (SID,NID) pair on its list, it does not re-register. Once a timer expires, the mobile deletes the pair associated with the timer from the list. If the mobile happens to be in the coverage area of a Base Station belonging to the (SID,NID) whose timer expired, it re-registers, adding the pair back to the list without a timer.

QUALCOMM cdma university

Multiple System Registration – Mobile on a System Boundary (continued)

CDMA2000 1x RC1 & RC2 Section 8-20



MMT98010349Ac.emf

Multiple SIDs/NIDs

The Base Station can control storage of multiple SIDs and/or NIDs in the mobile's SID_NID_LIST by use of the MULT_SIDS and MULT_NIDS parameters sent in the System Parameters Message.

When MULT_SIDS is set to zero, the mobile will not store multiple entries having identical SIDs. Thus, when it registers in a particular (SID,NID) pair, it removes from the list another pair having a different SID if such exists. Similarly, when MULT_NIDS is set to zero, the mobile stores only one (SID,NID) pair for every NID in which it registers.

cdma university

Multiple System Registration – System Parameters Message

CDMA2000 1x
RC1 & RC2
Section 8-21

Field	Length (bits)
MSG_TYPE ;('00000001')	8
PILOT_PN	9
CONFIG_MSG_SEQ	6
SID	15
NID	16
REG_ZONE	12
TOTAL_ZONES	3
ZONE_TIMER	3
MULT_SIDS	1
MULT_NIDS	1
BASE_ID	16
BASE_CLASS	4
PAGE_CHAN	3
MAX_SLOT_CYCLE_INDEX	3
HOME_REG	1
FOR_SID_REG	1
FOR_NID_REG	1
POWER_UP_REG	1
POWER_DOWN_REG	1
PARAMETER_REG	1
REG_PRD	7
BASE_LAT	22
BASE_LONG	23
REG_DIST	11
SRCH_WIN_A	4

MMT98010350Ag-rev1.emf

System Parameters Message

The System Parameters Message controls which types of Registration are to be used in the system. From this overhead message the mobile can determine which types are to be used, and the values of operation.

The Reg_Zone field is set to the registration zone of the Base Station. The Total_Zones field is set to the number of registration zones the mobile is to retain for the purposes of zone-based registration. The Zone_Timer sets the length of the zone registration timer to be used by the mobile, and ranges from 1 to 60 minutes.

QUALCOMM cdma university

Registration Parameters– Access Parameters Message

CDMA2000 1x RC1 & RC2 Section 8-22

Access Parameters Message

Field	Length (bits)
MSG_TYPE; ('00000010')	8
PILOT_PN	9
ACC_MSG_SEQ	6
ACC_CHAN	5
NOM_PWR	4
INIT_PWR	5
PWR_STEP	3
NUM_STEP	4
MAX_CAP_SZ	3
PAM_SZ	4
PSIST;(0-9)	6
PSIST;(10)	3
PSIST;(11)	3
PSIST;(12)	3
PSIST;(13)	3
PSIST;(14)	3
PSIST;(15)	3
MSG_PSIST	3
REG_PSIST	3
PROBE_PN_RAN	4
ACC_TMO	4
PROBE_BKOFF	4
BKOFF	4

MMT98010351Ag-rev1.emf

Access Parameters Message

The Access Parameters Message also lists the value for Registration Persistance (REG_PSIST). This value is used to control the priority of registration.

The basic description of *Registration Persistence* is:

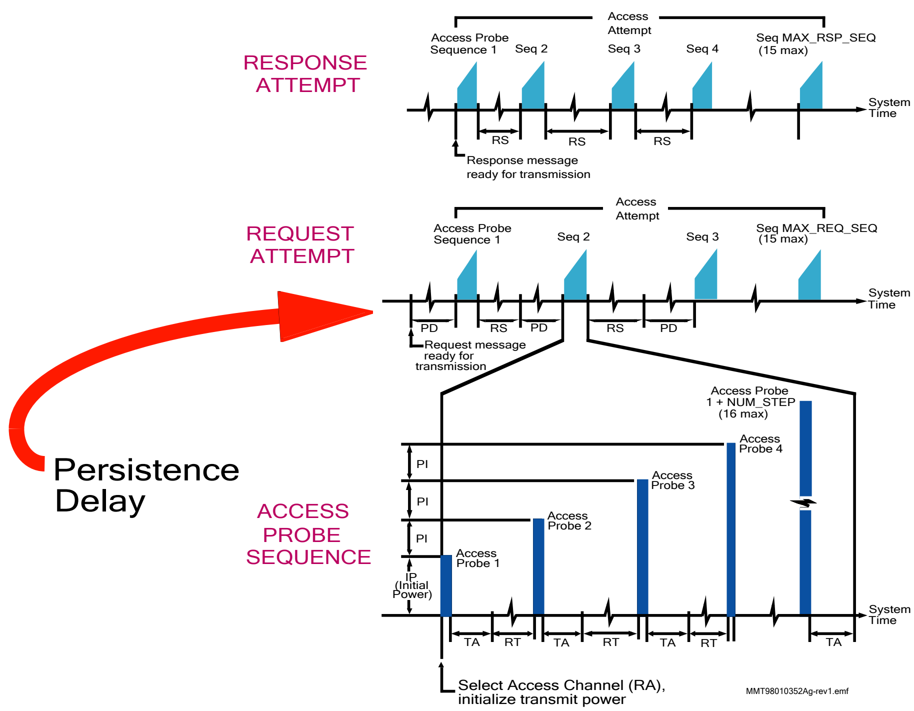
- Before transmitting the first Access Probe in each Access Sequence, the mobile shall perform a persistence test for each Access Channel Slot. The mobile shall transmit the first Access probe of a probe sequence in a slot only if the test passes for that slot. To perform the persistence test:
  - Generate a random number RP, $0<RP<1$
  - Calculate $P= 2^{-PSIST/4} * 2^{-REG\_PSIST}$

The persistence test is said to pass when RP is less than P.

QUALCOMM cdma university

Registration Parameters– Access Probing

CDMA2000 1x RC1 & RC2 Section 8-23



Access Probing

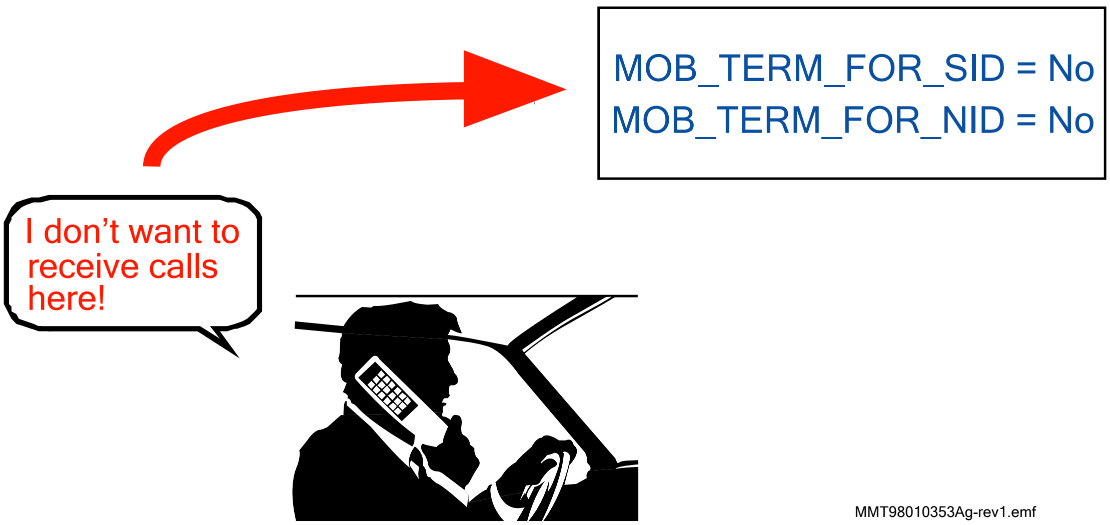
A mobile attempting to Register must follow the request attempt process. The first step in this process is to take the persistence test using the persistence parameter as an input. The system operator can adjust the value of this parameter to give Originations priority over Registrations.

QUALCOMM cdma university

Registration Parameters– Mobile Parameters

CDMA2000 1x RC1 & RC2 Section 8-24

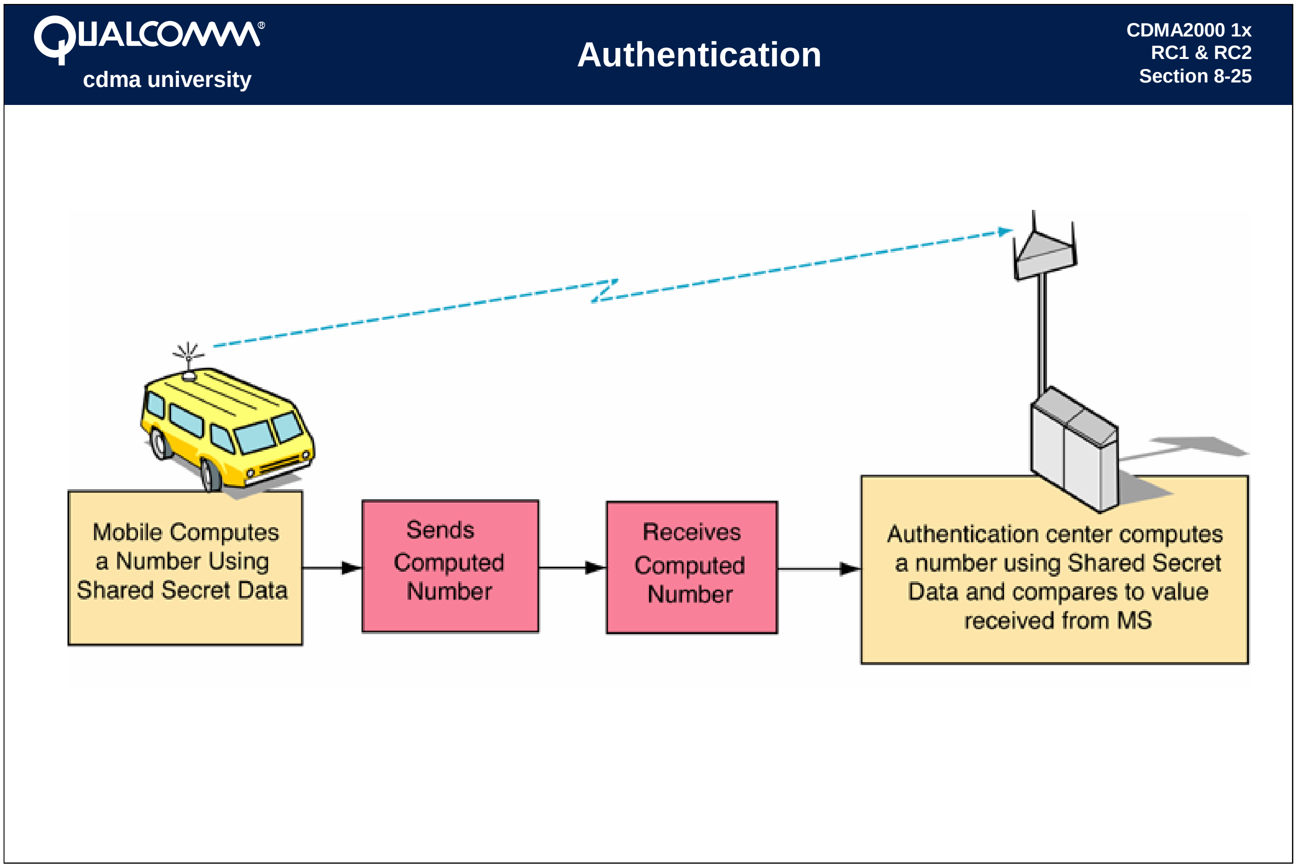
User Preferences are reflected in Mobile Parameters



Mobile Parameters

Certain parameters in the mobile directly affect the process of delivering calls to the mobile and therefore should be updated in the system whenever a change in them occurs.

Under most circumstances a CDMA phone can be programmed independently to accept calls when in the coverage area of a Base Station belonging to the system from which service is provided (the "home" system), when roaming in the serving system but a different network (a "NID roamer"), or when roaming in a different system (a "SID roamer").



Authentication

Authentication is the process by which a mobile confirms its identity to the Base Station. Fraud is a concern in wireless systems, and service providers want to protect themselves from lost revenues due to "cloned" mobiles.

CDMA2000 uses two types of authentication:

- *Global Challenge* – The mobile authenticates itself to the Base Station each time it sends certain messages on the Access Channel.
- *Unique Challenge* – The Base Station may challenge a mobile station to authenticate itself. This is typically done after the Global Challenge fails.

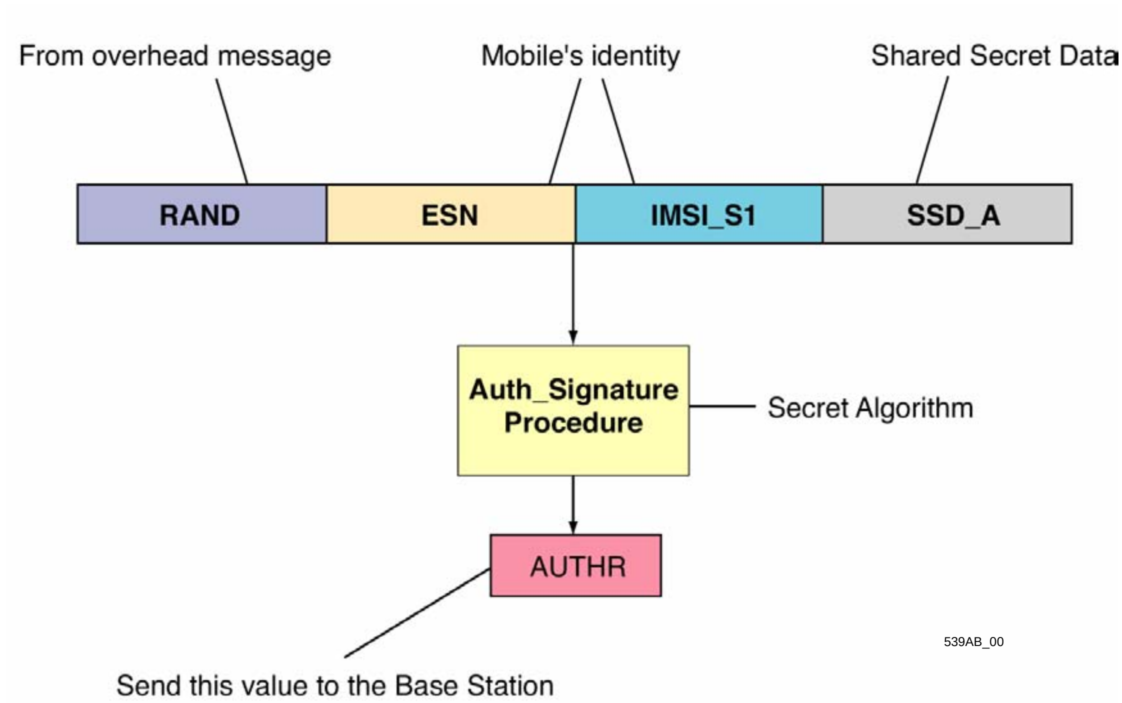
Shared Secret Data

The mobile and the Base Station each possess a copy of Shared Secret Data (SSD), which is used in the authentication process. The mobile is assigned an authentication key, called the A-key, when the subscription is activated. The A-key is used to compute the SSD. The SSD then is used in the authentication process. The Base Station may request that the mobile update the SSD, using the SSD Update Procedure.

QUALCOMM cdma university

Authentication – Global Challenge

CDMA2000 1x RC1 & RC2 Section 8-26



Global Challenge

The mobile authenticates itself to the Base Station each time it sends an Origination, Page Response, Registration, Data Burst, TMSI Assignment or PACA Cancellation Message on the Access Channel.

The Base Station sends a value called RAND in either the Access Parameters Message or the ANSI-41 RAND Message. The mobile uses RAND, its Electronic Serial Number (ESN), either its IMSI_S1 or the dialed digits, and a portion of the SSD as inputs to a secret algorithm. The output of the calculation is called the AUTH_SIGNATURE. The mobile sends this value over the air interface to the Base Station in AUTHR field of the Access Channel Message.

Upon receiving this message, the Base Station performs the same calculation, using the same input values:

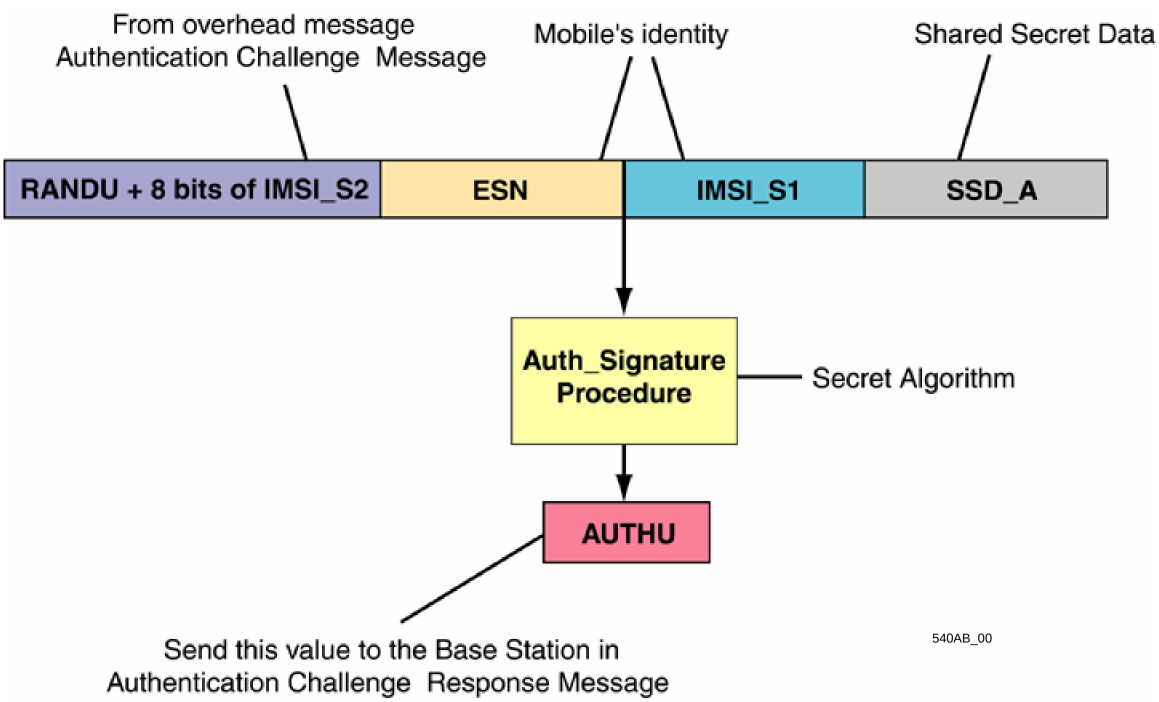
- If the Base Station calculates the same output value, then the authentication is said to succeed.
- If the Base Station calculates a different value, it typically initiates a Unique Challenge Procedure.

Note that the Shared Secret Data is never sent over the air interface, and that the secret algorithm is published only in a controlled document.

cdma university

Authentication – Unique Challenge-Response

CDMA2000 1x
RC1 & RC2
Section 8-27



Unique Challenge-Response

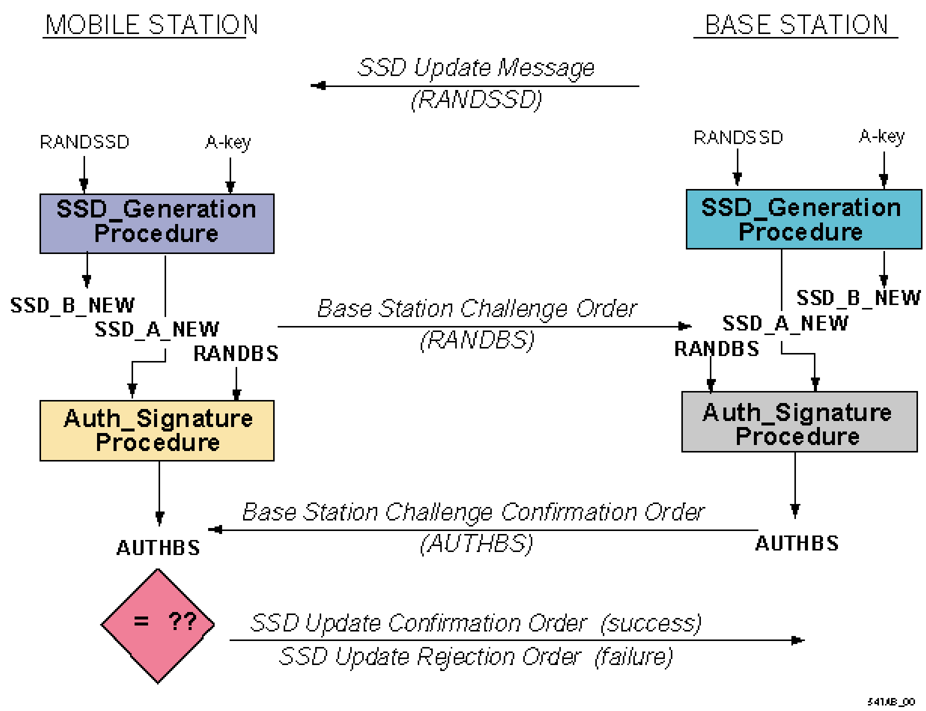
The Base Station may challenge the mobile at any time to authenticate itself. This typically happens after a Global Challenge has failed. The Base Station sends an Authentication Challenge Message containing a random value called RANDU.

The mobile uses RANDU, the eight least significant bits of its IMSI_S2, its ESN, its IMSI_S1, and a portion of the SSD as inputs to the secret algorithm. The mobile sends the output of the calculation over the air interface to the Base Station in the AUTHU field of the Authentication Challenge Response Message.

Upon receiving this message, the Base Station performs the same calculation, using the same input values:

- If the Base Station calculates the same output value, then the authentication is said to succeed.
- If the Base Station calculates a different value, it may deny further access attempts by the mobile, drop the call in progress, or initiate the process of updating the SSD.

Authentication – Updating the SSD



Updating the SSD

The Base Station may instruct the mobile at any time to update its SSD. This typically happens after a Unique Challenge has failed. The Base Station sends an SSD Update Message containing a random value called RANDSSD.

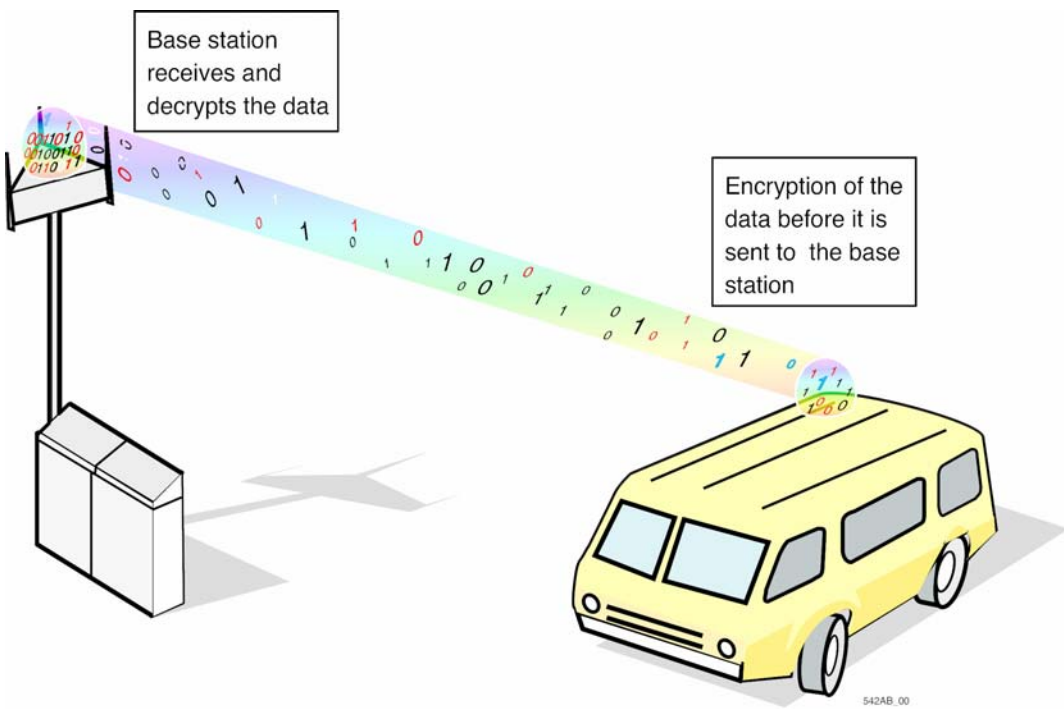
The mobile uses RANDSSD, its ESN, and its A-key as inputs to a secret algorithm called the SSD_Generation Procedure. The output of this procedure is a new SSD. The mobile generates a random number, RANDBS, and uses that value along with its ESN, its IMSI_S1, and the new SSD to compute the authentication signature, AUTHBS. The mobile sends the value RANDBS over the air interface to the Base Station in the AUTHR field of the Base Station Challenge Order.

Meanwhile, the Base Station has also calculated a new value for the SSD. Upon receiving the Base Station Challenge Order, the Base Station computes the authentication signature, AUTHBS, using RANDBS and the the new SSD. The Base Station then sends the output of the calculation back to the mobile in the Base Station Challenge Confirmation Order. The mobile compares this value of AUTHBS to the value it calculated. If they match, the mobile updates its SSD to the newly computed value and sends a SSD Update Confirmation Order to the Base Station, which then updates its SSD to the new value. Otherwise, the mobile sends a SSD Update Reject Order, and both sides discard the new SSD.

QUALCOMM cdma university

Encryption

CDMA2000 1x
RC1 & RC2
Section 8-29



Encryption

CDMA systems support encryption to protect sensitive subscriber information, such as Personal Identification Numbers (PIN), Short Message Service (SMS) messages, dialed digits, etc. Encryption is used in a CDMA system only if authentication is also used.

The details of encryption algorithms are controlled by the United States government, and are not published as part of the CDMA2000 standard. The following forms of encryption are supported in CDMA2000:

- Cellular Message Encryption Algorithm – CDMAOne and CDMA2000 systems support encryption of certain fields of selected fields of selected signaling messages. An Enhanced Cellular Message Encryption Algorithm was introduced in TIA/EIA-95B.
- Voice Privacy – CDMAOne and CDMA2000 systems provide voice (and data) privacy using a private long code mask.
- Extended Encryption – This new set of encryption procedures was introduced in CDMA2000. This allows encryption to be enabled over the entire Layer 3 signaling message, as well as over the user information (voice and user data).

QUALCOMM cdma university

Encryption – Cellular Message Encryption Algorithm

CDMA2000 1x RC1 & RC2 Section 8-30

Selected fields of these messages may be encrypted using the **Cellular Message Encryption Algorithm** or the **Enhanced Cellular Message Encryption Algorithm**:

- Alert with Information
- Flash with Information
- Send Burst DTMF Messages
- Continuous DTMF Tone Order
- Data Burst Message
- Power Up Function Completion Message
- Origination Continuation Message

Cellular Message Encryption Algorithm

The Cellular Message Encryption Algorithm is supported in TIA/EIA-95A/B systems as well as CDMA2000 systems. Selected fields of the messages shown above may be encrypted using the Cellular Message Encryption Algorithm.

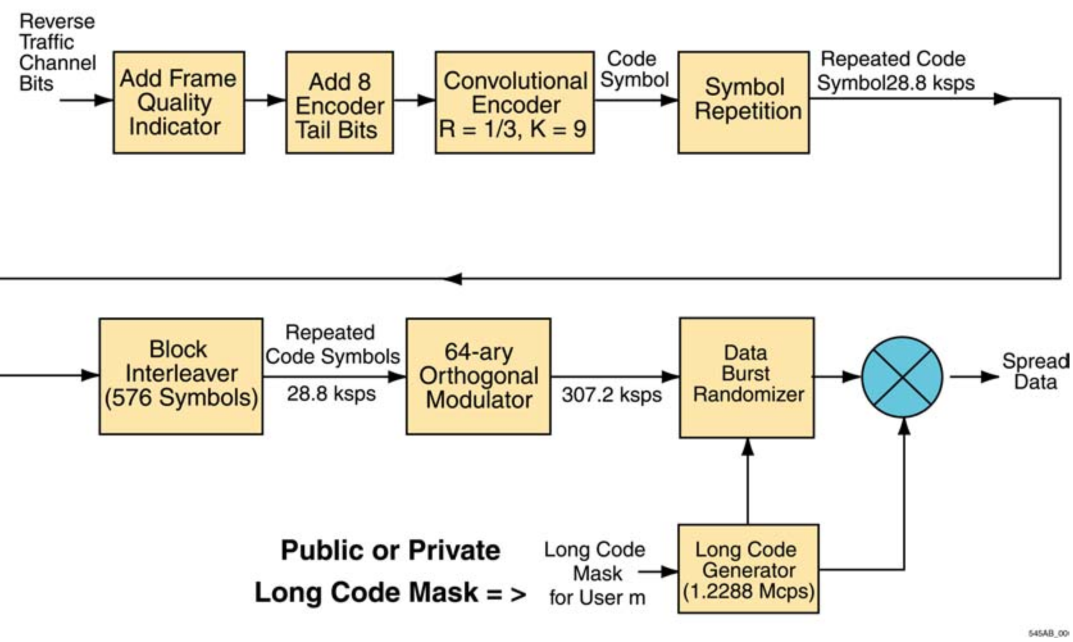
The Cellular Message Encryption Algorithm only operates on the Traffic Channel. Encryption is controlled for each call individually, and is enabled by the Base Station in the Channel Assignment Message or the Extended Channel Assignment Message.

The Base Station may also turn encryption on or off while operating on the Traffic Channel, by sending one of the following messages:

- Extended Handoff Direction Message
- General Handoff Direction Message
- Universal Handoff Direction Message
- Message Encryption Mode Order

Encryption – Voice Privacy

CDMA2000 1x RC1 & RC2 Section 8-31



Voice Privacy

Voice Privacy is supported in TIA/EIA-95A/B and CDMA2000 systems. It uses a private long code mask (Pseudorandom Noise [PN] spreading mask) on the Traffic Channel. Calls are initiated using the public long code mask, but either the mobile or the Base Station may request a transition to the private long code mask.

The private long code mask is generated during the authentication step performed for the Origination Message or Page Response Message. The mobile may request that voice privacy be used by setting a field in those messages.

The Base Station or the mobile requests a transition to the private long code after the Traffic Channel has been established, using the Long Code Transition Request Order. The Base Station may also cause a transition by setting a field in the Handoff Direction Message (Extended, General, or Universal).

Note that the private long code is applied to the entire Traffic Channel frame, including the signaling portion and the primary and secondary traffic portions. It may be applied to a data service call, so the name “voice privacy” is something of a misnomer.

QUALCOMM cdma university

What We Learned in This Section

CDMA2000 1x RC1 & RC2 Section 8-32

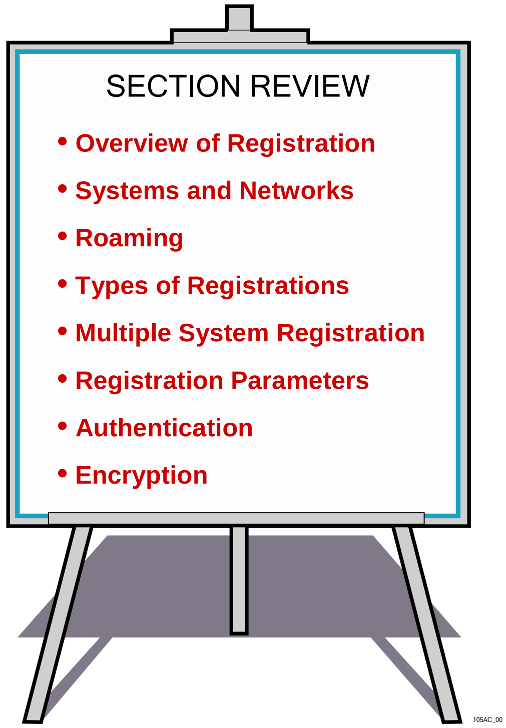
- ✓ The messages that contain registration information.
- ✓ The types of registrations supported by the CDMA specifications.
- ✓ The parameters that control the registration process.
- ✓ The authentication and encryption processes supported by the CDMA specifications.

Notes

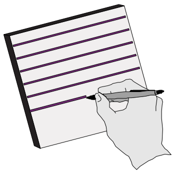
QUALCOMM cdma university

Registration – Review

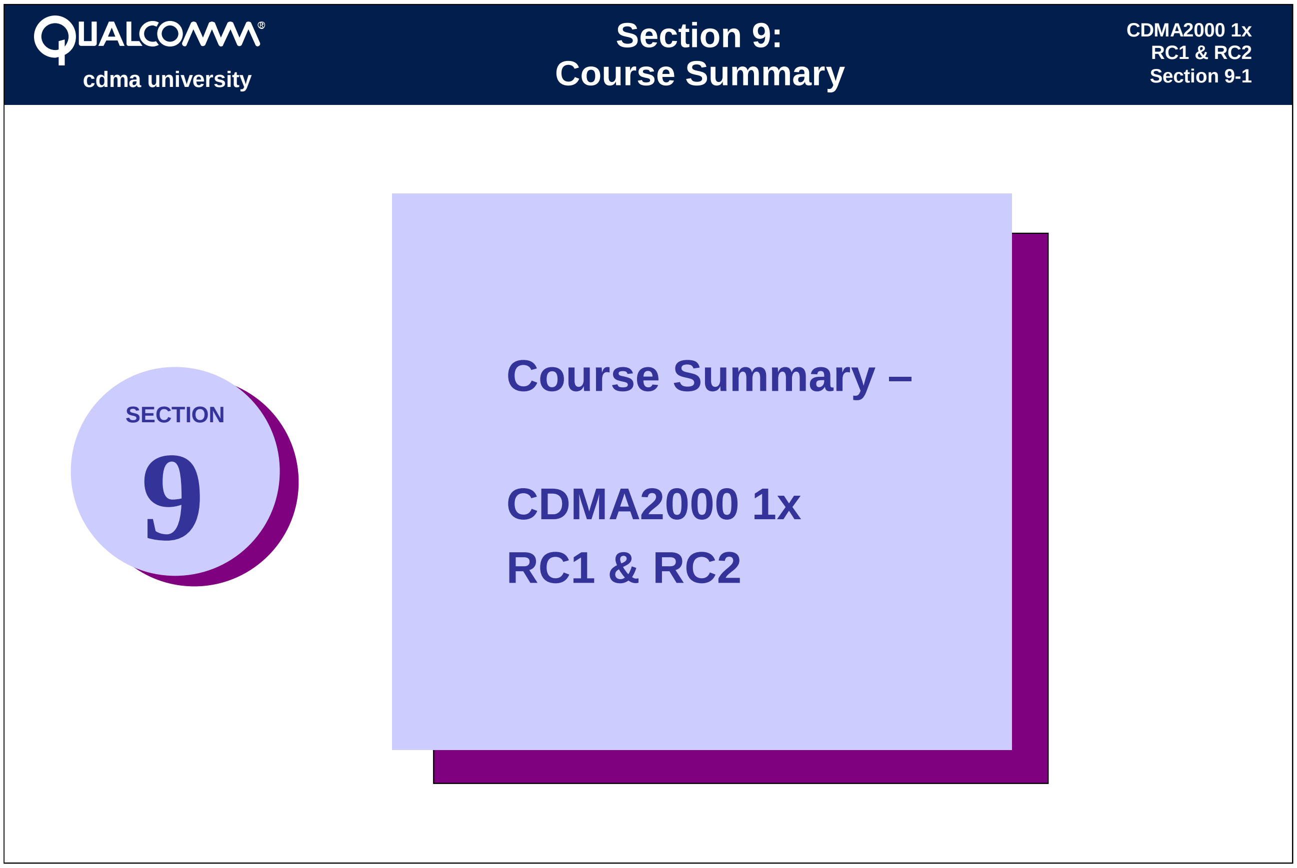
CDMA2000 1x RC1 & RC2 Section 8-33



Notes



Comments/Notes


QUALCOMM
cdma university
Section 9:
Course Summary
CDMA2000 1x
RC1 & RC2
Section 9-1
SECTION
9
Course Summary –
CDMA2000 1x
RC1 & RC2

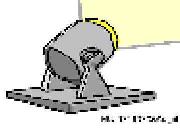
Notes

QUALCOMM cdma university

CDMA2000 1x RC1 & RC2 – Course Summary

CDMA2000 1x RC1 & RC2 Section 9-2

1) Introduction
2) Design Considerations
3) Codes in CDMA
4) CDMA Physical Layer
5) Power Control
6) Call Processing
7) Handoffs
8) Registration



Notes

QUALCOMM cdma university

What We Learned – Section 1
Course Introduction

CDMA2000 1x RC1 & RC2 Section 9-3

- ✓ TIA/EIA-95 is a subset of CDMA2000.
- ✓ New Physical Channels for CDMA2000.
- ✓ Many new Radio Configurations.
- ✓ CDMA2000 standards available from *3gpp2*.

Notes

QUALCOMM cdma university

What We Learned – Section 2 Design Considerations

CDMA2000 1x RC1 & RC2 Section 9-4

- ✓ The elements of a wireless architecture.
- ✓ Characteristics of the mobile radio channel.
- ✓ The mobile subscribers' requirements.
- ✓ The limitations of conventional approaches to mobile communications.
- ✓ Basic principles of spread spectrum communications.

Notes

QUALCOMM cdma university

What We Learned – Section 3 Codes in CDMA

CDMA2000 1x RC1 & RC2 Section 9-5

- ✓ The two types of code sequences used in CDMA2000 systems.
- ✓ The properties of orthogonal and PN codes.
- ✓ How these two code sequences are generated.
- ✓ The process of spreading and despreading using these two codes.
- ✓ The process of time-shifting a PN code sequence.

Notes

QUALCOMM cdma university

What We Learned – Section 4 CDMA Physical Layer

CDMA2000 1x RC1 & RC2 Section 9-6

- ✓ The generation of the CDMA waveforms in both the Forward and Reverse directions.
- ✓ The CDMA code channels.
- ✓ The steps in the generation of each code channel.
- ✓ The rationale for each step.
- ✓ The demodulation of the Forward and Reverse CDMA channels.

Notes

QUALCOMM cdma university

What We Learned – Section 5
Power Control

CDMA2000 1x
RC1 & RC2
Section 9-7

- ✓ The power control processes used in a CDMA system and the rationale for them.
- ✓ The requirements for Power Control.
- ✓ How to calculate an Open Loop Power Estimate.
- ✓ The Closed Loop Power Control process.
- ✓ Outer Loop Power Control.
- ✓ Forward Power Control.
- ✓ The use of a Power Measurement Report Message.

Notes

What We Learned – Section 6 Call Processing

- ✓ The call control signaling processes specified in the CDMA standards.
- ✓ System determination, synchronization, and timing in CDMA systems.
- ✓ The functioning of the Paging Channels.
- ✓ The functioning of the Access Channels.
- ✓ The Forward and Reverse Traffic Channel Signaling Structures.

Notes

QUALCOMM cdma university

What We Learned – Section 7 Handoffs

CDMA2000 1x RC1 & RC2 Section 9-9

- ✓ The types of CDMA handoffs.
- ✓ The Pilot Searching process.
- ✓ The messages important in the handoff process and how each message is used.
- ✓ Key handoff parameters.

Notes

QUALCOMM cdma university

What We Learned – Section 8 Registration

CDMA2000 1x RC1 & RC2 Section 9-10

- ✓ The messages that contain registration information.
- ✓ The types of registrations supported by the CDMA specifications.
- ✓ The parameters that control the registration process.
- ✓ The authentication and encryption processes supported by the CDMA specifications.

Notes